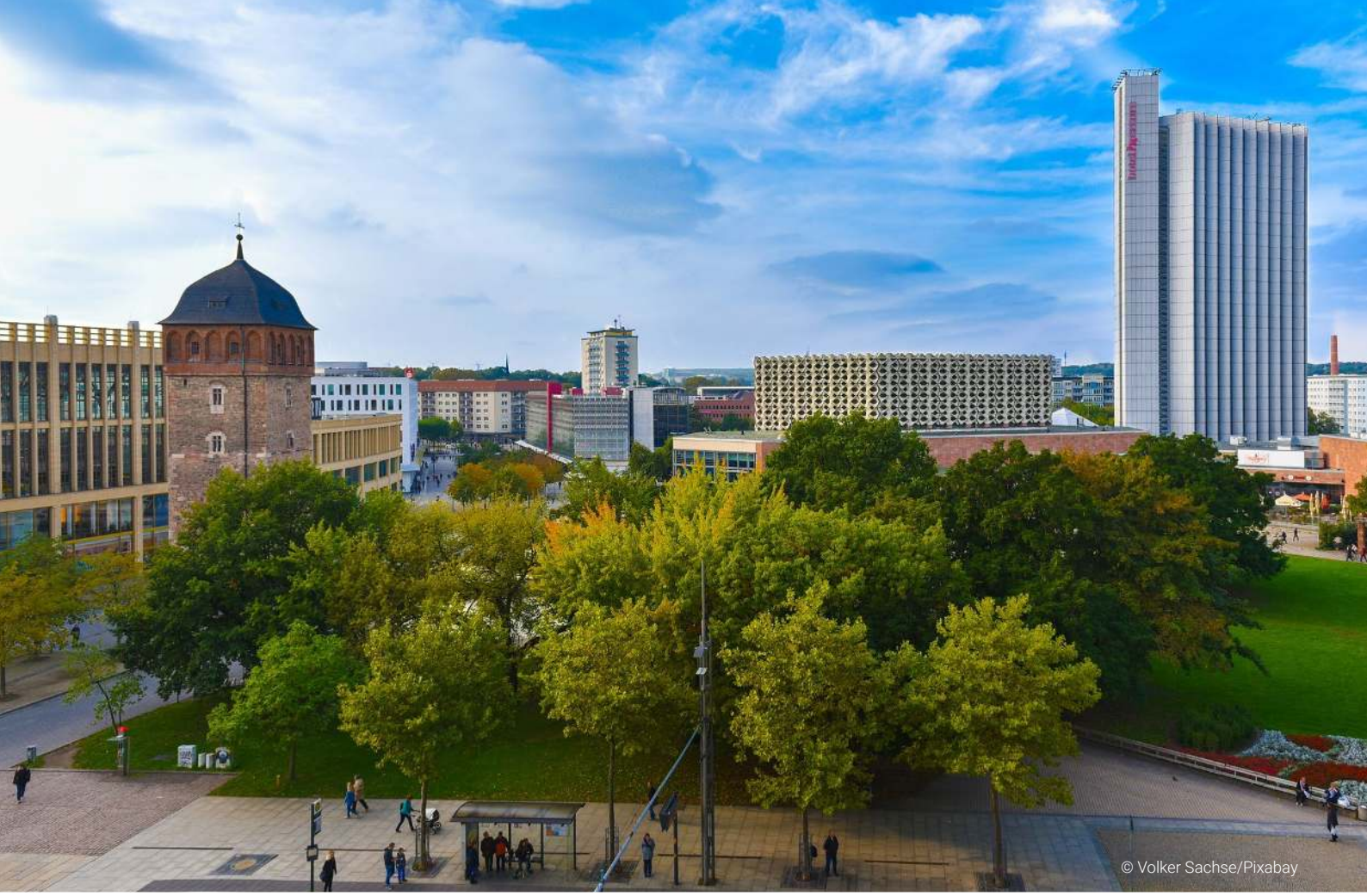

APMS 2024

IFIP International Conference on Advances in Production Management Systems

Production Management Systems for Volatile, Uncertain, Complex and Ambiguous (VUCA) Environments

UNIVERSITY OF TECHNOLOGY
IN THE EUROPEAN CAPITAL OF CULTURE
CHEMNITZ

WHZ Westsächsische Hochschule Zwickau
University of Applied Sciences

08 -12 September in Chemnitz/Zwickau, Germany

Preface
Welcome to APMS 2024!

The year 2024 highlighted that the world is getting more and more volatile, uncertain, complex, and ambiguous. There are no simple solutions to complex problems, which require new ways to solve and manage them. New technology opens new ways as does the continuous progress of science. But to bring real benefits to people on the ground who are suffering from the consequences of conflicts and climate change, just to name a few, more research is needed on how to apply and further advance this technology and knowledge. A scientific conference plays an important part in this. It is a symbol of aiming for a better future. We create new knowledge and solutions, we share all our achievements, and we meet to get to know people from all over the world, creating new ties and making new friends.

The International Conference on “Advances in Production Management Systems” (APMS) 2024 is the leading annual event of the IFIP Working Group (WG) 5.7 of the same name. At the Conference in Chemnitz, Germany, hosted by Chemnitz University of Technology and West Saxon University of Applied Sciences Zwickau, more than 200 papers were presented and discussed. This is a significant step up from the first APMS Conference in 1980, which assembled just a few participants.

The IFIP WG 5.7 was established in 1978 by the General Assembly of the International Federation for Information Processing (IFIP) in Oslo, Norway. Its first meeting was held in August 1979 with all its seven members present. The WG has since grown to 124 full and candidate members as well as 27 honorary members.

APMS is the first time in East Germany, which experienced specific challenges and disruptions, but also hopes and new futures. The Ore Mountains are a traditional industrial region, being it argued that the first textbook on operations management was written on the mining industry in this region. Mining always brought its own challenges in terms of sustainability, quality of work life and process efficiency, but also major technological advancements and highly skilled labour. Many of the papers presented address similar challenges as 500 years ago. The problems did not change but are more volatile, uncertain, complex, and ambiguous today given the interconnectedness of society and production. No other technology can show a more rapid development and impact in industry and society than Information and Communication Technology (ICT).

The APMS 2024 program shows that the IFIP WG 5.7 can still make, and will continue to make, a significant contribution to production and production management disciplines. In 2024, the international review board for APMS included 95 recognized experts working in the disciplines of production and production management systems.

For each paper, an average of 2.5 single-blind reviews were provided. Over two months, each submitted paper went through two rigorous rounds of reviews to allow authors to revise their work after the first round of reviews to guarantee the highest scientific quality of the papers accepted for publication. Following this process, 201 full papers were selected for inclusion in the conference proceedings from a total of 224 submissions.

APMS 2024 brings together leading international experts from academia, industry, and government in the areas of production and production management systems to discuss how to achieve responsible manufacturing, service, and logistics futures. This includes topics such as innovative manufacturing, service, and logistics systems characterized by their agility, circularity, digitalization, flexibility, human-centricity, resilience, and smartification contributing to more sustainable industrial futures that ensure that products and services are manufactured, servitized, and distributed in a way that creates a positive effect on the triple bottom line.

We would like to thank all contributing authors for their high-quality research work and their willingness to share their findings with the APMS and IFIP WG 5.7 community. We are equally grateful for the outstanding work of all the International Reviewers, the Program Committee Members, and the Special Sessions Organizers.

September 2024

Matthias Thürer

Ralph Riedel

Gregor von Cieminski

David Romero

Keynote Speakers

Prof. Dr. Julia Arlinghaus

Chair of Production Systems and Automation in the Department of Mechanical Engineering at Otto-von-Guericke University Magdeburg

A Major Step Towards the Factory of the Future?! – How Autonomous Vehicles as Self-driving Assembly Items can Replace Conveyor Technology in Automotive Assembly Systems

Abstract

The automotive industry is facing the transition to autonomous vehicles. This can mean novel challenges, but also chances for the redesign of assembly systems. This talk expands the idea of matrix production and explores how to exploit self-driving of autonomous cars already in an early assembly stage. Scrutinizing traditional assembly sequences, opens up potentials of up to 50% reduction of assembly takts requiring conveyor technology. This may result in a reduction of investments into material handling technology of up to 30% and may increase flexibility and changeability beyond the performance of AGV-based systems. The talk shows minimal technical and procedural requirements to exploit self-driving functions in assembly environments. Encompassing case studies from different green and brownfield assembly systems of one of the world leading OEMs serve as the basis to show

the necessary reorganization of assembly sequences and consequences for assembly structures as well as assembly performance.

Biography

Prof. Dr. Julia Arlinghaus holds the Chair of Production Systems and Automation in the Department of Mechanical Engineering at Otto-von-Guericke University Magdeburg. Moreover, she is the Director of the Fraunhofer Institute for Factory Operation and Automation. After her studies of Management and Engineering at the University of Bremen, Germany and Tokyo University, Japan, she received her PhD degree in 2011 from the University of St.Gallen, Switzerland. She has worked as a consultant for operational excellence and lean management at Porsche before she accepted the appointment as a Professor of Network Optimization in Production and Logistics at Jacobs University Bremen, Germany in 2013 and 2017 as Chair of Management of Industry 4.0 at RWTH Aachen University. Together with her team, she consults companies in questions of digital and circular logistics and supply chain systems, smart and sustainable production, robotics and automation technologies as well as transformation, digital transformation and innovation.

Keynote Speakers

Prof. George Q. Huang

Chair Professor and Associate Director of PolyU Research Institute of Advanced Manufacturing, Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University

In Search of Breakthroughs for High-Performance Cyber-Physical Smart Manufacturing

Abstract

The talk is about our search for an Industry 4.0 intelligent factory following a formal computer architecture and operating system. By so doing, computer hardware and software techniques can be adapted for high-performance factory production management. The breakthrough is achieved through a trilogy of innovations: (1) digitizing a factory with smart IoT devices into a “factory computer” (iFactory); (2) innovating iFactory visibility and traceability (VT) to enable “look around” techniques just as used in the “Out of Order Execution (OoOE)” algorithm by CPUs (Central Processing Units); and (3) developing novel models for iFactory shopfloor operations management. The iFactory architecture provides new opportunities to explore and study factory uncertainties through cyber-physical visibility and spatial-temporal traceability, and to develop brand-new data-driven decision models for factory operations planning,

scheduling and execution. iFactory demonstrates a new approach to implement Industry 4.0 smart manufacturing systems for high performance, responsiveness and resilience.

Biography

George is Chair Professor of Smart Manufacturing at Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University. He gained BEng and PhD in Mechanical Engineering from Southeast University (China) and Cardiff University (UK) respectively. He has conducted research projects in areas of Smart Manufacturing, Logistics, and Construction Systems Analytics through IoT-enabled Cyber-Physical Internet with substantial government and industrial grants exceeding HK$120M. He collaborated closely with industries through joint projects and start-up companies. He has published extensively and his works have been widely cited by research communities. He serves as associate editors and editorial members for several international journals. He is Chartered Engineer (CEng), Fellow of IEEE, IISE, ASME, CILT, HKIE, and IET.

Keynote Speakers

Prof. Dr. Dr. habil. Dmitry Ivanov

Professor of Supply Chain and Operations Management, director of the Digital-AI Supply Chain Lab (DAI), and faculty director M.A. Global Supply Chain and Operations Management

Resilience, Viability, and Digital Twins in Supply Chain Management

Abstract

In this talk, we discuss practical methods and digital tools to design and manage disruption-resistant supply chain networks to mitigate the ripple effects and shortages. We debate about extensions of supply chain resilience towards viability. We present the Viable Supply Chain model. Finally, we discuss the role of digital supply chain twins and platforms in managing resilience and viability, illustrate practical applications using industry examples, and project the lessons learned on possible future developments in supply chain management.

Biography

Prof. Dr. Dr. habil. Dmitry Ivanov is Professor of Supply Chain and Operations Management, director of the Digital-AI Supply Chain Lab (DAI), and faculty director M.A.Global Supply Chain and Operations Management at the Berlin School of Economics and Law.

His research spans supply chain resilience and digital supply chain twins. Author of the Viable Supply Chain Model and founder of the ripple effect research in supply chains. He gained Dr., Dr. Sc., and Dr. habil. degrees and won several research excellence awards. His research record counts around 420 publications, with more than 150 papers in prestigious academic journals and the leading books “Global Supply Chain and Operations Management” (three editions), “Introduction to Supply Chain Resilience”, „Structural Dynamics and Resilience in Supply Chain Risk Management“, “Scheduling in Industry 4.0 and Cloud Manufacturing”, “Digital Supply Chain” and „Handbook of Ripple Effects in the Supply Chain“. He delivered invited plenary, keynote, panel and guest talks at the conferences of INFORMS, IFPR, IFIP, IFAC, DSI and POM, and over 30 universities worldwide. He has been Chairman, IPC Chair, and Advisory Board member for over 60 international conferences in supply chain and operations management, industrial engineering, control and information sciences. Recipient of several prestigious academic awards. Principal investigator in several research projects on resilience and digital twins including European projects ACCURATE and CERERE and the DFG Collaborative Research Cluster on Resilience of Global Supply Chains at HWR Berlin. Listed in several rankings as one of the most cited researchers in Business and Management. Chair of IFAC CC 5 “Cyber-Physical Manufacturing Systems”, Editor of International Journal of Integrated Supply Management, Associate Editor of International Journal of Production Research and OMEGA, guest editor and Editorial Board member in over 20 leading international journals including IISE Transactions, IJPE, IJPDLM, ANOR, to name a few.

Keynote Speakers

Prof. Andrea Matta

Full Professor of Manufacturing and Production Systems at Department of Mechanical Engineering of Politecnico di Milano

System Mining for Data-Driven Digital Twins: from Logs to Models

Abstract

With the coming of the Industry 4.0 wave, digital representations of production systems have been promoted from marginal to central. Digital twins are not simply conceived as simulation models of their physical counterparts for offline what-if analysis, differently they are developed as self-adaptable and empowered decision-makers timely aligned with the dynamics of the real system. Enriched by these new features, digital twins are widely recognized as the key enablers for the implementation of the smart manufacturing paradigm. Despite this new role, there are significant barriers to the adoption of the digital twin concept in industrial applications. The creation and update of digital twin models is still a challenge because of the high skills required to use the simulation applications available in the market, the long development times, and their difficult integration with optimization and artificial intelligence packages. The frequent changes manufacturing systems encounter in their life cycle boost these issues.

This talk describes data-driven approaches for generating multi-fidelity models for digital twins of manufacturing systems from data acquired from sensors. Application examples will also be presented.

Biography

Andrea Matta is Full Professor of Manufacturing and Production Systems at Department of Mechanical Engineering of Politecnico di Milano. He graduated in Industrial Engineering at Politecnico di Milano where he develops his teaching and research activities since 1998. He was Distinguished Professor at the School of Mechanical Engineering of Shanghai Jiao Tong University from 2014 to 2016 and Guest Professor between 2017-2019. He has been visiting professor at Ecole Centrale Paris (France), University of California at Berkeley (USA), and Tongji University (China). His research area includes analysis, design and management of manufacturing and health care systems. He is Editor in Chief of Flexible Services and Manufacturing Journal since 2017, past member of editorial board of OR Spectrum journal and IEEE Robotics and Automation Letters journal. He was Chair of the technical committee IEE RAS Sustainable Production Automation. He is member of scientific committee in several international conferences. Member of the Steering Committee of PhD on Mechanical Engineering. Member of the ADA University Advisory Board. He was awarded with the Shanghai One Thousand Talent and Eastern Scholar in 2013.

Conference Program
Overview

Sunday 08 September 2024

08:30 - 15:00 Doctoral Workshop **TU Chemnitz - FPIL**

Carlowitz Congress Center

From 14:45 Registration Open
15:45 - 18:15 IFIP WG5.7 Working Group Meeting
18:30 - 19:30 Welcome Reception

Monday 09 September 2024

Carlowitz Congress Center

From 07:45 Registration Open
08:30 - 09:00 Opening Ceremony
09:00 - 09:45 Keynote 1 (George Q. Huang)
09:45 - 10:15 Coffee Break
10:15 - 11:15 Parallel Sessions 1 / Meet the Editor 1
11:15 - 11:30 Break
11:30 - 12:15 Keynote 2 (Andrea Matta)
12:15 - 13:15 Lunch
13:15 - 14:15 Parallel Sessions 2
14:15 - 14:40 Coffee Break
14:40 - 16:00 Parallel Sessions 3 / APMS Talks 1
From 16:00 Specific Social Events (pre-registered)

Tuesday 10 September 2024

Carlowitz Congress Center

From 07:45	Registration Open	
08:30 - 09:50	Parallel Sessions 4 / APMS Talks 2	
09:50 - 10:00	Break	
10:00 - 10:45	Keynote 3 (Julia Arlinghaus)	
10:45 - 11:10	Coffee Break	
11:10 - 12:30	Parallel Sessions 5 / Meet the Editor 2	
12:30 - 13:30	Lunch	
13:30 - 14:50	Parallel Sessions 6	
14:50 - 15:00	Break	
15:00 - 15:45	Keynote 4 (Dmitry Ivanov)	
15:45 - 16:15	Coffee Break	
16:15 - 17:15	Parallel Sessions 7	
17:15 - 17:30	Break	
17:30 - 18:30	Parallel Sessions 8	
19:00 - 23:00	Gala Dinner	**Turm-Brauhaus**


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Wednesday 11 September 2024

Carlowitz Congress Center

From 08:45	Registration Open
09:30 - 10:50	Parallel Sessions 9
10:50 - 11:10	Coffee Break
11:10 - 12:30	Parallel Sessions 10
12:30 - 13:30	Lunch
13:30 - 14:50	Parallel Sessions 11
15:00 - 16:00	Closing Ceremony

Thursday 12 September 2024

08:00 - 21:00	Mill Hiking in the Ore Mountains	**Ore Mountains**
09:00 - 18:00	Company Visit to Volkswagen Plant and August Horch Museum	**Zwickau**
09:00 - 18:00	Company Visit to BMW Group Plant	**Leipzig**
09:00 - 18:00	Visit to Dräxlmaier Battery Plant	**Leipzig**


© Öhlmuehle Dörnthal


© Volkswagen


© BMW Group

Detailed Presentation Schedule

Monday 09 September 2024: *Before Lunch*

08:30 - 09:00	Opening Ceremony					
09:00 - 09:45	**Keynote 1:** In Search of Breakthroughs for High-Performance Cyber-Physical Smart Manufacturing					
09:45 - 10:15	Coffee Break					
10:15 - 11:15	**Parallel Sessions 1.1** Barriers and Challenges for Transition towards Circular and Sustainable Production Processes and Servitized Business Models - Part 1	**Parallel Sessions 1.2** Engineering and managing AI for advances in asset lifecycle and maintenance management	**Parallel Sessions 1.3** Lean Thinking Models for Operational Excellence and Sustainability in the Industry 4.0 Era - Part 1	**Parallel Sessions 1.4** Smart Manufacturing Assets as Drivers for the Twin Transition towards Green and Digital Business - Part 1	**Parallel Sessions 1.5** Computer Vision-based Digital Twin and Digital Services for Dynamic Production and Logistics Environment - Part 1	**Parallel Sessions 1.6** Meet the Editor 1: Operations Research-oriented Journals
11:15 - 11:30	Break					
11:30 - 12:15	**Keynote 2:** System Mining for Data-Driven Digital Twins: from Logs to Models					
12:15 - 13:15	Lunch					

Detailed Presentation Schedule

Monday 09 September 2024: *After Lunch*

13:15 - 14:15	**Parallel Sessions 2.1** Barriers and Challenges for Transition towards Circular and Sustainable Production Processes and Servitized Business Models - Part 2	**Parallel Sessions 2.2** Implementing the EU Green Deal: Challenges and Solutions for a Sustainable Supply Chain - Part 1	**Parallel Sessions 2.3** Lean Thinking Models for Operational Excellence and Sustainability in the Industry 4.0 Era - Part 2	**Parallel Sessions 2.4** Smart Manufacturing Assets as Drivers for the Twin Transition towards Green and Digital Business - Part 2	**Parallel Sessions 2.5** Computer Vision-based Digital Twin and Digital Services for Dynamic Production and Logistics Environment - Part 2	**Parallel Sessions 2.6**
14:15 - 14:40	Coffee Break					
13:15 - 14:15	**Parallel Sessions 3.1** Open Knowledge Networks for Smart Manufacturing	**Parallel Sessions 3.2** Implementing the EU Green Deal: Challenges and Solutions for a Sustainable Supply Chain - Part 2	**Parallel Sessions 3.3** Lean Thinking Models for Operational Excellence and Sustainability in the Industry 4.0 Era - Part 3	**Parallel Sessions 3.4** Additive Manufacturing	**Parallel Sessions 3.5** Computer Vision-based Digital Twin and Digital Services for Dynamic Production and Logistics Environment - Part 3 & Digital twin concepts in production and services	**Parallel Sessions 3.6** APMS Talks 1
From 16:00	Specific Social Events					

Detailed Presentation Schedule

Tuesday 10 September 2024: *Before Lunch*

08:30 - 09:50	**Parallel Sessions 4.1** Smart and Sustainable Supply Chain Management in the Society 5.0 Era - Part 1	**Parallel Sessions 4.2** Methods and Tools to Achieve the Digital and Sustainable Servitization of Manufacturing Companies - Part 1	**Parallel Sessions 4.3** Lean Thinking Models for Operational Excellence and Sustainability in the Industry 4.0 Era & Experiential Learning in Engineering Education	**Parallel Sessions 4.4** Advancing Eco-Efficient and Circular Industrial Practices - Part 1	**Parallel Sessions 4.5** Digital Transformation Approaches in Production and Management - Part 1	**Parallel Sessions 4.6** APMS Talks 2
09:50 - 10:00	Break					
10:00 - 10:45	**Keynote 3:** A Major Step Towards the Factory of the Future?! – How Autonomous Vehicles as Self-driving Assembly Items can Replace Conveyor Technology in Automotive Assembly Systems					
10:45 - 11:10	Coffee Break					
11:10 - 12:30	**Parallel Sessions 5.1** Smart and Sustainable Supply Chain Management in the Society 5.0 Era - Part 2	**Parallel Sessions 5.2** Methods and Tools to Achieve the Digital and Sustainable Servitization of Manufacturing Companies - Part 2	**Parallel Sessions 5.3** Human in Command – Operator 4.0/5.0 in the Age of AI and Robotic Systems	**Parallel Sessions 5.4** Advancing Eco-Efficient and Circular Industrial Practices - Part 2	**Parallel Sessions 5.5** Digital Transformation Approaches in Production and Management - Part 2	**Parallel Sessions 5.6** Meet the Editor 2: Operations Management-oriented Journals
12:30 - 13:30	Lunch					

Detailed Presentation Schedule

Tuesday 10 September 2024: *After Lunch*

13:30 - 14:50	**Parallel Sessions 6.1** Smart and Sustainable Supply Chain Management in the Society 5.0 Era - Part 3	**Parallel Sessions 6.2** Inclusive Work Systems Design: Applying Technology to Accommodate Individual Workers' Needs	**Parallel Sessions 6.3** Evolving Workforce Skills and Competencies for Industry 5.0 - Part 1	**Parallel Sessions 6.4** Advancing Eco-Efficient and Circular Industrial Practices - Part 3	**Parallel Sessions 6.5** Digital Transformation Approaches in Production and Management - Part 3	**Parallel Sessions 6.6**
14:50 - 15:00	Break					
15:00 - 15:45	**Keynote 4:** Resilience, Viability, and Digital Twins in Supply Chain Management					
15:45 - 16:15	Coffee Break					
16:15 - 17:15	**Parallel Sessions 7.1** Decision-Making for AI-Enabled Industry 5.0 - Part 1	**Parallel Sessions 7.2** Risk Analysis and Sustainability in an Uncertain System in a Digital Era	**Parallel Sessions 7.3** Evolving Workforce Skills and Competencies for Industry 5.0 - Part 2	**Parallel Sessions 7.4** Advancing Eco-Efficient and Circular Industrial Practices - Part 4	**Parallel Sessions 7.5** Digital Transformation Approaches in Production and Management - Part 4	**Parallel Sessions 7.6**
17:15 - 17:30	Break					

Detailed Presentation Schedule

Tuesday 10 September 2024: *Afternoon*

17:30 - 18:30	**Parallel Sessions 8.1** Decision-Making for AI-Enabled Industry 5.0 - Part 2	**Parallel Sessions 8.2** Resilience management in supply chains	**Parallel Sessions 8.3** Human-centred Manufacturing and Logistics Systems Design and Management for the Operator 5.0 - Part 1	**Parallel Sessions 8.4** Transforming Engineer-to-Order Projects, Supply Chains, and Systems in Turbulent Times	**Parallel Sessions 8.5**	**Parallel Sessions 8.6**
19:00 - 23:00	Gala Dinner					

Detailed Presentation Schedule

Wednesday 11 September 2024: *Before Lunch*

09:30 - 10:50	**Parallel Sessions 9.1** Mechanism Design for Smart and Sustainable Supply Chains - Part 1	**Parallel Sessions 9.2** Optimization - Part 1	**Parallel Sessions 9.3** Human-centred Manufacturing and Logistics Systems Design and Management for the Operator 5.0 - Part 2	**Parallel Sessions 9.4** New Horizons for Intelligent Manufacturing Systems with IoT, AI, and Digital Twins - Part 1	**Parallel Sessions 9.5** Applications of artificial intelligence in manufacturing - Part 1	**Start at 08:30! In Presence + Online** **Parallel Sessions 9.6** Digital Track - Part 1 **Link:** https://eu02web.zoom-x.de/j/66235628809?pwd=JVbbDG6hrKT5G8kI0eoFP5KrMtyTrl.1 **Meeting-ID:** 662 3562 8809 **Kenncode:** 848188
10:50 - 11:10	Coffee Break					
11:10 - 12:30	**Parallel Sessions 10.1** Mechanism Design for Smart and Sustainable Supply Chains - Part 2	**Parallel Sessions 10.2** Optimization - Part 2	**Parallel Sessions 10.3** Human-centred Manufacturing and Logistics Systems Design and Management for the Operator 5.0 - Part 3	**Parallel Sessions 10.4** New Horizons for Intelligent Manufacturing Systems with IoT, AI, and Digital Twins - Part 2	**Parallel Sessions 10.5** Applications of artificial intelligence in manufacturing - Part 2	**In Presence + Online** **Parallel Sessions 10.6** Digital Track - Part 2 **Link:** https://eu02web.zoom-x.de/j/66235628809?pwd=JVbbDG6hrKT5G8kI0eoFP5KrMtyTrl.1 **Meeting-ID:** 662 3562 8809 **Kenncode:** 848188
12:30 - 13:30	Lunch					

Detailed Presentation Schedule

Wednesday 11 September 2024: *After Lunch*

13:30 - 14:50	**Parallel Sessions 11.1** Mechanism Design for Smart and Sustainable Supply Chains - Part 3	**Parallel Sessions 11.2** Intralogitics	**Parallel Sessions 11.3** Modelling supply chain and production systems - Simulations	**Parallel Sessions 11.4** Modelling supply chain and production systems	**Parallel Sessions 11.5** Industrial Product Service Systems
14:50 - 15:00	Break				
15:00 - 16:00	Closing Ceremony				

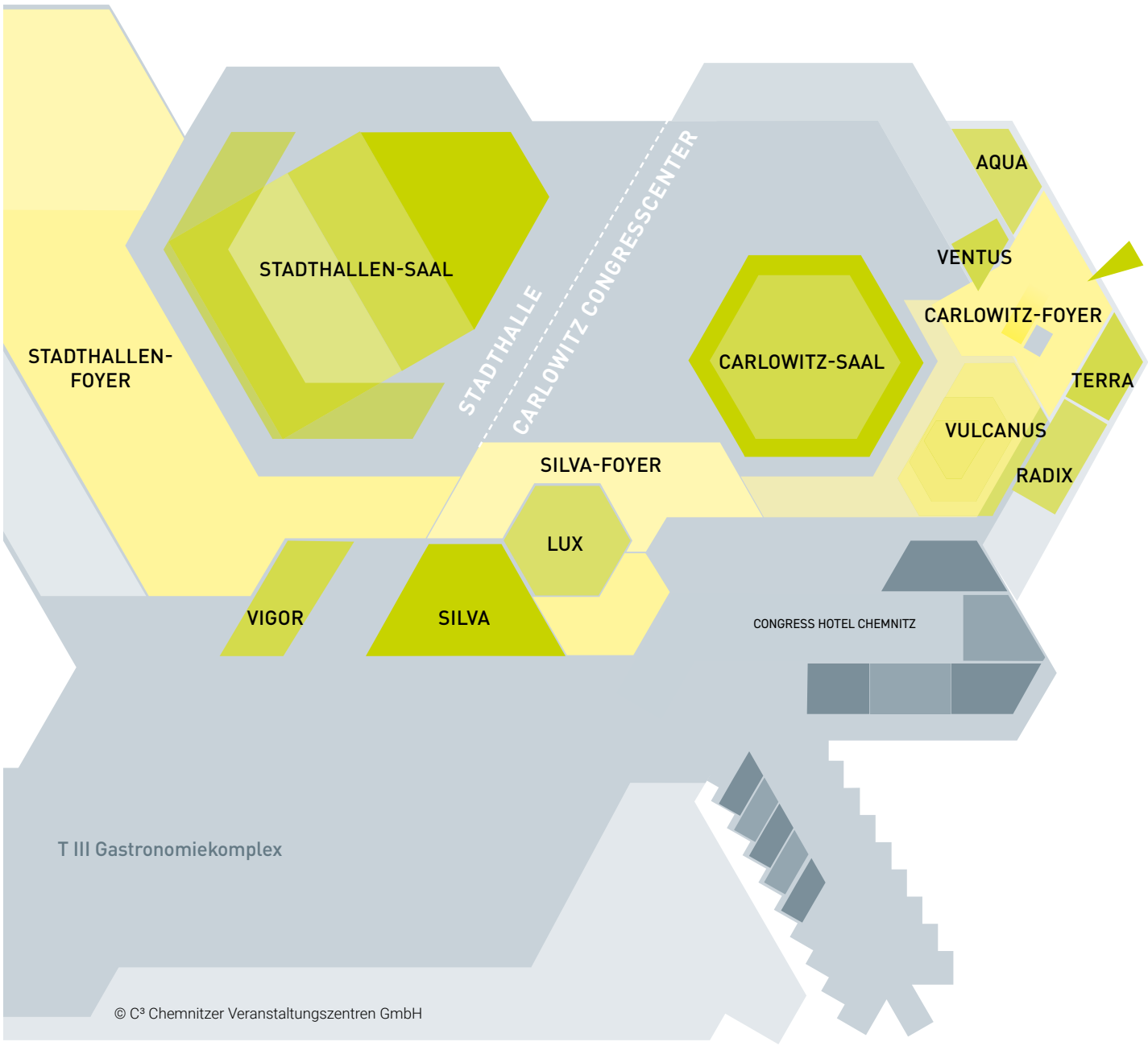
Start at 12:50! In Presence + Online

Parallel Sessions 11.6 Digital Track - Part 3

Link: https://eu02web.zoom-x.de/j/66235628809?pwd=JVbbDG6hrKT5G8kI0eoFP5KrMtyTrl.1

Meeting-ID: 662 3562 8809
Kenncode: 848188

Site Map
Carlowitz Congress Center



Premises
Carlowitz Congress Center

Room: **Terra**

Room: **Aqua**

Room: **Radix**

Room: **Vulcanus**

Room: **Vigor**

Room: **Carlowitz-Saal**

Monday
09 September 2024

Presentations

Parallel Sessions 1.1	Time: 10:15 - 11:15	Room: Terra

Barriers and Challenges for Transition towards Circular and Sustainable Production Processes and Servitized Business Models - Part 1

Roberto Sala, and Marco Ardolino

Barriers and challenges toward the servitization of the machinery sector: evidence from theory and practice

Marco Ardolino, Roberto Sala, Laura Scalvini, Syed Kazam Sajjad, Federico Adrodegari, and Giuditta Pezzotta

Business offerings based on the sale of services on top of products is always more diffused, disclosing the opportunity of defining new business models based on subscription or product performance. To remain competitive on the market, manufacturers are always more frequently relying on servitized business models, and nowadays an increasing number of studies is addressing this topic in terms of benefits for these companies and possible obstacles to a suc-cessful implementation. This paper wants to contribute to this research stream by focusing on the machinery that, due to the nature of their products and the financial exposure required for their production, need to carefully consider the structure of a servitized offering to make it profitable. By a mixed-methodology approach, the paper aims at listing and discussing the main barriers and challenges that these companies need to address to structure profitable servitized business offerings.

Exploring Servitization in Building Technology: The Case of Piping Systems

Luca Keller, Omid Maghazei, Clemens Gróf, and Torbjørn Netland

This study explores the case of servitization in building technology from three perspectives: market, organizational, and technological. This paper draws upon findings from a single case study of a multinational manufactur-er of piping systems. Products with advanced technological solutions, a comprehensive portfolio of products and services, and partnering are enablers for offering product–service bundles in the building technology sector. Fur-thermore, the development of a consultative sales approach, adaptations to the organizational structure, and internal collaborations could foster the pro-vision of more service-oriented solutions.

Market needs for a circular transition: implemented practices and required skills

Federica Acerbi, Adriana Hofmann Trevisan, Micaela Vitti, Paulina Caldarelli, Iskra Dukovska-Popovska, Sarah Downes, Marco Taisch, Sergio Terzi, and Claudio Sassanelli

The circular economy (CE) transition demands a paradigm shift requiring to incorporate changes in manufacturing processes, business relationships, innovations. and professional skills. In particular, there is a growing demand for skills associated with developing circular business models and exploring innovative solutions derived from emerging digital technologies. The CE job market is highly heterogeneous, with individuals from different educational backgrounds who can work in numerous sectors. However, to date, the literature has offered few insights regarding the skills required for CE applied in manufacturing, especially in industrial sectors considered critical to advance CE initiatives, such as Textiles, Waste from Electrical and Electronic Equipment (WEEE), and Automotive. Therefore, the re-search objective of this contribution is to explore, from a practitioner's point of view, the current needs and already-in-place actions to align the skills and job profiles required for the circular transition in the textile, WEEE, and automotive sectors. This study relies on 6 interviews to collect empirical evidence in terms of job profiles, critical skills, and possible training programs already implemented to fill organizational demand. As a result, digital skills resulted to be important to monitor performances and track products across the value chain. This is pushed especially by the creation of DPPs that are entering all the sectors. Soft skills are considered essential especially to drive collaboration (both internally and externally) which is considered the key pillar under the creation of circular systems. Last, no specific job profiles are needed but those already existing need to be enhanced with CE-oriented knowledge.

Parallel Sessions 1.2	Time: 10:15 - 11:15	Room: Aqua

Engineering and managing AI for advances in asset lifecycle and maintenance management

Anders Skoogh, and Alessandro Ruberti

Integrating Machine and Quality Data for Predictive Maintenance in Manufacturing System

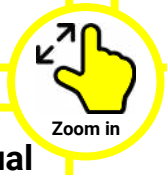
Sabino Francesco Roselli, Martin Dahl, Mukund Subramaniyan, Ebru Turanoglu Bekar, and Anders Skoogh

Maintenance and quality control are typically disjoint areas in a production system and even though interactions between them do exist, they are limited. In some cases, the quality deviations are reported directly by the client the product is sold to before maintenance actions are taken to repair the faulty machines and prevent these specific deviations. In this paper, we claim that by using machine and quality data in combination, it is possible to generate information about the process and the resulting product, that will allow to detect deviations in earlier stages, likely before the product reaches the client, possibly even before it is produced. We analyze a production process over a period of two years, during which operational parameters of the machines executing the process are reported, as well as the quality deviations of the parts produced. The data gathered is used to establish whether there exists a correlation between the machine status and the quality deviations of the products. Experiments show that the correlation increases when adjustments to the machines are made. This evidence supports our hypothesis of the possibility of using quality and machine data in combination in the development of future predictive maintenance solutions.

Adoption of AI-based systems in industrial maintenance: empirical evidences from an action research in the maintenance service business

Marco Macchi, Alessandro Ruberti, and Adalberto Polenghi

The adoption of AI-based systems in industrial contexts is a hot topic in the scientific and technical arena. The present paper aims to bring a contribution to this regard. It sheds light on the adoption of AI-based systems starting from the evidences gathered during an action research in the maintenance service business. The action research deals with the adoption of AI in Predictive Maintenance within the service offering of an Original Equipment Manufacturer that takes advantage of Digital Servitization. The maintenance data-driven decision-making is studied based on the triad of three related entities: technologies, humans and organizations. Moreover, the inclusion of advances potentially available from AI is discussed by means of two selected use cases where advanced data analytics embedding Machine Learning (ML) and Transfer Learning (TL) techniques are considered. As AI is infused along the Predictive Maintenance process implemented with the digital transformation, the use cases are presented as meaningful examples in order to deduce strategic considerations in terms of strengths, weaknesses, opportunities and threats as implied by their deployment in Predictive Maintenance processes at full scale.



Comparing Digital Twins and Virtual Engineering in buyer supplier relationships for complex production facilities

Luca Janecki, Oliver Antons, Daniel Reh, and Julia C. Arlinghaus

In todays highly competitive and interconnected global marketplace, the ef-fective management of buyer-supplier relationships is essential for organiza-tions seeking to stay ahead. With the rise of complex production facilities, ensuring product quality and optimizing communication between buyers and suppliers presents an escalating challenge. This complexity is further com-pounded by the integration of Digital Twins and Virtual Engineering, requir-ing innovative solutions to navigate the intricacies of modern supply chain dynamics. This article explores the role of Digital Twins and Virtual Engi-neering as a strategic approach to enhance buyer-supplier relationship man-agement within the context of complex production facilities using insights from the Principal Agent Theory. Based on a systematic literature review, we explore current approaches to the use of virtual engineering and digital twins to overcome existing tensions from principal-agent theory.

Parallel Sessions 1.3

Lean Thinking Models for Operational Excellence and Sustainability in the Industry 4.0 Era - Part 1

Federica Costa, and Matteo Zanchi

Understanding the Drivers of Lean Learning in Industrial Environments

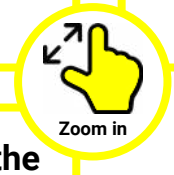
Bruno Pereira, Luís Miguel Ferreira, and Cristóvão Silva

Organizations are increasingly recognizing the benefits of adopting lean tools. However, a successful lean transformation depends on the active involvement of all organizational members. Comprehensive employee training is, therefore, fundamental to the effective implementation of lean manufacturing practices. Although collaborative and dynamic practical sessions have been implemented in certain university settings for teaching lean principles, there is limited research exploring how learning outcomes are influenced by participants' characteristics, such as self-efficacy belief, motivation, or prior knowledge. Examining these relationships is even scarcer in the literature concerning industrial training activities. This study examines the impact of lean training on employee learning within an industrial organization, looking at 177 participants and analyzing the relationship between learning outcomes and variables such as self-efficacy beliefs, prior knowledge, motivation, and enjoyment. The results show that the training significantly improved the participants' lean knowledge level. A significant relationship was found between self-efficacy beliefs and employees' motivation, which in turn had a positive impact on their learning. Based on these findings, companies should consider lean training that engages employees' curiosity using non-traditional teaching methods in transferring lean knowledge.

Digitally-Enhanced Shu-Ha-Ri Learning Cycle for Assembly Procedures in Smart-Lean Workstations

Matteo Zanchi, David Romero, and Paolo Gaiardelli

The impact of Digital/Smart Technologies on Lean Manufacturing has brought significant improvements in terms of both performance and working conditions for assembly operators. To this matter, one of the aspects that have been most positively affected by this Digital Transformation concerns "Human-Workstation Interaction (HWI)". Whereas before the Digital Transformation of assembly processes, workstations were mostly characterised by entirely manual (human-intensive) operations, the advent of modern Digital/Smart Technologies has provided the blue-collar worker with fundamental assisting tools in the execution of job tasks, both from a physical and cognitive point-of-view. Such assisting tools are aimed not only at supporting the quality of work but also the "on-the-job" training and development of the workforce in real-time. Hence, when it comes to workforce "on-the-job" training and development, the Lean philosophy offers a unique learning model, known as the "Shu-Ha-Ri" cycle, consisting of three phases: (i) "learning the rule", (ii) "mastering it", and (iii) "breaking it down to make it better". However, modern workstations, whether enhanced with Digital/Smart and/or Lean tools, are not always able to support all phases of this learning cycle. In this regard, this paper proposes a "Digitally-Enhanced Shu-Ha-Ri Learning Cycle" model that can support in the definition of which Digital/Smart Technologies are necessary to ensure that assembly operators are properly trained and developed in the emerging Digital Lean Manufacturing World.



Sustainable Lean Practices in the Luxury Fashion Industry: a case study

Alessia Bilancia, Federica Costa, and Alberto Portioli Staudacher

The luxury fashion industry faces increasing inspections due to its significant environmental footprint and overproduction issues. In the last years, lean management principles have emerged as a potential solution to address sustainability challenges in manufacturing. This study investigates how lean practices can contribute to environmental sustainability in luxury fashion production processes, focusing on personal luxury goods due to their significant growth within the global luxury market. Employing a multiple case study approach, the study examines two Italian luxury fashion companies covering the entire production process. Thanks to an analytical framework which integrates lean practices with environmental performance indicators, it has been possible to collect information from the interviews conducted. The results indicated a comprehensive adoption of lean practices in both companies, with positive impacts on environmental sustainability, particularly in materials, energy, emissions, and waste management. However, certain lean practices exhibit nuanced effects, underscoring the need for tailored approaches in different production phases. The study contributes insights into sustainable practices in luxury clothing manufacturing, suggesting avenues for future research to enhance operational excellence while balancing environmental sustainability.

Parallel Sessions 1.4

Smart Manufacturing Assets as Drivers for the Twin Transition towards Green and Digital Business - Part 1

Stefan A. Wiesner, and Matthias Kalverkamp

From Vineyard to Smart Factory: The case for a Digital Innovation Hub in the Atacama Desert

Matthias Kalverkamp, Maja C Willimowski, Stefan A Wiesner, and Raúl Enrique Zúñiga Arriaza

This paper explores the challenges posed by the low digital maturity of Small and Medium-sized Enterprises (SMEs) in developing countries, using the example of viticulture in the northern region of Tarapacá in Chile. The study proposes a con-cept for a digital competence center that considers region-specific requirements both from a business and from an environmental perspective. The study ground is located in the Atacama Desert, one of the driest places on earth. In this paper, we argue that the low Computer and Information Literacy (CIL) score in Chile exemplifies a broader issue in developing countries. Drawing upon previous in-sights from an explorative study on digital maturity in Chilean SMEs, we pro-pose an action-oriented approach and delve into the critical role of so-called digi-tal competence centers as a facilitator to realize the vision of a digitally trans-formed business landscape for SMEs. Such centers can offer competent and pro-vider-neutral contact points for information, awareness-raising, and qualification of SMEs and craft businesses. Central to such an approach are considerations of regional and cultural characteristics that influence the uptake and sustainable im-plementation of digital technologies. Amongst these characteristics are, for exam-ple, the level of hierarchy in Chilean businesses and the environmental challenges posed to the region due to the extensive use of freshwater by the mining industry in competition with agricultural food production. While such conditions are spe-cific to the location, the concept of digital competence centers considering region-al and cultural characteristics may be beneficial for SMEs in other developing countries.

Construction of a Demonstrator for Artificial Intelligence-supported, automated Dismantling of Battery Systems

Gerald Bräunig, Sara Menetrey, and Dominik Hertel

In the context of increasing environmental concerns and the push towards sustainable practices, the recycling and repurposing of battery systems have become imperative. This paper presents a concept for the automated disas-sembly of battery systems from pack to module using artificial intelligence. The focus is on the design and process sequence of two independently de-signed systems. One system is responsible for the separation and screwing processes within the dismantling of battery systems, while the other system handles the removal of corresponding battery components. The generation of data for linking artificial intelligence with dismantling systems and network-ing using digital twins is a topic that requires investigation and practical im-plementation through several experiments in the future.

Key factors for sustainability along the lifecycle of smart Product Service Systems

Stefan Alexander Wiesner, and Jannicke Baalsrud Hauge

This paper applies an explorative literature review to analyze the generalizability of the lifecycle of industrial smart Product-Service Systems (PSS), comprising both capital goods and associated services. It investigates the factors influencing sustainability throughout this lifecycle, considering the complexities inherent in such systems. The article discusses whether assessing the sustainability of services versus goods within the PSS framework requires distinct criteria. By analyzing existing lifecycle models and indicator frameworks, the research identifies key dimensions and criteria essential for describing and evaluating economic and environmental sustainability across the lifecycle. Key questions addressed include the identification of dimensions and criteria crucial for sustainability assessment, considering the complexities and uncertainties inherent in the lifecycle of capital goods. The findings provide a first step towards a framework for measuring and improving sustainability within our context. To better understand the dynamics and uncertainties along the lifecycle, enhanced collaboration between the involved domains is recommended. This could be realized through industrial case studies and comprehensive impact assessments.

Parallel Sessions 1.5	Time: 10:15 - 11:15	Room: Vigor

Computer Vision-based Digital Twin and Digital Services for Dynamic Production and Logistics Environment - Part 1

Yongkuk Jeong, and Erik Flores-García

Product-centric Simulation for Proactive Evaluation of Production Plan in Shipyard

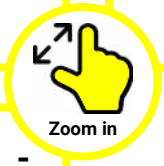
DongHyun Lee, Jisoo Park, Changha Lee, Seoyoung Jo, Yonghee Kim, Seungwoo Jeon, Jongpil Yun, and Sang

The shipbuilding industry encompasses various stages in constructing a ship, culminating in the final product. Managing and optimizing these complex pro-cesses necessitates considerable time and feasible mid- to long-term planning. A crucial aspect of effective and competitive production management within the shipbuilding industry involves establishing and implementing accurate production plans tailored to the specific situations. While various attempts have been made to utilize modeling and simulation methodologies for this purpose, they have often been hindered by difficulties in accurately capturing the actual situations and con-straints of the production site. This paper proposes the use of a product-centric simulation for proactive evaluation of master production plans, alongside the pre-diction and validation of these plans using shop floor data. By an industrial case study for a Korean shipbuilding company, the effectiveness of the proposed methodology was verified through comparison with existing way. By product-centric simulation, it is expected that production planning could become more ac-curate by reflecting the actual situation and constraints.

Instance Segmentation and Digital Twin Use Case for WIP Tracking in Heavy Industry

Jang Won Choi, Shashidhar Patil, ChoongJe Lee, and Jong-Hoon Park

Industries such as railways, aerospace, shipbuilding, and construction are known for their heavy manufacturing processes, which involve the production of large and complex products. The railway industry is known for its tight delivery schedules, which make timely production and logistics critical. To address these challenges, manufacturers are increasingly turning to advanced technologies such as AI and digital twin technology. These technologies allow for the automatic creation and consolidation of key production and logistics information, resulting in improved manufacturing productivity. This study focuses on the implementation of a digital twin in a railway train manufacturing plant. Specifically, this study discusses the use of object detection through instance segmentation to track train body parts, particularly underframes. Using this method, manufacturers can identify status changes in each production process, enabling them to facilitate work-in-process logistics within factory workstations. This approach contributes to gain real-time process visibility and corresponding work efficiency. By embracing these advanced technologies, industrial facilities can build point-of-production systems in a cost-effective way. The use of AI-vision and digital twin technology is transforming the manufacturing industry, allowing manufacturers to boost productivity, reduce costs, and improve the overall quality of their products.



Centering on humans - Intersectionality in vision systems for human order picking

Erik Flores-García, Yongkuk Jeong, Enrique Ruiz Zuniga, and Magnus Wiktorsson

This study applies an intersectional approach to address concerns about diversity of data acquisition when applying vision systems in human order picking. The study draws empirical data from a single case study conducted at an automotive manufacturer. It identifies critical factors of intersectionality for the use of vision systems in human order picking at four levels including form and function, experience and services, systems and infrastructure, and paradigm and purpose. These findings are helpful for mitigating bias and ensuring accurate representation of the target population in training datasets. The results of our study are indispensable for enhancing human-centricity when applying vision systems, and facilitating the acquisition of unstructured data in human order picking. The study contributes to enhancing diversity in human order picking, a situation that is highly relevant because of the variations in age, gender, cultural background, and language of staff. The study discusses theoretical and managerial implications of findings, alongside suggestions for future research.

Parallel Sessions 1.6	Time: 10:15 - 11:15	Room: Carlowitz

Meet the Editor 1: Operations Research-oriented Journals

Gregor von Cieminski

Production Planning and Control: The Management of Operations

Associate Editor: Prof. Dr. Paolo Gaiardelli, University of Bergamo, Italy

International Journal of Production Research

Editor-in-Chief: Prof. Dr. Alexandre Dolgui, IMT Atlantique, France

International Journal of Integrated Supply Management

Editor-in-Chief: Prof. Dr. Dimitry Ivanov, Berlin School of Economics and Law, Germany

Parallel Sessions 2.1	Time: 13:15 - 14:15	Room: Terra

Barriers and Challenges for Transition towards Circular and Sustainable Production Processes and Servitized Business Models - Part 2

Roberto Sala, and Marco Franke

Towards a service marketplace to empower circular economy transition: An example application in the supply chain of textile industry

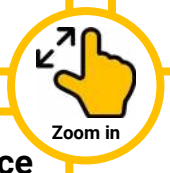
Marco Franke, Quan Deng, Karl A. Hribernik, Klaus-Dieter Thoben, and Gessica Ciaccio

The environmental impact of the textile industry is driving a shift towards circular economy (CE) practices. The EU's 2022 strategy mandates the Digital Product Passport (DPP) for textiles, which requires environmental and circularity data along the value chain. To comply with DPP, it is necessary to use digital services for CE in supply chains to assess the environmental impact of textile products. CE services requires addressing interoperability issues and facilitating data ex-change between these CE services used by different companies for their individu-al products. Although various CE services are available as commercial off-the-shelf products, they are often provided with a generic data model for a specific product, and significant effort is required by SMEs to address customisation. Ex-isting service marketplaces are either not domain specific or do not facilitate easy (re-)use and adoption of these CE services. This paper proposes a marketplace to address this challenge. It connects solution providers offering CE services with SMEs seeking solutions. The marketplace implements Software as a Service (SaaS) and provides public APIs and domain & product specific data connectors to facilitate data exchange and interoperability between individual services from companies and CE services in the marketplace. This will minimise the effort re-quired to discover, deploy and use CE services within SMEs, and facilitate the (re)use of CE services across different products. With this the marketplace aims to promote sustainability and traceability in the circular economy of the textile sector, which is shown for Preferential Certificate of Origin.

Designing and implementing second life for electric vehicle batteries: An integrated framework to navigate

Koteshwar Chirumalla, Erik Dahlquist, Ignat Kulkov, Ioana Stefan, and Glenn Johansson

The electrification of vehicles has become a critical means to achieve climate-neutral transportation. As more electric vehicles (EV) are adopted, an increasing number of lithium-ion batteries will be utilized, inevitably experienc-ing capacity degradation over time. Retaining the value of these retired batteries through remanufacturing, reusing, and repurposing to create a second life holds significant environmental and economic benefits. However, many companies within the battery ecosystem struggle to capitalize on this opportunity due to a lack of business insight and suitable business models tailored to their operational contexts. The purpose of this paper is to propose an integrated framework for designing and implementing second life for the EV batteries that could guide and navigate ecosystem actors towards circularity. This study employed an explora-tive qualitative inquiry approach, utilizing interviews and workshop methods, in-volving 15 companies in the EV battery ecosystem. Data collection involved 24 semi-structured interviews and 22 workshops. The framework includes four building blocks, including 1) barriers and enablers, 2) circular business models archetypes and design principles, 3) ecosystem management, and 4) battery performance monitoring. Further, the paper explains criteria influencing the selection of design and implementation of strategies for battery second life. This re-search contributes to the theory of circular business models and ecosystem management in general, with specific relevance to battery second life and circularity.



A holistic framework to enhance sustainable development and reporting in corporate sustainability

Alessia Bilancia, Federica Costa, and Alberto Portioli Staudacher

Despite the increasing momentum towards sustainability in the corporate world, a comprehensive management tool integrating internal development and external reporting is lacking in the literature. Over the past decade, sustainability has become a focal point for companies, necessitating a reshaping of strategies to minimize environmental impacts and enhance societal contributions while ensuring long-term economic sustainability. However, existing literature lacks a unified approach to integrate internal development and external reporting within sustainability management. The review highlights the absence of a comprehensive management tool and identifies commonalities and limitations in existing solutions. Leveraging the Triple Bottom Line model and Global Reporting Initiative Standards, the study aims to address this gap by developing a holistic framework that incorporates widely adopted indicators and disclosures. The study begins with an analysis of existing literature to build a solid foundation of knowledge on sustainability management. Based on that, a novel framework is proposed, integrating dimensions such as sustainable development, reporting, and accountability across organizational functions and decision-making levels. The study contributes to bridging the gap in sustainability management by proposing a comprehensive framework that addresses the need for integrated internal development and external reporting, particularly crucial for companies striving to align their operations with sustainability goals and enhance accountability to stakeholders. Moving forward, the framework offers a valuable tool for companies to enhance their sustainability practices and accountability to stakeholders.

Parallel Sessions 2.2	Time: 13:15 - 14:15	Room: Aqua

Implementing the EU Green Deal: Challenges and Solutions for a Sustainable Supply Chain - Part 1

Giovanni Romagnoli, and Mélanie Despeisse

Supply Chain Collaboration to Mitigate Food Loss and Waste In Food Supply Chain: A Literature Review

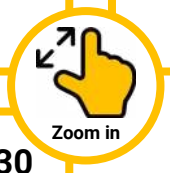
Lien Bui, and Frédéric Gautier

This study employed a bibliometric review technique to investigate trends and patterns in food supply chain collaboration (SCC) and food loss and waste (FLW) research. This research aimed to identify potential avenues for future investigation by analyzing frequently occurring keywords within the field. A Boolean search strategy was implemented across four major academic databases: Scopus, Web of Science, Science Direct, and EBSCO. The search focused on articles published between 2011 and December 2023, yielding 983 articles. Following removing duplicates and including relevant articles identified through reference list snowballing, a final selection of 112 journal articles was established. Bibliometric coupling analysis, examining the co-occurrence of keywords, was visualized using VOSviewer software. The analysis of these publications revealed four prominent research themes: 1) How to manage the relationship between supply chain collaboration and FLW; (2) Applying technology toward innovation collaboration and reduction FLW; (3) Sustainable supply chain collaboration and how to achieve sustainable food supply chain (FSC); (4) Risk and uncertainty impact on FLW and the need for resilient collaboration. We believe that the four themes underscore the critical importance of vertical and horizontal collaboration among FSC members, governments, the private sector, educational institutions, and researchers to reduce FLW, a key goal of sustainable supply chains.

Characterising the relationship between environmental sustainability and resilience in manufacturing

Arpita Chari, Mélanie Despeisse, Maria Holgado Granados, Björn Johansson, and Johan Stahre

The study of resilience has grown since the 70s, with the impacts of the Covid-19 pandemic and geo-political issues around the world more recently influencing manufacturing supply chain operations. Moreover, sustainable supply chains will continue to drive businesses to operate in more competitive environments where there is resource scarcity, demand uncertainty, environmental concerns from stakeholders, etc. Few studies have at-tempted to study the synergies and trade-offs between sustainable and resilient practices for manufacturing; however, these findings are insufficient and need further exploration. This study explores the relationship between environmental and manufacturing resilience practices to support decision-making in dynamically changing environments and jointly build resilient and green SCs. This characterisation was studied based on four relation-ships—whether they were equivalent, supporting, competing/ incompatible, or overlapping. The study hence advances the understanding of the relation-ships between manufacturing resilience and sustainability considering the uncertain context within which manufacturing supply chains currently operate.



Toward the European Union 2030 Strategy for textiles: a review

Guillherme Hörner Bussolo, Gianmarco Bressanelli, Filippo Visintin, and Nicola Saccani

The European Union 2030 Strategy for Textiles is a framework aimed at creating a sustainable and circular textile industry. This strategy includes a vision for 2030 where textile products are long-lived, recyclable, and made of recycled fibers while being free of hazardous substances and compliant with social rights. However, the strategy also presents challenges that require the adoption of comprehensive transformations across supply chains, governments, and societies. This study analyzes the scientific literature on circular and sustainable textile industry initiatives within the European Union's Strategy for Sustainable and Circular Textiles. A systematic literature review has been carried out to combine scientific insights with legislative analysis. Results show that more research is needed to determine the optimal technology for a Digital Product Passport for textiles (Action #1.2); and that issues such as standardizing consumer information and engagement in the circular economy remain unresolved for empowering consumers in the textile green transition (Action #2.1); that the Extended Producer Responsibility for textiles still needs to be examined from various perspectives due to upcoming legislative implementations (Action #3.1); and that understanding how to implement circular business models while maintaining profitability is crucial for textile companies (Action #4.3). Managers and policymakers can use this article to better understand how scientific literature can support the implementation of the European Union's Strategy for Textiles.

Parallel Sessions 2.3	Time: 13:15 - 14:15	Room: Radix

Lean Thinking Models for Operational Excellence and Sustainability in the Industry 4.0 Era - Part 2

Federica Costa, and Daryl Powell

Towards a Sustainable Digitalization Roadmap for SMEs

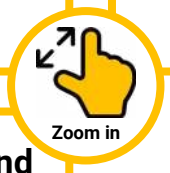
Daryl Powell, Jacobo Marino, Christian Holm Edvardsen, and Emrah Arica

Digitalization has become a megatrend in the modern manufacturing indus-try. While the digitalization of production and supply chain operations arises as a challenge even for large companies, for small- and medium-sized enter-prises (SMEs) the task is downright daunting. Many such firms turn to con-sulting firms, or academic / research institutions in the hope of finding a roadmap to the promised land. However, a review of the academic and prac-titioner literature leaves much to the imagination. In this paper, we present a summary of the key existing works on digitalization roadmaps, and through use of a single case study, present a more holistic, descriptive roadmap that can be used by SMEs to guide their sustainable digitalization efforts more systematically.

Enhancing Labor Flexibility in Workload Control: The Development and Application of a Framework

Alireza Ahmadi, Alessandra Cantini, Federica Costa, and Alberto Portioli Staudacher

This article delves into the integration of labor flexibility within Work-load Control (WLC) in Make-to-Order (MTO) production settings. In a domain where existing literature offers limited guidance on data collection for optimizing labor flexibility, our study introduces the 'FlexiFlow' framework. This practical tool is designed to bridge this gap by enhancing operational efficiency and im-proving labor resource management and data acquisition in high-variety, low-volume MTO environments. We explore the interplay between WLC and labor flexibility through a systematic and narrative literature review. We explain effec-tive data collection strategies, encompassing manual and digital methods, includ-ing Manufacturing Execution Systems (MES). The FlexiFlow framework, artic-ulated through four detailed tables, equips companies with the tools to manage labor flexibility effectively, offering practical implications for practitioners. This framework extends theoretical understanding and offers actionable insights, sig-nificantly enhancing operational adaptability and efficiency. FlexiFlow improved production efficiency and responsiveness by reducing lead times and improving labor resource allocation.



Analyzing the Interplay of Agile and Digital Transformation in Modern Management Theory: A Systematic Literature Review

Bojan Grebić, Danijela Ćirić Lalić, Uglješa Marjanović, Bojan Lalić, and Milena Savković

Given the complexity inherent in the interweaving of agile and digital trans-formation, this paper aims to decipher these two similar yet different phenomena by fostering a deeper understanding of their coexistence and the potential benefits they can offer when implemented concurrently. Therefore, we have conducted a comprehensive systematic literature review on agile transformation (AT), digital transformation (DT), and agile digital transformation (ADT) as a synthesis of these concepts, encompassing over thirty papers published in the past eight years that have been deemed relevant to one or more elements of ADT. The key contributions of this paper lie in identifying and explaining the various interplays between agile and digital transformation and in creating a unified perspective on this subject presented through a conceptual ADT model grounded in levels of agility and digitalization. Accordingly, this paper surveys both theoretical and practical implications of agile and digital transformations, thus proposing a strategic approach to transformation and the conceptual model for ADT. Moreover, the pro-posed ADT model can be used as maturity assessment tool that helps organisations recognize and streamline their transformative initiatives.

Parallel Sessions 2.4	Time: 13:15 - 14:15	Room: Vulcanus

Smart Manufacturing Assets as Drivers for the Twin Transition towards Green and Digital Business - Part 2

Stefan A. Wiesner, and Khaled Medini

Exploring Agile Methods Application in Manufacturing

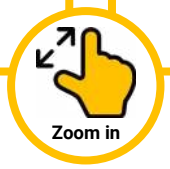
Solène AlHayek, Soukayna Souib, Kunruthai Meechang, and Khaled Medini

In the contemporary business environment, production and manufacturing organizations face increased customer demands, market volatility, and various constraints. These challenges require the implementation of new methods to stay competitive, especially the utilization of digital technologies. Recently, agile principles and methods have spread into the manufacturing business. Therefore, this paper explores the applications of agile methods in manufacturing organizations and how they enhance production in terms of speed, cost-effectiveness, and quality. A mixed research methodology relies on a systematic literature review and interviews. The analyzed papers present the increasing developments in agile manufacturing since 2019. We found that agility is addressed as a capability for manufacturing to operate a business in an uncertain environment and react flexibly to serve customer demand. The results uncover significant opportunities and challenges for agility enhancement, which could be useful for production and operations managers. The methods in achieving agility include, for example, day-to-day business activities, local supply chain, big data, leagile, buffer, and effective communication. Meanwhile, barriers impeding agility were inconsistent processes, organization constraints, workforce, inadequate engagement, and bull-whip effects. Based on in-depth interviews, experts highlight dominant perspectives of resource mobilization and visibility to create team dynamics, project-based innovation, and risk stemming, which are key factors of agility. The primary research findings with the secondary data enable recommendations for those pursuing agile manufacturing. It is a propitious pathway to stimulate further in-depth research on the emerging application of agile methods in the manufacturing domain.

Empirical grounded simulation models for Make-to-order (MTO) supply chains: an application in the furniture industry

Alexandra Lagorio, Giulio Mangano, Roberto Pinto, Carlo Rafele, and Giovanni Zenezini

The Make-to-Order (MTO) supply chain seeks to balance cost reduction with satisfactory customer service, especially concerning order lead times. Simulation plays a vital role in this balance, identifying risks, analyzing scenarios, and evaluating key performance indicators. However, existing simulation models often overlook suppliers and inventory management, focusing more on production, sales, and distribution. To address this, a simulation model tailored for the furniture industry integrates supplier selection with inventory management strategies, considering geographical complexities. Through a case study, various scenarios are assessed, revealing a trade-off between lead times and costs. Close MTO suppliers decrease lead times but increase costs due to transportation expenses, while distant sourcing minimizes costs but extends lead times, challenging customer expectations. This simulation model offers insights for MTO companies navigating supplier selection and inventory management, enhancing decision-making and customer satisfaction. Future research aims to expand the model into a supply chain Digital Twin, incorporating resilience and risk management to tackle broader MTO supply chain challenges.



Parallel Sessions 2.5	Time: 13:15 - 14:15	Room: Vigor

Computer Vision-based Digital Twin and Digital Services for Dynamic Production and Logistics Environment - Part 2

Yongkuk Jeong, and Seokhwan Yu

Advanced Time Block Analysis for Manual Assembly Tasks in Manufacturing through Machine Learning Approaches

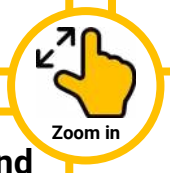
Yongkuk Jeong, Donggyun Park, Jesper Gans, and Magnus Wiktorsson

The management of assembly tasks within manufacturing, which traditionally relies on using stopwatches and video review, is both labour-intensive and prone to errors. This paper explores an approach utilizing machine learning (ML) and human pose estimation technologies to automate and enhance the classification and management of time blocks for manual assembly tasks in manufacturing environments. We developed and tested ML models capable of classifying manual assembly actions by converting video clips into a time series coordinate dataset via a human pose estimation library. The research highlights the potential of these technologies to significantly reduce the reliance on manual methods by providing a more adaptable, efficient, and scalable system for time data management. Our findings demonstrate accuracy variances across different actions, underscoring the challenges and potential of integrating ML in real-world manufacturing settings. This study provides a promising direction towards revolutionizing traditional practices and enhancing operational efficiencies in manufacturing.

Graph-to-sequence Approach for Job shop Scheduling Problem

Seung Heon Oh, Young In Cho, Seungwoo Han, and Jong Hun Woo

Reinforcement learning has recently been frequently researched for solving the Job Shop Scheduling Problem (JSSP). Typically, JSSP is approached through a dynamic scheduling perspective, applying the Markov Decision Process. This study breaks out of the mold and provides a static perspective for solving JSSPs. To this end, a graph-tosequence (graph2seq) architecture incorporating graph neural networks, multi-head attention, and pointer Network is proposed. Experiments are conducted on JSSP benchmarking data to validate the proposed method.



A Mobile Air-Purification Device and Digital Twin for Managing Hazardous Gases at Industrial Sites

Seokhwan Yu, Sejin An, Changha Lee, Hyunsuk You, Ilheum Choi, and Sang Do Noh

The presence of hazardous gases in industrial sites where various substances are utilized poses safety concerns to workers. In particular, failure to prompt-ly address hazardous situations can result in severe consequences such as significant casualties. Whereas many industrial sites have adopted air-purification systems to remove hazardous gases, most of those systems are fixed and focus on specific hazardous gases. Therefore, a safety system and response plan that can effectively manage the generation and dispersion of hazardous gases as well as for addressing unexpected situations must be es-tablished in industrial sites. This study proposes the development and appli-cation of a digital twin for the intelligent control mobile air-purification de-vices. The mobile air-purification device selects the appropriate removal module based on the type of hazardous gas and predicts the dispersion of gas through the digital twin. Based on the predicted results and derived puri-fication priorities, the mobile air-purification device autonomously drives to the leakage point and removes the leaked hazardous gas. Hence, a digital twin is constructed and utilized to predict the concentration of hazardous gases in the field based on sensor data from the environment. Based on in-door experiments and simulations, we validate the effectiveness of the pro-posed methodology, which is expected to facilitate crisis response and im-prove worker safety in industrial settings.

Parallel Sessions 3.1

Open Knowledge Networks for Smart Manufacturing

Boonserm Kulvatunyou, and Perawit Charoenwut

An Introduction to Machine Learning Lifecycle Ontology and its Applications

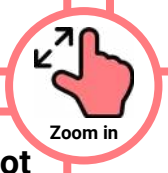
Milos Drobnjakovic, Perawit Charoenwut, Ana Nikolov, Hakju Oh, and Boonserm Kulvatunyou

Machine Learning (ML) adoption is on the rapid rise, with a nearly 40% compound annual growth rate over the next decade. In other words, companies will be flooded with ML models developed with different datasets and software. The ability to have information at one's fingertips about how these ML models were developed, what they were used for, what their performances and uncertainties are, what their internal structure looks like, and what datasets were used can have several benefits. These pieces of ML metadata are what we collectively call ML lifecycle data. In this paper, we explain our current research into developing an ML Lifecycle Ontology (MLLO) to capture such data in a knowledge graph. The motivation is not only to make such data available in a standard queryable representation across different ML software but also to connect it with other domain knowledge. We will introduce MLLO at the high-level and outline basic and advanced use case scenarios, in which the data, the MLLO, and domain knowledge may be used to improve the development and usage of ML models and associated datasets. We then describe future work we are undergoing to demonstrate the hypothesis.

Open Manufacturing Capability Network Supported by Formal Ontologies

Farhad Ameri, Mukund Shenoy, Ali Hasanzadeh, and Sambhav Koomar

Access to accurate manufacturing capability information is necessary for efficient supplier discovery and agile supply chain formation. However, manufacturing capability data, particularly for small and medium-sized manufacturers, is often unavailable or, if accessible, lacks essential qualities such as correctness, completeness, interoperability, and openness. The objective of the research presented in this paper is to develop an open Manufacturing Capability Network (MCN) that represents various manufacturers' capabilities as an interconnected and formal knowledge graph. This capability graph is part of a larger graph referred to as the Supply and Demand Open Knowledge Network (SUDOKN). The ontologies that provide the semantics of the knowledge graph comply with the Basic Formal Ontology (BFO). A proof-of-concept knowledge graph, based on 1700 manufacturers, is presented in this work. The graph's validity was assessed by submitting queries related to supplier discovery use cases. SUDOKN, once fully deployed, serves as a shared, canonical, and consensus-driven knowledge backbone, that supports supply chain analytics solutions with AI-ready data.



Integrating Ontology with Cobot Execution for Human-robot Collaborative Assembly using Heterogenous Cobots

Yee Yeng Liau, and Kwangyeol Ryu

The manufacturing industry has heavily relied on robotic automation since the third industrial revolution. However, traditional robots struggle to adapt to the variability of modern production demands. Collaborative robots (cobots) offer a solution by providing flexible automation tailored to personalized manufacturing requirements. Human-robot collaboration systems, particularly beneficial for small-scale manufacturing, integrate human capabilities with technological advancements. Cobots enhance productivity, offer ergonomic benefits, and facilitate automation transformation through connectivity and data analytics. Effective communication between resources is crucial for enabling the execution of shared subtasks and ensuring the safety and efficiency of collaborative assembly. This study proposes integrating ontology with cobot execution programs to enhance collaborative assembly operations. The ontology encompasses knowledge related to the products to be assembled, the HRC environment (including re-sources, tools, and regions), and the relations between these entities and monitoring data. Additionally, establishing a connection between cobot controllers enables the seamless exchange of commands for coordinated execution. By enabling communication between resources, collaborative assembly tasks can be executed either sequentially or simultaneously, monitored for progress, and adjusted as necessary without manual intervention. This study contributes to streamline cobot execution and decision-making processes in manufacturing environments by incorporating ontology-based knowledge into cobot execution programs.

Parallel Sessions 3.2

Implementing the EU Green Deal: Challenges and Solutions for a Sustainable Supply Chain - Part 2

Giovanni Romagnoli, and Jan Frick

An association analysis of Digital Technologies in Circular Economy scenarios

Mosè Gallo, Francesco Moroni, Valentina Popolo, and Giovanni Romagnoli

The paper investigates the role of Digital Technologies (DTs) in fostering the implementation of CE models and practices by means of a systematic literature review. It first identifies available CE frameworks, by focusing on the so called 9R framework and the ReSOLVE framework. Then, DTs are briefly described and their features are appropriately summarized. Relevant literature is categorized by industry sector, study type, and CE strategies and employed DTs. Later, the collected papers are statistically analysed in order to highlight association effects between CE strategies, DTs and industrial sectors. As previous works highlighted that, in many instances, DTs are integrated in order to support CE objectives, we also verify the existence of preferred combinations of DTs for specific CE strategies.

Do we really need simulation for a transition towards Circular Supply Chain Management? A possible answer from scientific literature

Francesco Moroni, Alessandro Viola, Mosè Gallo, Giovanni Romagnoli, and Francesco Zammori

In this paper, we went through a structured literature review of 98 contributions between articles and conference proceedings papers that have been classified to investigate the impact of simulation techniques in SC modelling and towards sustainability. In today's business environment, enterprises need to extend their focus beyond their internal operation boundaries, leveraging their business partners to access unique skills, resources, and market value. These aspects belong to the established field of Supply Chain Management. However, a massive number of resources are being used to make and to manage products and the availability of natural resources is becoming scarcer every day. This poses a challenge that SCM must address, together with an enhanced customer awareness toward environmental issues. Recent strategies to solve these issues include concepts such as the Circular Economy. Integrating the CE principles in the SCM led to the development of Circular Supply Chain Management, and the transition from linear supply chain networks towards circular models is gaining interest in research studies. Nevertheless, these systems are more complex than the traditional ones hence requiring more advanced tools to design, optimize and deploy. Amongst these tools, simulation modelling techniques such as Discrete-Event Simulation and Agent-Based Simulation are emerging. Our findings pointed that there is still a lack of closed-loop and circular supply chain networks models. Although we considered only scientific literature contribution, the results clearly show that further investigation are required to comprehend and evaluate the simulation effectiveness in SC modelling and sustainability.

Addressing Supply Chain's Circularity Through Simulation: Textile Waste Separate Collection Models

Francesco Zammori, Giovanni Romagnoli, and Nicola Mercogliano

Every year, the textile industry produces vast quantities of textile waste, leading to environmental deterioration. This is primarily due to its con- ventional supply chain approach, marked by excessive production of virgin fibres and inefficient waste management practices favouring landfill disposal or incin- eration. Hence, a fundamental requirement for widespread adoption of sustaina- ble practices by all stakeholders in the textile supply chain, including consumers, is the development and validation of circular models. These models should in- corporate innovative systems for collecting, sorting, reusing, and recycling tex- tiles, along with resilient configurations for circular supply chains in the textile industry. Given these premises, this paper aims to assess the effect, measured in terms of environmental performance, achievable by adopting advanced waste management models in the textile supply chain. Specifically, two agent-based simulation models of a "standard" and "innovative" collection system of house- hold textile waste are presented and compared. Benefits of the innovative model are finally provided, along with possible managerial insights.

Enhancing Logistics Performance: Integrating Ports, Custom Clearance, Digitalization, and European Product Passport

Jan Frick, and Kenn Steger-Jensen

This research scrutinizes the pivotal role of logistics, often re-ferred to as the backbone of global commerce, in sculpting the economic scenarios of countries in an increasingly globalized world. Through an in-depth examination of literature, the paper elucidates the evolution of logis-tics performance over time, placing a spotlight on primary influencers - ports, custom clearance, digitalization, and the European Product Passport (EPP). The impact of these factors on shaping logistics performance and their indispensability in strengthening the logistics network are deeply ana-lyzed. Moreover, the study unveils the significance of emergent technolo-gies in the light of Industry 5.0, emphasizing their potential to transform lo-gistics and customs clearance processes. The paper reaffirms the necessity of harmonizing these elements to en-hance logistics performance, portraying them as essential pillars underpin-ning economic growth. The findings intimate that the adoption of advanced technologies can boost supply chain visibility, curtail costs, and elevate logistics efficiency, while initiatives like EPP foster sustainability across the supply chain. The research concludes by advocating for persistent in-vestments in these critical facets by the EU and other regions to optimize logistics performance and escalate global competitiveness. It prompts im-mediate action from policymakers, practitioners in the logistics industry, and academics to align with the swiftly changing dynamics of global logis-tics, thereby promoting logistics systems that are more efficient, sustaina-ble, and transparent.

Parallel Sessions 3.3

Lean Thinking Models for Operational Excellence and Sustainability in the Industry 4.0 Era - Part 3

Federica Costa, and Ugljesa Marjanovic

How Lean tools contribute to a production system, investigation in the automotive industry

Wiesław Urban, and Daniel Tochwin

Lean Manufacturing adoption is a gradual process, and the application status of Lean tools influences enterprise performance. Only well-prepared Lean initiatives bring real benefits. This study aims to identify the effective Lean tools required for eliminating waste and also verify the main factors that motivate companies to Lean applications. The study adopted a quantitative research method. Research data were collected through a questionnaire to the target population of medium and large companies in the automotive industry in Poland. The study confirmed that Lean tools are regularly implemented in automotives and the most popular tools are 5S and Visual Management. Statistically significant relationships were identified between specific Lean tools and waste reduction. The widest relation-ship with waste reduction is observed in VSM application, which is not frequent-ly used by companies. This suggests that great benefits can be obtained when an organization employs the approach focusing on the whole stream of value in the company. The study provides also a basis for a practical guidance for business how to introduce Lean tools to eliminate particular types of waste.

Integrating Multilayered Agility into Production Planning and Control: A Conceptual Model for Enhanced Manufacturing Efficiency

Danijela Ciric Lalic, Ugljesa Marjanovic, Milena Savkovic, Bojan Lalic, and Andrea Ivanisevic

This article introduces a conceptual model that integrates multilayered agility into Production Planning and Control (PPC), addressing the urgent need for manufacturing firms to adapt to the unpredictable challenges of the 21st-century marketplace. Grounded in the dynamic capabilities theory, our model synergizes organizational, operational, and personal-workforce agility layers within the PPC framework to enhance manufacturing efficiency in a Volatile, Uncertain, Complex, and Ambiguous (VUCA) environment. Through a comprehensive literature review, we identify gaps in the operationalization of agility in PPC and propose a structured approach to its integration. Our model offers a novel perspective on embedding agility into PPC, aiming to provide a roadmap for manufacturing firms to achieve operational excellence and a sustainable competitive advantage. The anticipated benefits of this model include improved responsiveness to market changes, enhanced operational flexibility, and a stronger innovation capability, paving the way for future empirical research in agile manufacturing.

Data-Driven Root-Cause Analysis in the Scope of Continuous Improvement Projects

Hugo Botelho, Paulo Peças, Diogo Jorge, James Mcleod, Loris Albertoni, Luís Caldas de Oliveira, and Marco Leite

Lean Manufacturing is widely recognized as a prominent methodology for implementing Continuous Improvement (CI) in industrial settings. Root Cause Analysis (RCA) plays a vital role in problem-solving projects, serving as a key component within CI methods like the Plan-Do-Check-Act cycle. However, the RCA process can be time-consuming, relying heavily on the expertise of technicians to manually analyze substantial amounts of data. To address these challenges Industry 4.0 technologies, namely Machine Learning (ML), are being implemented into RCA bringing new challenges such as the need for ML expertise in the lean field. Aiming to contribute to overcoming with these challenges, this work presents the development of an Assistance System (AS) that integrates descriptive analysis with ML techniques to support lean technicians in the root cause identification phase. This AS encompasses feature selection, hyperparameter tuning, data balancing, and feature importance. Logistic Regression, Decision Tree, Random Forest, and XGBoost are the models employed, with F1-Score being the evaluation metric. Besides the ML analysis, the AS also allows for descriptive analysis without ML and data profiling. The results of the ML analysis are presented and compared with the standard descriptive analysis to highlight the effectiveness of the AS in the root cause identification process. The successful integration of descriptive analysis and ML techniques enables a systematic approach to problem-solving, leading to improved overall efficiency and competitiveness in industrial settings.

Inspection Planning Improvement Framework Based on the PDCA Cycle

Angelica Reis, Lino Costa, and Sergio Sousa

Inspection Planning (IP) is critical to assure product quality during the Manufacturing Stage. IP takes place mainly during the stage of Process De-velopment and is considered an inflexible static output resulting from the initial plan. However, revisions can become necessary according to the manufacturing system's dynamic situation. Therefore, a flexible IP is need-ed, which can be achieved through a Continuous Improvement (CI) ap-proach. Although the advantages of feedback mechanisms are renowned, the design of quality control loops is not common in practice. Specifically, there has been no application of the PDCA cycle aimed at performance im-provement of IP. This paper proposes an IP improvement framework based on the PDCA cycle. The framework is applied in a case study in which IP changes were driven by a Kaizen Event. This paper provides new empirical evidence and extends the body of knowledge related to the CI of IP, show-ing that companies can stabilize and even increase their inspection perfor-mance by implementing improvement actions through the proposed frame-work. The case study describes alterations related to which quality charac-teristics to inspect and whereby, while suggesting that changes in inspec-tion extent are more likely to happen during the ramp-up phase. It con-cludes that companies need to create and maintain structures and processes that enable a quick, effective response to internal and external change driv-ers through a well-structured approach. This framework provides an orga-nized and easily understood management approach for the effective im-provement of IP.

Parallel Sessions 3.4	Time: 14:40 - 16:00	Room: Vulcanus

Additive Manufacturing

Siavash Haghighat Khajavi, and Leonie Pauline Pletzer-Zelgert

An Accessibility Assessment Algorithm for Support Structure Removal in Parts Produced by Powder Bed Fusion of Metal Using a Laser Beam

Leonie Pauline Pletzer-Zelgert, Lukas Unruh, Martin Iza-Mendez, and Johannes Henrich Schleifenbaum

In the additive manufacturing process of Powder Bed Fusion of Metals using a Laser Beam (PBF-LB/M), the removal of support structures represents a costly step, predominantly carried out manually in current industrial practices. Particu-larly challenging are areas of the parts where tools for support removal struggle to access. Therefore, in the data preparation of parts manufactured via PBF-LB/M, attempts are often made to orient the parts within the build chamber in such a way that no supports are needed in the difficult-to-access areas. However, identifying these areas is error-prone and typically relies on manual evaluation by engineers. To reduce susceptibility to errors, this paper introduces an algorithm called the Accessibility Assessment Algorithm (AAA), which automatically evaluates the accessibility of parts. The algorithm is implemented and tested on ten parts. Five experts experienced in removing support structures from PBF-LB/M-printed parts are interviewed and asked to evaluate the same parts for inac-cessible areas, and then to assess the calculation results of the AAA. Subsequent-ly, the results regarding inaccessible areas are compared between the algorithm's assessment and the experts' evaluations. The results show a 71% agreement, indi-cating its effectiveness in assessing the accessibility of parts.

Conceptualization of an Operational Capability Development Framework to Facilitate the Integration of Additive Manufacturing based on a Use Case Perspective

Christopher Gustafsson, and Christer Nygren

This paper proposes an operational capability development framework to fa-cilitate additive manufacturing (AM) integration from an AM use case per-spective. We conducted a single case study in collaboration with master stu-dents and AM actors. Data was collected through interviews with respond-ents from five AM actors and additional data collection methods. Data was analyzed thematically. The conceptualization of the proposed framework was performed iteratively by revisiting the literature and empirical data. The proposed framework provides insights on targeted operational performance and operational capabilities, including its constituents and development mechanisms, based on AM use cases which are evaluated regarding AM's potential and fit to fulfill a company's needs. We evaluated the framework based on selected AM use cases and additional insights from industry professionals and academics. This paper introduces a novel framework for operational capability developed to facilitate AM integration. Thereby, yielding another way of working with AM integration based on an AM use case perspective for engineers, managers, and other decision-makers. Therefore, we recommend that future research should extend the framework to include, evaluation using additional AM use cases, the development of dynamic capabilities, and evaluate other industrial contexts.

Operations Management of Additive Manufacturing

Siavash Haghighat Khajavi, Jan Holmstrom, and Mika Salmi

This article reviews the growing literature on additive manufacturing (AM) operations management and sheds light on the emerging research areas in this field. As the AM use cases of final parts rapidly expand, it is essential to focus on the operations management of this technology and determine the primary current and future research streams. A literature study method is utilized to select, review, and categorize articles in the field of AM. The 108 articles selected after the initial evaluation were carefully examined and categorized. The selected papers evaluate AM from an operations manage-ment perspective. This article categorizes the body of knowledge studying the application and operations management of additive manufacturing into three categories: studies concerned with the industry's current state, for-ward-looking studies with a conceptual approach, and forward-looking pa-pers with empirical grounding. Different AM processes studied are also considered. Our categorization showed that the latter category is still under-researched and presents an opportunity for future investigations. Moreover, six emerging streams of research in the third category were recognized. In addition to pointing out the areas of research that require more attention, this article aims to assist the researchers in better positioning their research.

Parallel Sessions 3.5

Computer Vision-based Digital Twin and Digital Services for Dynamic Production and Logistics Environment - Part 3 & Digital twin concepts in production and services

Yongkuk Jeong, and Sang Do Noh

Digital Twin-driven Reinforcement Learning for Dynamic Path Planning of AGV Systems

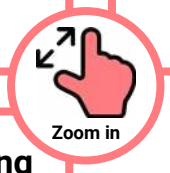
Donggun Lee, Yong-Shin Kang, Sang Do Noh, Jaeung Kim, and Hijun Kim

With the digitalization of industries, manufacturing systems are becoming increasingly complex and diverse. There is a growing focus on production flexibility and automation, leading to active research on production logistics (PL) systems that can effectively address these challenges. PL systems sig-nificantly influences the quality and productivity of products, and the proper design and optimization of path planning for logistics robots are crucial. This paper proposes a novel approach, Digital Twin (DT)-driven reinforcement learning (RL) for dynamic path planning of automated guided vehicles (AGVs) systems. The complex real-world path planning problem is repre-sented as a Markov Decision Process (MDP) and a DT-based Q learning algo-rithm that can solve the represented path planning problem is proposed. To validate the effectiveness and adaptability of the proposed approach, a sys-tem is implemented and applied to an actual manufacturing site.

An Authoring Tool for Mixed Reality Interfaces for Digital Twins in Manufacturing

Aubrey Elizabeth Simonson, and Guodong Shao

While the concept of digital twins has a history of at least twenty years, the design of user interfaces for digital twins is less well studied. Extended Reality (XR) interfaces show particular potential in this domain. Creating a custom XR interface for a digital twin requires the involvement of software engineers with diverse skill sets. Existing efforts to create XR interfaces for digital twins have been case studies designed for the specific use cases they were tested on. This paper introduces an authoring tool that allows end users without programming expertise to create XR interfaces for digital twins without writing any code themselves. Our initial prototype demonstrates the ability to parse machine data formatted according to the MTConnect standard, and provides menu-based interfaces and a sandbox of data visualizations to guide users through interpreting and displaying data.



A Dynamic Fit-out Scheduling Framework for Digital Twin-enabled Modular Integrated Construction

Qiqi Chen, Jiyuchen Ding, Mingyue Sun, Zhiheng Zhao, and George Q. Huang

Modular Integrated Construction (MiC) is a novel construction method for its approved space-saving and time-saving for the construction industry. MiC produces modules using factory assembly and on-site installation. Fit-out construction is the last essential process of MiC module assembly in the factories to enable the functions of the completed infrastructures. Fit-out construction significantly affects the delivery of MiC modules for its complexity and flexibility in operations. Fit-out operations are complex for multiple jobs and flexible for job sequencing. In addition, fit-out efficiency is decided by fit-out workers with specific certificated skills, considering worker factors such as process proficiency, fatigue, and working hours. Many studies introduce advanced technologies, such as the Internet-of-Things (IoT) and Digital Twin (DT), to collect real-time operational data and resource information in the logistics and assembly operations. The existing studies reveal two research gaps: 1) how these real-time data can be extracted and organized for decision-making in fit-out construction, and 2) how to integrate worker assignment with job scheduling in the fit-out scheduling problem. This study proposes a dynamic framework to integrate job scheduling and worker assignment for DT-enabled fit-out operations in the MiC. This study defines the fit-out scheduling problem in MiC, which integrates job scheduling and worker assignment simultaneously, designs a DT-enabled framework for cyber-physical synchronization in MiC, and implements a dynamic fit-out scheduling method based on Reinforcement Learning. This work intends to conduct experimental analysis using real-life case data.

Parallel Sessions 3.6	Time: 14:40 - 16:00	Room: Carlowitz

APMS Talks 1

Supporting the transition of machinery companies towards sustainable servitization: The Role of Assessment in Pay-per-X offerings

Prof. Giuditta Pezzotta and Roberto Sala, University of Bergamo
Disscussant: Klaus-Dieter Thoben

Renewable hydrogen supply chains: A planning matrix and an agenda for future research

Prof. Fabio Sgarbossa, NTNU
Discussant: Dmitry Ivanov

Tuesday
10 September 2024

Presentations

Parallel Sessions 4.1	Time: 08:30 - 09:50	Room: Terra

Smart and Sustainable Supply Chain Management in the Society 5.0 Era - Part 1

Toshiya Kaihara, and Eiji Morinaga

Data-Driven Control System Using Machine Learning in Production Process

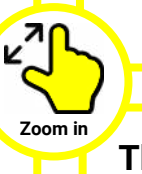
Takashi Tanizaki, Ayumu Fukuyama, Kunimi Uchino, Tetsuaki Kurokawa, Shigemasa Nakagawa, and Takayuki Kataoka

Many manufacturing companies control their production machines to produce good products within quality standards by using the results of research on physical or chemical models. Those models are developed from knowledge of the physical or chemical changes that occur when the products are processed and operational knowledge. However, it is difficult for some companies to research physical or chemical models. We study data-driven control systems to enable the stable production of good products when it is difficult to study and develop physical and chemical models or to use operational knowledge. In this paper, we propose an algorithm that builds an alternative model from actual operation data using machine learning and finds the optimal operating conditions under which the product is within the quality standards range using 0-1 integer programming. The effectiveness of the proposed algorithm was verified using operation data generated using a simulator for a food manufacturing process.

Data-Driven Scheduling of Cellular Manufacturing Systems using Process Mining with Petri Nets

Hidefumi Kurakado, Tatsushi Nishi, and Ziang Liu

Petri net is a mathematical model for representing parallel, asynchronous, and distributed systems. Petri nets can model parallel and synchronous activities in manufacturing systems at various levels of abstraction. In this study, we propose data-driven modeling and scheduling for cellular manufacturing systems using process mining with Petri nets. In the proposed method, the event log data is extracted from a virtual plant and then the Petri net model considering the movement of products and operators is developed by using the process mining technique with the Petri net model. We also derived an approximate solution for the derived Petri net model from the event log using a local search method using a Petri net simulator. The analysis and modification of the model are conducted in the proposed method. Near-optimal schedules are derived using Petri net simulations. The validity of the proposed model is evaluated.



A Study on Sophisticated Production Management for Engineer-to-Order Production: A Mixed Integer Programming Formulation for Production Scheduling

Eiji Morinaga, Koji Iwamura, Yoshiyuki Hirahara, Masamitsu Fukuda, Ayumu Niinuma, Hirotomo Oshima, and Yasuo Namioka

Engineer-to-order (ETO) production in which products are designed and manufactured in response to customer orders is required to respond flexibly to customer requests at various stages from design to maintenance. This characteristic makes it difficult to apply a standard production planning strategy which divides the planning into three phases, i.e., long-term, medium-term and short-term planning (production scheduling), because there are large discrepancies among the phases and rescheduling requires a lot of man-hours. We proposed a production planning framework that unifies the granularity of resources and unit time in all of the planning phases aiming to reduce the discrepancies, and a model that is commonly used in the three phases of planning was organized as flexible job-shops. This paper provides a mixed integer programming formulation of the production scheduling problem based on the model considering the following characteristics of the target ETO production site: (1) The planner has discretion in shortening required processing time; (2) Operation time is limited to day time of weekdays; (3) Overtime works can be accepted if necessary; (4) Some operations of multiple parts must be processed at the same time on the same machine. A numerical experiment showed validity of the model.

Three-Dimensional Bin Packing Problems with the Operating Time of a Robot Manipulator

Naoya Mikyu, Tatsushi Nishi, Ziang Liu, and Tomofumi Fujiwara

Many optimization algorithms for solving three-dimensional bin-packing problems have been addressed. The problem is to minimize the cost of the bins in which packages are placed with the aim of reducing transportation costs and improving productivity. From the viewpoint of actual optimization of the entire factory, it is necessary to consider the motion planning of a robot manipulator to handle the items in the three-dimensional bin packing problem. This study considers a three-dimensional robotic bin packing problem, which minimizes the weighted sum of bin cost and the robot's operating time. A genetic algorithm is developed using Sequence-Triple representation, a layout representation of a three-dimensional arrangement. For robot motion planning, the Rapidly Exploring Random Tree Star is used for trajectory generation to obtain near-optimal solutions. Computational experiments show the superiority of the proposed optimization method by comparing it with a conventional sequential optimization method.

Parallel Sessions 4.2

Methods and Tools to Achieve the Digital and Sustainable Servitization of Manufacturing Companies - Part 1

Roberto Sala, and Ugljesa Marjanovic

Maturity Models for Servitization: A Systematic Literature Review

Elena Beducci, Anna De Carolis, and Marco Taisch

Servitization is the transition from selling products to selling integrated offerings of products and services. This trend is growing in the manufacturing context, being recognized as an opportunity to increase economic, environmental and social sustainability. To support companies in the transition towards servitization, Maturity Models represent a powerful tool to assess the maturity, strengths, and weaknesses and identify improvement activities. Existing literature proposes multiple maturity models for servitization and product service systems, with different focuses and structures. This paper aims to analyze the status of the existing literature on maturity models for servitization, identifying main characteristics, structures, trends, and gaps. To achieve this objective the paper operated a systematic literature review, including the identification and analysis of 19 contributions and 16 distinct maturity models. Based on the findings of the literature, the paper proposes categories of analysis that should be considered while assessing the maturity of companies involved in the servitization transition. This paper contributes to existing literature on servitization, it proposes an analysis of existing maturity models and rationalizes elements of analysis that should be taken into consideration in future works for the development of new maturity models.

Towards Human-Centric Digital Services: A Development Framework

Dragana Slavic, David Romero, Giuditta Pezzotta, Ugljesa Marjanovic, Borislav Savkovic, Ioan Alexandru Popan, and Slavko Rakic

Industry 5.0 is initiating changes in different aspects of manufacturing business, as well as products and services. Industry 5.0 pillars – human-centricity, sustainability, and resilience – are leading these changes, with an aim to provide a smart, green, and digital global society. The human-centric pillar has an aim to bring people back in the centre of attention, by using technologies developed in Industry 4.0. Previous studies have shown a tendency of new services development based on Industry 5.0. This paper has an aim to show the development from product-related services influenced by digital technologies to human-centric product-related services. Data used for this study was obtained through the Digital Servitization Survey in 2023, and the dataset represents current state of Republic of Serbia's manufacturing sector. The main findings of this paper show correlation between human-centricity and digital technologies, human-centricity and product-related services with the use of digital technologies, and their influence on firms' annual turnover.

Quantitative assessment of Product-Service System sustainability: a literature review

Veronica Arioli, Roberto Sala, Fabiana Pirola, and Giuditta Pezzotta

The adoption of Product Service Systems (PSS) offers an innovative perspective to promote sustainability. However, assessing the overall impact of PSS requires an accurate evaluation of their economic, environmental and social implications. Specifically, there is a need to quantify these impacts. Therefore, this study focuses on the analysis of quantitative methods and methodologies to assess the sustainability of PSS solutions, considering the economic, environmental and social dimensions of the Triple Bottom Line (TBL). Through a literature review, the different quantitative methods and methodologies were analysed and the main economic, environmental and social sustainability indicators evaluated by them were collected and discussed. The review shed light on five aspects (i.e., life cycle perspective, stochasticity, TBL comprehensiveness, TBL interdependencies, and interpretation of the results) that are critical for a comprehensive and holistic assessment of PSS sustainability. These aspects are widely discussed and future research directions for the PSS sustainability assessment are suggested.

Navigating the Shift: From Traditional Sales to Product- as-a-Service (PaaS)

Alessio Bertelli, Shaun West, and Mario Rapaccini

This paper considers alternative revenue models for companies traditionally reliant on transactional sales models. The research question explores viable revenue strategies for a firm with a traditional transnational revenue model and wants to transition to a product-as-a-service-based revenue model. To understand the transition, the study employs a multi-stage methodology that includes assessing the product-service system and analytical tools for contextual understanding. Insights into different approaches and their practical applications were gained, with detailed analyses based on avatar mapping, lifecycle examination, and a total cost of ownership analysis that must be adapted for data scarcity. Where data is unavailable, the paper provides an approach to support collecting the necessary lifecycle costs to allow PaaS models to be developed based on the average spend profile.

Lean Thinking Models for Operational Excellence and Sustainability in the Industry 4.0 Era & Experiential Learning in Engineering Education

Federica Costa, and Ivan Tomašević

Lean and Green Manufacturing operationalization through Multi-Layer Stream Mapping in an Industry 4.0 context – Lean&Green 4.0

Paulo Peças, Jéssica Lopes, Diogo Jorge, Anshuman Kumar Sahu, António J. Baptista, and Marco Leite

Lean and green (L&G) manufacturing in Industry 4.0 (I4.0) has brought many advantages in manufacturing industries by minimizing waste and maximizing efficiency with the integration of renewable energy sources and sustainable materials. Multi-layer Stream Mapping (MSM) is a new framework for the performance assessment of complex manufacturing processes. MSM is used for the multi-domain analysis of manufacturing processes to assess resources, and processes, that are used to identify Non-Value Added (NVA) procedures or steps that consume unnecessary time and resources, and/or release emissions and waste that can no longer be reused or recycled to be eliminated or replaced to create a Value Added (VA) process flow that avoids waste in a clean, green and environmentally friendly manner. This paper presents the implementation of the (L&G) strategy through MSM in metalworking production systems.

The Facets of 'Respect for People' Principle: A Systematic Review and Thematic Analysis of the Literature

Ivan Tomašević, Dragana Stojanović, Barbara Simeunović, and Dragoslav Slović

The core of lean is formed by two key principles: continuous improvement (CI) and respect for people (RFP). Although lean holds a lot of promise to improve operations, the implementation success rate outside of Japan is still fairly low. Recent literature shows that one of the main reasons for failed implementation is a lack and poor understanding of RFP principle, which results in reduced people involvement. This paper aims to improve the understanding by exploring the pre-vailing discourses in lean literature related to the RFP principle to distil dominant themes which break this complex concept into facets that could be systematically studied. For this purpose, we propose a systematic literature review of 26 articles published in 21 peer-reviewed international journals that explicitly discuss RFP principle. Four themes emerged from the analysis, and three RFP facets were dis-tilled from these themes. The analysis shows that all of RFP facets must be in place to enhance people's involvement in problem-solving. A specific relation be-tween the facets is observed that needs to be acknowledged when RFP is consid-ered. The results also show that RFP enables CI and complements it as an inter-vention in its own right. While this study is far from exhaustive, we believe the results will introduce additional clarity and improve the utility of the complex RFP principle for research and practice.

Pick-and-Place Robotics Implemen-tation Under the Influence of Lean Manufacturing – A Process Model

Matteo Rossini, Bassel Kassem, Gopalakrishnan Narayanamurthy, and Alberto Portioli-Staudacher

The article seeks to develop a process model to guide research and practice in the effective integration of robotics for pick-and-place activities in manufac-turing firms, where lean management tools and practices are being em-braced. Utilizing a multiple case study analysis, the researchers conducted on-site visits to production facilities and analyzed 16 diverse projects, 11 coming from manufacturing companies and 5 projects provided by System Integrators, to gain heterogeneous and wide-spanning insights. The unit of analysis is the single robotic implementation, spanning across various sectors to extract patterns independently from the specific industry. These projects yielded a substantial volume of information, knowledge, and best practices related to the adoption of Robotics. Following a meticulous examination of the case studies, a process model was formulated to guide companies through decision-making, implementation, monitoring, and sustain stages in robotics introduction projects. This research disentangles the influence of lean management in ensuring the optimization of benefits derived from such projects. The process model seeks to offer practical guidance for companies approaching the complexities of robotics integration within manufacturing processes, successfully filling in the pre-existing research gap.

Designing an Online Workshop for Creativity and Value Co-Creation: Three Case Studies in Gastronomic Sciences on Viewpoint Setting and Sustainability Education

Tomomi Nonaka, Masayoshi Ishida, Seiko Shirasaka, Tomomi Honda, Masami Oginuma, Kan Yoshitake, and Kazuki Taniguchi

To co-create value in sustainable communities, it is essential to understand the nature of social issues from multiple perspectives and to communicate and dialogue with people with different values and expertise from a com-prehensive and integrated perspective. This study poses the following two research questions 1) What are the key components of an effective online sustainability education workshop that encourages active participation and dialogue? and 2) How can the integration of food and local resources in online workshops enhance participants' awareness and understanding of sustainability? In this research, we develop an online workshop to connect the world on the theme of food as knowledge acquisition and exchange (in food contexts). We focus on communication and interaction between dif-ferent actors in the creation of local industries using food and local re-sources. The aim of this research project, called "GAstroEdu", is to develop an online workshop for creativity and value co-creation that supports value co-creation among different stakeholders in the region and encourages par-ticipants to set their own points of view and learn from them. As an imple-mentation, we present three GAstroEdu projects. Tomato Adventure for el-ementary school students, Lemon Adventure2 held in Setoda, Onomichi, Hiroshima, and Potato Adventure Workshop held in Kutchan-cho, Hok-kaido.

Parallel Sessions 4.4

Advancing Eco-Efficient and Circular Industrial Practices - Part 1

Mélanie Despeisse, and Federica Acerbi

Research Challenges for Eco-Efficient and Circular Industrial Systems

Mélanie Despeisse, Federica Acerbi, Veronica Arioli, Stephen Childe, Beatrice Colombo, Steve Evans, Clarissa A. González Chávez, Saul Jones, Bella Nujen, Giuditta Pezzotta, Daryl Powell, Carl Toller Melén, Margarida Vasconcelos, Miying Yang, Thorsten Wuest, and David Romero

The field of industrial sustainability is rapidly expanding with new concepts and frameworks emerging almost daily. At the same time, mature ones are being used in new applications and combined with new technologies and methodologies. While these developments are promising, the ambitions, scale, and speed of the change required to meet sustainability goals urgently need to increase. To accelerate industrial sustainability research and its impact, experts were invited to discuss research challenges in a webinar series focused on ten priority areas for eco-efficient and circular industrial systems. This paper presents the research challenges discussed to share sustainability practices, stimulate collaborations, and inspire change for more impactful applied research and knowledge transfer to industry.

Mapping current research for eco-efficient and circular industrial systems

Federica Acerbi, and Mélanie Despeisse

With the growing sense of urgency to tackle climate change and other environmental issues, integrating sustainability as a central component of production research and industrial practice is imperative. Eco-efficiency and circular economy are powerful concepts to guide actions as a response to these environmental concerns. To encourage the uptake of these concepts in research and development, a thematic research framework for eco-efficient and circular industrial systems was proposed in 2022. This framework is composed of ten priority areas with more specific challenges captured in the form of research questions to call for collaborative research efforts. To map current research against these challenges and priority areas, a survey was launched to reach out to experts from different overlapping research themes within the research community in the field of production management: operations management, supply/value networks, technological development, business development, human factors, and performance management. This paper presents the initial survey results based on 50 responses to investigate which priority areas are being addressed by this community, as well as point to avenues for further work to support the transition to more sustainable industrial systems. Finally, we conclude that there is a need to better engage manufacturing companies to address sustainability challenges, exploiting tools and methods available in the literature to make sustainability become the new industrial norm.

Exploring Trends and Insights in Industrial Symbiosis Research in Italy: A Bibliometric Approach

Beatrice Colombo, Valentina Ventura, Paolo Gaiardelli, and Marco Bortolini

Industrial symbiosis is increasingly recognised as a practical tool for companies to valorise their industrial surpluses and reduce the use of raw materials. This paper reports a comprehensive map of studies addressing the industrial symbiosis topic in the Italian context. The primary goal is to provide an overview of the existing literature for highlighting the main research trends and supporting both academics and practitioners in industrial symbiosis implementation. A sample of 37 published articles, gathered from Scopus using a systematic approach is carefully investigated. Through bibliometric analysis, the publication trend, most relevant/impactful authors, journals and keywords are determined. To the best of the authors' knowledge, this is the first systematic review leveraging a bibliometric analysis on the topic under investigation. One of the main findings is that economic feasibility should be considered in future assessments to prevent industrial symbiosis pilot projects from remaining in a preliminary state. Lastly, this research, through the identification of research hotspots and gaps, serves as a valuable roadmap for directing future studies.

Investing Ahead - Industrial outlook on circularity within production development

Malin Elvin, Jessica Bruch, Ioanna Aslanidou, and Monica Bellgran

The manufacturing industry contributes to climate change and must take action to reach its high-set target. Implementation of circularity to reach sustainability has shown to be beneficial for products, but there is a lack of knowledge on how to transfer the concept to the design of factories. The purpose of the paper is to identify and systemically analyse areas of importance to enable circularity in production development to better understand what requires attention to achieve a circular factory. The focus of the study is on production development narrowed down to production equipment. A case study approach was used with interviews as the main method for data collection. Four main themes were identified: competence, collaboration, mindset and time. These were considered as areas of importance to enable circularity and to understand what needs further attention they were analysed in a systemic view of macro-, meso- and microlevel. The findings stress the need for investing in circularity in early phases to achieve circularity and that all levels of the industry need to take part in the transition towards circularity. Further, research within areas with similar complexities could benefit and learn from each other.

Parallel Sessions 4.5	Time: 08:30 - 09:50	Room: Vigor

Digital Transformation Approaches in Production and Management - Part 1

Selver Softic, and Stefanie Hatzl

Leveraging Sentiment Analysis and Reporting for Re-Designing Business Processes using Large Language Models: A SentiProMo Case Study in Airline Check-In Processes

Selver Softic, Egon Lüftenegger, Daniel Resanovic, Safet Softic, and Alexandru Popan

In today's competitive landscape, optimizing business processes is crucial for maintaining effciency and customer satisfaction, particularly in the manufacturing sector. This paper presents SentiProMo, a self-developed tool that integrates sentiment analysis of collaborative comments with summarization features to enhance the design phase of business processes. Leveraging the capabilities of large language models (LLMs) such as Chat-GPT, this tool empowers managers with insightful reports for informed decision-making. To demonstrate the effectiveness of SentiProMo, a case study was conducted focusing on the check-in process at airports, a critical aspect of the airline industry. Real-world data from collaborative comments during the design phase of the check-in process were analyzed using sentiment analysis techniques. Additionally, summarization features were employed to generate concise and informative reports for management stakeholders. The results of the case study showcase the potential of LLM-powered tools like SentiProMo in streamlining business processes. By harnessing sentiment analysis, organizations can gain valuable insights into employee perceptions and identify areas for improvement. Moreover, the summarization capabilities facilitate the effcient communication of findings to management, enabling them to make informed decisions promptly. This research not only underscores the power of LLMs in enhancing business process design but also highlights the promising avenues for future applications. With its wide array of potential applications across various industries, SentiProMo represents a significant advancement in process optimization and management.

Development of a Framework for Data-Supported Personas

Eva Schirgi, Stefanie Hatzl, and Katharina Moitzi

This paper presents a design science research project in which a framework for the creation of personas is being developed. The framework is intended to help SMEs to better understand their customers based on personas and to improve products and services or develop new products and services on this basis. The framework is developed and evaluated in several iterative cycles. To develop the personas, the company's own data is collected, cleansed, and clustered using the k-means method. The persona profiles are created using generative artificial intelligence and processed using qualitative methods.

Fuzzy Maturity Model for Transformative Procurement Readiness: Procurement 4.0 perspective

Areej Althabatah, Mohammed Yaqot, Regina Padmanabhan, and Laoucine Kerbache

In today's dynamic business environment, transformative procurement is essential for organizations to adapt to changing market conditions and maintain competitiveness. While the Procurement 4.0 notion is still in its early stages, it is essential for large, medium, and small-sized enterprises, particularly in the energy sector, to possess a certain level of maturity in order to initiate the deployment of innovative and sophisticated procurement operations. Therefore, this work proposes the development of a fuzzy-rule-based model to assess the maturity level of procurement. This is accomplished through the creation of a fuzzy expert system that relies on criteria derived from four primary Procurement 4.0 components: modularity, resilience, agility, and human-centricity. Finally, the fuzzy maturity model is validated using a case study involving a company in the energy industry. By leveraging fuzzy logic modeling, the framework accommodates the inherent uncertainty and ambiguity in procurement operations, enabling organizations to make more informed decisions and optimize their procurement strategies. Through the case study and empirical validation, this work demonstrates the effectiveness of the proposed framework in enhancing procurement functions and driving digital transformation in all industrial sectors.

The Impact of Blockchain Implementations on Supply Chain Collaboration

Yutong Bai, Ming Lim, Wee Meng Yeo, and Yang Liu

Blockchain technology is increasingly gaining attention from practitioners and academics in supply chain management due to its potential to enhance transparency, efficiency, and trust among trading partners. This study explores the impact of blockchain deployment on supply chain collaboration (SCC), with a focus on information sharing, trust, and commitment. Through a multiple case study of six companies, we found that while blockchain enhances information sharing by facilitating digital transformation in the supply chain, concerns about data privacy pose significant challenges. Moreover, blockchain technology can foster trust through immutable record keeping and automated smart contracts, alleviating concerns related to data tampering and enhancing the reliability of transactions. Commitment within SCC is also influenced by blockchain, as it requires joint investment in specific assets, thereby strengthening partnerships. However, asymmetric willingness to adopt blockchain, especially among smaller supply chain participants, may undermine these benefits. Our findings provide valuable insights into the strategic implementation of blockchain in supply chains and highlight the crucial balance needed between technology adoption and stakeholder engagement.

Parallel Sessions 4.6	Time: 08:30 - 09:50	Room: Carlowitz

APMS Talks 2

Emerging technologies to overcome Lean implementation barriers in Engineer-to-Order: Empirical insights in the field of Augmented Reality and Visual Management

Prof. Dr.-Ing. Patrick Dallasega, Free University of Bozen-Bolzano
Discussant: Hermann Lödding

Drones and industrial applications

Prof. Omid Maghazei, University of Bath School of Management
Discussant: Gregor von Cieminski

Parallel Sessions 5.1

Smart and Sustainable Supply Chain Management in the Society 5.0 Era - Part 2

Toshiya Kaihara, and Alexandra Lagorio

Basic research on worker state prediction towards the realization of human digital twin

Ruriko Watanabe, Yoshitaka Tanimizu, Kotomichi Matsuno, and Yuu Takihara

In the manufacturing field, the diversification of consumer needs is forcing a shift to variable-mix, variable-volume production, making it increasingly difficult to achieve the conventional uniformity of machine-centered production, the ability to respond to diverse needs, and the improvement of production efficiency. In addition, Japan will become a super-aging society where 40% of the population will be elderly by 2060, and there is an urgent need to restructure the securing and utilization of human resources. To solve these issues, a new manufacturing system in which "people" play a leading role has been proposed. To realize this system, the human-digital twin is attracting attention. The human-digital twin is the reproduction in digital space of an individual's physical, behavioral, and psychological states in the real world, which is thought to enable prediction of worker fatigue, improvement of work efficiency, and enhancement of worker safety. In this study, we conducted basic research on predicting worker fatigue toward the realization of the human digital twin. By conducting demonstration experiments assuming a cell production site, acquiring biometric information, and analyzing it using an autoencoder, we will clarify the prediction of worker fatigue and the relationship between biometric information and fatigue.

Resilient supply chain network planning method with two-stage stochastic programming: Extension to multiple product supply chains

Toshiya Kaihara, Hibiki Kobayashi, Daisuke Kokuryo, Masashi Hara, Yuto Miyachi, Dickson Hideki Yamao, and Puchit Sariddichainunta

In supply chain management, risk management is crucial to ensure a stable product supply while considering economic efficiency. It is essential to design resilient supply chains that can maintain production capacity by preparing for and responding to predictable risks. Our group has proposed strategic planning methodologies for the selection of appropriate material suppliers and the optimization of inventory levels across the supply chain, including suppliers, manufacturers, and wholesalers, with considering potential risks. We have introduced a planning method for resilient supply chain networks using two-stage stochastic programming. This paper extends the proposed method to accommodate supply chains managing multiple products, aiming for more realistic conditions. The effectiveness of the extended method is assessed through computational experiments.

Study on developing a comprehensive inspection system that parallel improves the accuracy of manual and automatic inspections

Harumi Haraguchi, and Takumi Miyamoto

This study summarizes a three-year project targeting dental component manufac-turing sites. The target inspection departments have always conducted manual in-spections twice each. This department wanted to be performed automatically at least once by introducing an automatic inspection machine. We have two problems that need to be solved. The first is to equalize the judgment criteria that differ from one inspection operator to another, and the second is to develop an automatic inspection tool with the same accuracy level as the inspection operator's judgment criteria. However, the target product, a rotary tool for dental treatment (diamond bar), has diamond particles attached to its tip; every part is slightly different. Therefore, creating an inspection tool with a simple threshold setting was impossible. In this study, we developed an automatic inspection tool using machine learning, and at the same time, we developed an inspection training tool to equalize operators' skills. Each tool was repeatedly improved through verification experiments. In addition, we developed feedback rules for the results obtained from the training tools to the training data for the machine learning model to improve the accuracy of the discriminant model. Furthermore, we have proposed a labeling tool that establishes criteria for judging whether a product is quality or defective in consideration of the introduction of new products, thereby realizing the continuous introduction of products and the stabilization of inspection operations.

AI Applications in the Healthcare Logistics and Supply Chain Sectors

Claudia Piffari, Alexandra Lagorio, and Anna Corinna Cagliano

Artificial Intelligence (AI) has recently been established in healthcare management to support clinical activities and pharmaceutical research and development. Moreover, AI can potentially improve decision-making in healthcare supply chains (HSCs) by leveraging the information provided by various sources. However, research on the application of AI to HSCs is still in its infancy. This work presents a Systematic Literature Review to identify the main trends and future research directions. The analysis of the 23 pertinent papers suggests that more quantitative case studies on AI implementation in HSC are necessary. Additionally, the role of AI in facilitating logistics and supply chain management activities, promoting supply chain resilience, and ultimately creating integrated and agile HSCs should be investigated. Further literature reviews on AI-driven HSC management will help to keep the focus on this research field and its relevant developments.

Parallel Sessions 5.2

Methods and Tools to Achieve the Digital and Sustainable Servitization of Manufacturing Companies - Part 2

Roberto Sala, and Shaun West

Transforming a new-build factory into a service operations workshop: A PDCA approach to change management in industrial servitization

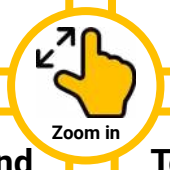
Thomas Sautter, Shaun West, Benjamin Biesinger, and Daryl Powell

This study investigates the transformation of a large industrial plant into a service operations workshop through the Plan-Do-Check-Act (PDCA) cy-cle, emphasising continuous improvement and strategic adaptability. Initi-ated due to financial challenges and the need to capitalise on existing ser-vice portfolios, the transformation marks a strategic change from manufac-turing to service-oriented operations, addressing with limited guidance managers on servitization change management. Employing an action-based research methodology guided by the PDCA framework, the study addresses the complexities of organizational learning, culture, and mindset shifts es-sential for transitioning to a service workshop. It describes the journey of strategic adaptation, from planning and executing service-centric initiatives to evaluating and refining processes based on feedback and market de-mands. The case highlights the importance of stakeholder engagement, de-veloping a service-oriented workforce, and aligning operational strategies with long-term business goals. By validating the PDCA cycle as a flexible tool for change management, the study contributes to the literature on ser-vitization strategies and managerial roadmaps, offering insights into achiev-ing sustainable growth and innovation in service operations. The findings advocate for the PDCA cycle's utility in fostering a culture of continuous adaption, which is crucial for supporting the ongoing adaptions needed to support servitization.

Navigating Lifecycle Management Models: Testing of a lifecycle management framework for Product-Service Systems

Oliver Stoll, Shaun West, Clarissa González, Simon Züst, and Stefan Wiesner

There is a gap between the concepts of Product-Service System (PSS) and Lifecycle Management (LCM) models. This study highlights the organisational hurdles in assimilating PSS into existing LCM frameworks, emphasising the disconnect between current models and the dynamic digital transformations reshaping organisational landscapes. It argues that the inability of existing LCM frameworks to accommodate the rapid pace of digitalisation is a critical barrier to effective PSS management, underscoring the need for a digital-inclusive approach to LCM. This paper takes a case study approach, examining various industry cases and describing organisations' practical struggles aligning PSS LCM frameworks with digital advancements and organisational dynamics. These real-world examples provide a foundation for developing a novel, comprehensive PSS LCM framework that integrates digital tools and systems as central components. This proposed framework aims to enhance organisational adaptability, streamline processes, and foster better communication and collaboration within entities managing PSS. This study contributes to academic research and practical applications in PSS LCM, advocating for a more digitally integrated, organization-centric approach and offering a dual contribution of theoretical insights and practical implementations.



Asset lifecycle management and digital servitization: A case study in machining

Mattia Galimberti, Clarissa Alejandra González Chávez, Mélanie Despeisse, Chiara Cimini, and Shaun West

Digital servitization is increasingly relevant for competitiveness and long-term sustainability in several industrial sectors. Firms with capital assets and long lifespans have been documented as promising candidates for maximiz-ing the value of resource-efficient operations and lifecycle extension opportunities. This paper investigates the conceptual overlap of asset lifecycle management and digital servitization in the context of machining in indus-try to maximize resource efficiency and lifecycle extension. While existing literature primarily focuses on early-stage strategic planning, this study emphasizes the significance of decision-making during the use phase of assets, highlighting the need for a balanced allocation of resources between late-stage decisions and early strategic planning, to capture sustainable value. This study presents a map of strategic options that connect levels of digital servitization and eco-efficiency principles across an asset's lifecycle. By ex-emplifying through a case study, the results of this paper include a mapping of scenarios highlighting the importance of integrating digital servitization and asset lifecycle management strategies to achieve improved sustainability in industrial settings.

Towards a Maturity Model for Intelligent Digital Twins in Manufacturing

Luis Felipe Villegas Torres, Marco Macchi, and Adalberto Polenghi

The adoption of Digital Twins (DTs) in manufacturing is promising as they hold the potential to bring key changes in the way industrial systems are managed and optimized. As enabling technologies continue to emerge, their integration into these complex systems enhances the granularity of intelligence and functionalities available within the Cyber-physical Systems. Such granularity accentuates the need to clarify the distinctive features of this emerging class of DTs, where the transition from conventional DTs to Intelligent DTs marks a shift towards increasingly proactive, autonomous, and cognitive systems. This paper particularly explores the evolution of Intelligent DTs, focusing on formalizing the enhanced intelligence in correspondent maturity levels that express the progression on DT systems. The maturity levels of Intelligent DTs are categorized into predictive, prescriptive, and autonomous stages, to then identify both the associated capabilities and technologies across different application domains related to manufacturing. On its whole, the outcome of this paper can be seen both as a current map on the maturity of Intelligent DTs implementation, and as a research agenda to explore capabilities and technologies from different domains in manufacturing.

Parallel Sessions 5.3

Human in Command – Operator 4.0/5.0 in the Age of AI and Robotic Systems

Doris Aschenbrenner, and Johan Stahre

What matters for managers when adopting Cobots in manufacturing organisations? - The results of a survey study in Portuguese SMEs

Guilherme Couto, Ana C Correia Simões, Luís Miguel D. F. Ferreira, Paulo S. A. Sousa, Maria R. A. Moreira, and Fillipe L. Ribeiro

Collaborative robots, or cobots, are increasingly used by manufacturing companies to meet the demands for greater flexibility and to adapt to the trend of mass customisation in production. When considering the adoption of cobots, companies enter a critical decision-making phase. This study aims to identify the relevant decision factors for adopting collaborative ro-bots (cobots) in manufacturing medium-sized enterprises (SMEs) in Portu-gal, using a combined framework of Technology-Organisation-Environment (TOE), Diffusion of Innovations (DOI) theory, and Institutional Theory. Data was collected through an online survey distributed to Portuguese manufacturing companies, yielding 78 valid responses. Analysis conducted using SmartPLS 4 revealed that top management support, resource availabil-ity, and industry pressure significantly influence the adoption decision. However, factors such as the relative advantage of cobots, compatibility with existing processes, organisational innovativeness, human resources quality, and external support did not significantly impact SMEs' adoption of cobots. These findings enhance the understanding of technology man-agement, specifically the process of adopting cobots in manufacturing. The insights from this study help managers focus on the key factors critical for successful cobot adoption, supporting decision-makers in making more in-formed choices.

A leap from operator 4.0 to operator 5.0: Antecedents, enablers, and barriers in human-centered manufacturing

Anne Grethe Syversen, Martina Ortova, Godfrey Mugurusi, and Kristin Hartveit Hansen

When one considers the journey from Operator 4.0 (O4.0) to Operator 5.0 (O5.0), given the current evolution of the Industry 4.0 (I4.0) investments in many manufacturing firms today, there appears to be no clear pathway towards O5.0. One therefore wonders if such a pathway is for example shorter, longer, faster, slower, etc. for workers in firms of different characteristics, e.g. size, resources, I4.0 maturity, etc. And if so, what does the operator's journey from O4.0 to O5.0 look like? This study therefore aimed to examine what the path to Industry 5.0 (I5.0) demands of an Operator 4.0 in the human-centered manufacturing environment. An in-depth case study was implemented to assess the antecedents, enablers, and barriers for shop floor workers in the transition from Operator 4.0 to Opera-tor 5.0. The results show that the motivation of operators to co-evolve their skills either under or over the I4.0 maturity level of the firm is enabled by the type of leadership style, and strategic orientation of the firm on one hand, or is inhibited by the leaders and organizational culture on the other hand. The study concludes that the development path of the worker from O4.0 to O5.0, especially the human-centricity dimension, is still greatly underdeveloped in both practice and theory.

Research Interpretation of Article 14 of the EU AI Act: Human in Command

Doris Aschenbrenner, Lisa Jantzen, Cecilia Colloseus, Andrea Sell, and Regina Kempen

The rapid integration of artificial intelligence (AI) into various sectors necessitates rigorous frameworks to ensure that human oversight remains central, aligning with regulatory requirements such as Article 14 of the European Union's AI Act. This paper introduces the "Human in Command" model, a novel approach designed to foster effective human-AI collaboration, particularly in manufacturing environments. Our model is bifurcated into two primary components: Design4Command and FeelingInCommand. Design4Command outlines a comprehensive set of methodologies for constructing human-AI-teams that emphasize human leadership and decision-making authority, ensuring that AI systems enhance rather than replace human capabilities. FeelingInCommand, on the other hand, presents innovative metrics and tools for assessing the psychological and ergonomic factors impacting humans' perception of control and efficacy when interacting with AI systems. With the help of this model, organizations can optimize the efficiency and satisfaction of human operators in AI-enhanced settings. This paper details the theoretical underpinnings of our approach, the design principles of our methodologies, and potential applications across various domains, offering a guideline for developers and policymakers aiming to preserve human oversight in the age of AI.

Immersive Human-Robot Collaboration in Restricted or Confined Spaces

Omkar Salunkhe, Anna Syberfeldt, David Romero, Dan Lämkull, and Johan Stahre

The emergence of collaborative robots in confined spaces marks a new era in manufacturing and automation. Robots designed to assist human operators in complex and physically demanding tasks are gaining popularity due to their ability to work alongside humans, minimising risks and maximising productivity. However, most applications are in open areas where operators have enough space to move out of the robot's trajectory in the case of an emergency. This paper pre-sents a unique case study of Human-Robot Collaboration (HRC) inside a car body, a scenario that has yet to be extensively explored. This study utilises the NASA TLX method to evaluate the workload of human operators in an HRC application. The paper presents findings of various factors such as mental, physical, and temporal demands, as well as performance, effort, and frustration levels experienced by operators while performing HRC tasks within a car body. The experiences of the participants were explored in detail through semi-structured inter-views. The study indicates that operators are willing to collaborate with robots within car bodies. However, ergonomic obstacles and difficulties still exist when robots are deployed in confined spaces like car bodies. A new concept called "Immersive Human-Robot Collaboration" is proposed in this paper, aiming to overcome the challenges and enable effective HRC in confined spaces.

Parallel Sessions 5.4

Advancing Eco-Efficient and Circular Industrial Practices - Part 2

Federica Acerbi, and Anita Romsdal

Developing a Circular and Resilient Information System: A Design Science Approach

Timoleon Farmakis, Anastasios Koukopoulos, Georgios Zois, Ioannis Mourtos, Stavros Lounis, and Kostas Kalaboukas

As we cross by Industry 4.0, circularity and resiliency are crucial for manufacturing. There is a need for collaboration across the value chain, deployment of critical enablers, and connection of traceability to sustainability and business objectives to accelerate the shift towards circular and resilient production processes. This study reviews circular economy and resilient manufacturing by further analysing the literature on circular and resilient information systems. We identify key performance indicators for circularity and resiliency and utilise a design science research approach to develop prescriptive knowledge on traceability data and digital services to design the circular and resilient information system (CRIS) conceptual architecture. We further propose leveraging cutting-edge technologies and tools to enable real-time decision-making, monitoring, and certification of materials and products, facilitating sustainable and resilient manufacturing practices. The deployment of CRIS as part of digital transformation efforts represents a strategic move to meet the growing demands for sustainability and resilience.

Circular Product Development Framework Enhancing Extended Producer Responsibility - A Medical Device Case Study

Kartika Nur Alfina, and R.M. Chandima Ratnayake

The healthcare industry, a significant contributor to carbon emissions, faces increasing pressure to reconcile environmental sustainability with delivering high-quality patient care. A shift from linear production is necessary for the transition to the Circular Economy. Extended Producer Responsibility (EPR) schemes, which consider the environmental performance of products throughout their lifecycle, hold great promise for driving this circular transition. Under EPR, product development must take a comprehensive life-cycle perspective, which includes manufacturing, pricing, product use, end-of-life disposal and remanufacturing processes. This study introduces the concept of 'Circular Product Development', which integrates circular economy principles to reduce the carbon footprint within the healthcare supply chain and mitigate the bullwhip effect. Circular product development aims to consider how products are designed, used and managed after use to minimize waste and environmental impact, in line with Circular Economy Goals (CEGs). Through a synthesis of literature analysis and qualitative analysis using a case study, this paper develop a new framework promotes the adoption of circular product development strategies to shift away from linear consumption patterns. Additionally, it takes a holistic approach to comply with the European Commission's Council Directive 93/42/EEC on medical device standards and considers Conformité Européenne (CE) certification to ensure consumer safety during the circular transition.

Challenges and Enablers for Textile SMEs Towards Circular Production Systems

Melina Ettehad, Jenny Bäckstrand, Kerstin Johansen, and Malin Löfving

The textile industry includes SMEs, which play an important role worldwide in the economy and society. However, their activities can contribute to some environmental issues, like climate change, and resource scarcity, which are lately at the center of attention. Due to increasing pressure from governments and society regarding sustainability issues, textile SMEs need to become sustainable, and one solution to achieve sustainability is transitioning towards circularity in production. Nevertheless, textile SMEs encounter numerous challenges and enablers on their journey towards circularity, particularly in areas like production systems where knowledge remains insufficient. Thus, this paper aims to identify the challenges and enablers faced by textile SMEs in transitioning towards circular production systems. This study is based on a literature study, workshops, and interviews with Swedish textile SMEs. The results show that textile SMEs encounter seven challenges towards circular production systems, including a lack of knowledge and awareness, limited resources, limited access to technology, complexity of input and finished product, a lack of proper regulations and strategy, a lack of collaboration among stakeholders, and a lack of interest and support from stakeholders and customers. In contrast, education, collaboration, supportive regulations, and circular production system design can be considered as enablers for their transition.

Upcycling of Food Waste through Bioconversion by Insect Larvae: Conceptual Model and Research Agenda for a Circular Food Supply Chain

Anita Romsdal, Heidi Carin Dreyer, Steffen J. S. Bakker, and Ana Carvajal

The transition towards a circular economy in the food sector is crucial to meet society's sustainability challenges. One promising approach is upcy-cling of food loss and waste sidestreams (FLWS) which can be converted in-to raw materials for another cycle. This paper focuses on the circular supply chain involved in upcycling of FLWS through bioconversion by insect lar-vae. Using a two-step upcycling strategy, FLWS is converted into substrates for insect larvae. The larvae are subsequently processed into protein meal that is used as ingredients in livestock feed, thus creating a circular supply chain. The paper explores the consequences this approach has for the devel-opment of the circular food supply chain and reverse logistics. The study provides an overview of the current state of knowledge, presents a case study from a poultry supply chain, and synthesizes key concepts and insights into a conceptual logistics model. The model outlines the actors, processes, and material flows involved in the circular supply chain. A research agenda proposes topics to guide future studies towards full-scale realization of the concept, highlighting both structural and planning issues. Topics include de-velopment of suitable systems for reverse material flows and sorting and storage solutions, determination of how to integrate FLWS and circular mate-rials into existing production capacities, and planning issues related to bal-ancing supply and demand, particularly related to the predictability of vol-umes, timing, and yield. The paper concludes by highlighting the theoretical contributions and practical implications of the study.

Parallel Sessions 5.5

Digital Transformation Approaches in Production and Management - Part 2

Selver Softic, and Mario Henrique Callefi

Assessing Additive Manufacturing and Digital Inventory Ecosystem in the Oil & Gas Context

Kristian Bang-Olsen, and Ali Turkyilmaz

The integration of additive manufacturing and digital inventories presents a paradigm shift in supply chain management, promising reduced lead times, decreased complexity, lowered inventory storage costs, and improved sustainability. De-spite the substantial benefits, the oil and gas (O&G) industry has been slow in adopting this technology. Drawing insights from companies already leveraging AM, this study investigates the critical functions in a DI ecosystem, challenges and actions required for the effective utilization of DI within the O&G sector. Through qualitative analysis, the research identifies key factors influencing the adoption and implementation of DI in on-demand manufacturing and inventory management strategies. By understanding the challenges and opportunities associated with AM and DI integration, this study contributes to the discourse on innovative supply chain strategies and provides practical insights for DI ecosystems stakeholders.

Unlocking the potential of blockchain in road freight transportation operations

Mario Henrique Callefi, Pierre Grzona, Adalto Bueno, Dayvid Souza Santos, and Moacir Godinho Filho

Road freight transportation operations are impact companies and countries economically and socially, making it critical to utilize technologies that increase its efficiency. Blockchain is one of the increasingly key technologies in the supply chain context, including freight operations. Although several studies have been conducted to investigate blockchain's role in supply chains, there is still a lack of research on freight transportation, specifically related to blockchain-enabled capa-bilities. Our study identified a blockchain-enabled capabilities framework that en-ables an understanding of blockchain's role in road freight transportation opera-tions. This framework will support operators in determining which capabilities should be prioritized for higher visibility and efficiency in road freight transportation operations.

Digital Transformation Towards Human-Centricity: A Systematic Literature Review

Jelena Crnobrnja, Danijela Ćirić-Lalić, David Romero, Selver Softic, and Ugljesa Marjanovic

The advent of Industry 4.0, over its decade-long evolution, primarily concentrated on digital and smart technologies to enhance production efficiency, often overlooking human involvement and environmental considerations. Despite the recent emergence of Industry 5.0 as a new research paradigm, its exploration is still in its early stages, with limited systematic investigation and a lack of empirical evidence. Therefore, this paper aims to examine the research topics at the intersection of "Human-Centricity" and "Industry 5.0" in the field of manufacturing as covered by academic journals and conference proceedings. We used the systematic literature review method PRISMA to identify 77 publications. The results portray six avenues for future research: (i) Human-Centric Design and Human-Robot Interaction, (ii) Industry 5.0 Frameworks and Theoretical Models, (iii) AI and Advanced Data Analytics, (iv) Smart Manufacturing and Sustainability, (v) Training, Skills Development, and Worker Wellbeing, and (vi) Ergonomics and Safety in Manufacturing.

Literature Review on the Current State-of-the-Art in Research and Technological Advancements in the Field of Machine Learning applied to Predictive Maintenance

Daniel Resanovic, and Nicolae Balc

This literature review examines the technologies of Machine Learning (ML) in Predictive Maintenance (PdM), highlighting the necessity for industries to boost production efficiency for competitive advantage amid growing global demands. It underscores the pivotal roles of technological advancements, especially the Inter-net of Things (IoT) and Big Data, in enabling smarter automation and intelligent production processes. By leveraging equipment sensor data, Predictive Mainte-nance serves as a crucial proactive maintenance strategy, enhancing reliability and accuracy through its diagnostic and prognostic stages. However, challenges in fi-nancial, organizational, data, and repair complexities hinder its full-scale imple-mentation, necessitating a deeper understanding of ML techniques in PdM. The review further discusses AI/ML's role in enhancing predictive maintenance, de-tailing applications of AI, ML, and Deep Learning (DL) in predictive analytics and identifying emerging trends like transformers and self-supervised learning, which promise to improve PdM outcomes. Through a structured analysis, this report underscores the evolving landscape of ML applications in PdM, highlight-ing both challenges and opportunities, and suggesting further exploration of ML algorithms in this field.

Parallel Sessions 5.6	Time: 11:10 - 12:30	Room: Carlowitz

Meet the Editor 2: Operations Management-oriented Journals

Gregor von Cieminski

International Journal of Industrial Engineering and Management

Editor-in-Chief: Prof. Dr. Uglješa Marjanović, University of Novi Sad, Serbia

Computers and Industrial Engineering

Area Editor – Human-Centric Systems: Prof. Dr. David Romero, Tecnológico de Monterrey, Mexico

Smart and Sustainable Manufacturing Systems

Associate Editor: Prof. Dr. Thorsten Wuest, University of South Carolina, Columbia, SC, USA

Parallel Sessions 6.1	Time: 13:30 - 14:50	Room: Terra

Smart and Sustainable Supply Chain Management in the Society 5.0 Era - Part 3

Toshiya Kaihara, and João Gilberto Mendes dos Reis

Analysis of Critical Success Factors of a Sustainable and Resilient AIoE-Based Supply Chain in Industry 5.0

Reza Tavakkoli-Moghaddam, Hamed Nozari, and Alexandre Dolgui

Critical success factors (CSFs) are constrained components crucial to the or-ganization's victory. If the organization needs to proceed with its presence, it must give them. Therefore, organizations should consider these factors in their operational processes. In today's world, which is mixed with transformative technologies and business and supply chain processes have different conditions than in the past, understanding the CSFs for smart processes in the supply chain is very necessary because it can guarantee the success of smart organiza-tions. Understanding these factors and their position can greatly help the resili-ence and sustainability of the supply chain, which are key indicators of Indus-try 5.0. Therefore, this research aims to extract and analyze the critical success factors in resilient, sustainable, and intelligent supply chains based on Artifi-cial Intelligence is Everything (AIoE) in Industry 5.0. To evaluate the critical factors of success, this research has prioritized these factors using a fuzzy non-linear approach based on the hierarchical analysis method and pairwise com-parison tables based on linguistic variables. The results show that the existence of technical infrastructure and hardware have the highest priority in the im-plementation of these systems. Understanding the framework presented in this research can provide a deep insight into the effective implementation of these smart supply chain systems in the age of transformative technologies.

Trading Digital-Valued Assets within Cyber-Physical Manufacturing Supply Chains: A Scoping Review of Additive Manufacturing and Digital Trade

Kwaku Adu-Amankwa, Andrew Wodehouse, Angela Daly, Athanasios Rentizelas, and Jonathan Corney

Additive manufacturing, a cyber-physical process that has gained popularity, can revolutionise manufacturing across various industries. By trading digital assets globally, additive manufacturing can support Industry 5.0 principles like sustainability or resilience. Thus, examining the potential for digital trade within cyber-physical manufacturing supply chains is crucial. This paper responds to the research challenge by providing an overview of digital trade (including e-commerce) within the additive manufacturing research landscape. The scoping review technique systematically investigated the extant literature and comprehensively summarised evidence based on their emergent themes and recurring content. The paper enumerates evidence of research efforts made so far within this field. The findings reveal that the topic is still not extensively studied despite this research field's growth. It has also been discovered that existing studies predominately focus on digitally-ordered processes rather than digitally-delivered processes, which primarily involve the trade of physical artefacts rather than cyber artefacts. These knowledge gaps highlight the opportunities for further research that will advance the field and significantly contribute to society's transition into Industry 5.0. It is anticipated that this paper, by providing a comprehensive overview and identifying research gaps, will guide stakeholders (practitioners, researchers, academics, educators, and policymakers) with foundational knowledge on the subject and inspire more studies in this area, ultimately enhancing society's readiness to embrace active trading of digital-valued assets within cyber-physical supply chains using additive manufacturing.

Optimization of Reconfigurable Manufacturing Systems Configuration using Constraint Programming

Damien Lovato, Hamza Bouzekri, Rachel Campos Sabioni, and Slim Zidi

To cope with market unpredictability and uncertainty, manufacturing indus-tries should be able to rapidly adapt their manufacturing systems to be more responsive to market changes. Reconfigurable Manufacturing Systems (RMS) offer an alternative to traditional manufacturing systems. They can rapidly reconfigure and readapt their capability and functionality to meet new requirements without the need to start from scratch. RMS are complex systems and a critical phase in their implementation involves their design. We propose a new constraint programming approach to minimize the total investment cost of a multi-part flow line configuration. The approach was implemented and tested on a literature case study. The results show the abil-ity of the method to find an optimal solution in few seconds for a small in-stance.

Analysis of People's Continental Behavior Regarding Cycling in Light of The Cyclability Index

Izolina Margarida Souza, João Gilberto Mendes dos Reis, Lucas Santos de Queiroz, and Alexandre Formigoni

The excessive use of motor vehicles in urban mobility has caused many negative impacts on both society and the environment in several cities around the world. Issues such as traffic congestion, noise, and air pollution caused by the excessive release of CO2 into the atmosphere, and inefficient use of public spaces, conse-quently making people more stressed, with cardiovascular and respiratory prob-lems. In recent years, there has been much discussion about the use of bicycles as an alternative form of active and sustainable mobility, which not only does not contribute to pollution but also promotes physical activity. After categorizing cit-ies considered bicycle-friendly by continent, the objective of this study is to eval-uate if there are significant differences in the bike-friendliness index presented by these cities when compared by continent groups. Data were collected from the Global Bicycle Cities Index - GBCI for the year 2022. For this purpose, indica-tors such as safety, infrastructure, events, critical mass, and availability of shared bicycles are considered, and the social network analysis tool using graphs ob-tained with the NetDraw® software is utilized. It is concluded that there are no significant differences among the presented indices according to the analyzed cri-teria, except for the index related to the availability of shared bicycles.

Parallel Sessions 6.2

Inclusive Work Systems Design: Applying Technology to Accommodate Individual Workers' Needs

Sabine Waschull, and Jos Bokhorst

An examination of the limited adoption of personalized work instructions in assembly to accommodate individual worker's needs

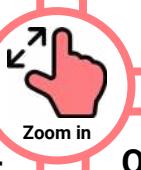
Jos Bokhorst, Sabine Waschull, and Christos Emmanouilidis

Creating a good fit between an individual's information needs and the information provided in work instructions by personalizing its content and form facilitates allocating a more diverse group of operators to a particular assembly task, stimulating the labor force participation rate and inclusiveness. While on-going technological development should make the personalization of work in-structions easier, adoption in practice is still limited. Analyzing nine companies through a multiple case study approach, this paper investigates the challenges organizations face when creating, maintaining, and using personalized work in-structions in practice. Overall, organizations struggle to adopt personalization due to its demanding nature, involving complex and time-consuming mainte-nance to keep personalized, and thus a large number of instructions, up-to-date. Personalization found in the cases mainly involves the use of a personal mentor to adapt the information detail to the characteristics of the worker, as well as allowing employees to conduct minor edits or to create their own instructions. Despite its possibilities, technology hardly played a role in creating and com-municating personalized work instructions. To facilitate a more inclusive work design in practice, creating, implementing, and maintaining work instructions must become more accessible and manageable.

Skills and information needed for Operator 5.0 in emergency production

Sandra Mattsson, and Martin Kurdve

This paper explores what skills and information are needed to meet the chal-lenges of emergency production. In the near future, Operator 5.0 will operate within Industry 5.0, a sector focused on fostering innovation for all stake-holders, including the environment. One of the core pillars of Operator 5.0 is resilience which means being able to manage emergencies and uncertainties. Achieving this poses a challenge, as the industry struggles to acquire the necessary skills recommended. A framework for skills and information need-ed for Operator 5.0 to perform emergency production was suggested and used in a case study for face mask production. The results are as follows: 1) skills needed for emergency production are the cognitive/physical ability to perform a task and basic overall digital skills, and 2) the information needs are standards, instructions, and training materials. To create information the following demands on the system were suggested: Universal design, mini-mize unexpected events, productivity and product quality and safety. The framework could be used with existing contingency planning and preparato-ry emergency production to plan for better management of emergencies in Sweden or Europe.



Augmenting the One-Work-Multiple-Machine (OWMM) System: An Industrial Softbot Approach

Ricardo José Rabelo, Lara Popov Zambiasi, Saulo Popov Zambiasi, Stefan Wellsandt, Mina Foosherian, David Romero, and Karl Hribernik

Industry 5.0 fundamentally relies on humans surrounded by massive digitalization, data generation, and data-driven management. However, this brings more complexity to the operators as they are exposed to vast amounts of data as well as to many situations of overwhelming cognitive load, hence, to potentially less assertive decision-making. This becomes challenging when operators should manage two or more machines – as in an OWMM (One-Worker-Multiple-Machine) system – especially if that includes critical processes. This paper proposes a softbot-based approach to address these issues, devising an integrated, immersive, and virtual environment where an intelligent softbot assists the operator in several production situations. A software prototype was developed to show the high potential and benefits of this approach.

Quantitative Models for Workforce Management in a Large Service Operation

Siddhanth Shetty, and Vittaldas Prabhu

This paper develops quantitative models for optimizing employee scheduling in large labor-intense service operations that face complexities such high employee turnover, contractual service-level agreements (SLA), non-billable overtime cost, and rising minimum wages. The workforce analytics part of the model uses payroll data to characterize employee features such as consistency, overtime affinity, and retention. The business analytics part of the model ensures that adequate employees are assigned to a shift to comply with SLA while minimizing anticipated overtime cost based on the prevailing overtime salary. A Mixed Integer-Linear Program is formulated with the objective of balancing total overtime cost reduction, employee preferences, and employee features. Additionally, employees can be clustered to identify distinct patterns based on their features of consistency, overtime, and retention. The proposed approach has been applied at a North American service provider with over 4,000 employees across more than 100 sites. K-means clustering based on employee features identified four distinct clusters. Deeper analytics using mixed-effects analysis can show the contribution to profitability from reliable employees, which are limited in availability. Boosted tree importance scoring can establish the influence of moderately reliable employees on overtime cost. Furthermore, decision tree model highlighted that tactical hiring and scheduling must account for collective workforce variability rather than individual attributes in isolation. A partial dependence plot helps visualize the relationship between employee reliability and overtime, thereby helping to characterize the impact of workforce mix on cost. Key impact from this work is that the company management is working to improve its recruitment, retention, and scheduling policies to better align business needs and human capital.

Parallel Sessions 6.3

Evolving Workforce Skills and Competencies for Industry 5.0 - Part 1

Alexandra Lagorio, and Elias Montini

A State-of-the-Art Review and Framework for Human-Centric Automation in Industry 5.0

Mohammed Yaqot, Brenno Menezes, Abdulfatah Mohammed, and Kim Moloney

As we go beyond the concept of Industry 4.0 (I4.0), the point where industry and human participation meet becomes a matter of philosophical debate. What is the rationale for developing a substitute for human effort? The expected substitution of several work positions sparks debate on society's ability to adjust to this technology-driven change, necessitating a comprehensive investigation. The primary research question in this work addresses how Industry 5.0 (I5.0) can enhance human-machine collaboration to improve operational efficiency and worker satisfaction. The methodology employed in this work involves a systematic review of relevant literature, focusing on two particular aspects of human-centric manufacturing: the symbiotic relationship between humans and automation and the identification of the capabilities that automation can enhance in worker skills amidst the myriad challenges of digital governance. To address these challenges—such as job displacement, skill gaps, and ethical concerns in automation—the Enhanced Human-Automation Symbiosis (EHAS) framework is proposed. This framework aims to balance technological advancements with human needs by enhancing our understanding of the complex dynamics between human capacities and automation. In this paper, we present a comprehensive state-of-the-art review and outline our proposed framework, discussing future research directions, developmental prospects, and practical implementation issues.

Impact of Collaborative Robots on Human Trust, Anxiety, and Workload: Experiment Findings

Elias Montini, Giovanni Ploner, Davide Matteri, Vincenzo Cutrona, Paolo Rocco, Andrea Bettoni, and Paolo Pedrazzoli

This work proposes an experiment setup and its protocols to investigate the impact of cobot's size, speed and collaboration modes on different human factors including trust, propensity to trust, anxiety, and mental workload. The setup and the protocols supported the execution of different experiments where the 29 participants were asked to complete the Tower of Hanoi in collaboration with a cobot. The setup and the protocols provide a ready-to-use solution to expand experiments for further studies. Moreover, statistical analysis of the results shows higher cobot speeds increased trust propensity despite not significantly affecting overall trust or anxiety. Collaboration modes significantly influenced perceived workload and task performance, with the "Collaboration with Trigger" mode resulting in lower mental workload but longer task completion times. No significant differences were found in human factors concerning cobot size, indicating that variations in size do not significantly impact trust, propensity to trust, anxiety, or workload. Additionally, the collaboration mode with cobots notably affects workload perception and task performance, with specific modes reducing perceived effort but not necessarily improving task efficiency.

Integrating Industry 5.0 competencies: a learning factory based framework

Lorenzo Agbomemewa, Fabio Daniele, Michele Foletti, Matteo Confalonieri, and Paolo Pedrazzoli

Industries across the world are witnessing profound technological paradigm changes, necessitating a new set of engineering skills and capabilities for the future workforce. This paper investigates the needed engineering competencies required to bridge the skills gap related to Industry 5.0. Our work analyses current educational frameworks on the topic and proposes a new concept based on the exploitation of learning factories. The paper showcases the conception, execution, and evaluation of a summer school program dedicated to such an objective. It discusses the structure, methodologies, and outcomes of this course, demonstrating the effectiveness of the proposed didactic framework. The findings offer valuable insights for educators and industry professionals alike in preparing the future workforce for the challenges and opportunities of Industry 5.0.

Strategies for managing the ageing workforce in manufacturing: a survey-based analysis

Andrea Rubini, Claudia Piffari, Alexandra Lagorio, and Chiara Cimini

In recent years, the phenomenon of an ageing workforce has emerged as a critical area of concern, drawing attention from various stakeholders, including policymakers, researchers, and industrial practitioners. The rapid advancements in digitalisation within the manufacturing sector have compounded this issue, highlighting the need for a comprehensive understanding of its contextual underpinnings and implications. As a result, the responsibility of addressing these shifts in the human resource markets and, more importantly, their implication for working conditions falls on industrial engineering and production research communities as well as national and corporate policymakers. Addressing these problems is particularly important in manufacturing or assembly lines where workers must execute manual and cognitive tasks requiring both their full physical and mental faculties. A dual research approach was employed, comprising in-depth interviews and targeted questionnaire surveys conducted within an Italian province. By engaging directly with industry stakeholders and workforce representatives, the research sought to extract insights regarding the awareness of the ageing workforce phenomenon and the practices employed to address its challenges.

Parallel Sessions 6.4

Advancing Eco-Efficient and Circular Industrial Practices - Part 3

Beatrice Colombo, and Mélanie Despeisse

Life Cycle Analysis for the concept design of a Smart Mobile Factory (SMF) for infrastructure construction projects

Patrick Dallasega, Ishaan Kaushal, Andrea Revolti, and Nicholas Miori

Infrastructure construction projects are very important for the development and improvement of people's lives, but they have significant environmental impacts. Traditionally, the prefabrication is organized in a centralized manner, with big lot sizes and long lead times. Specifically, in the case of linear infrastructure construction projects, where the building site needs to move as the construction progresses, centralized manufacturing creates high environmental impacts. On the other hand, a Smart Mobile Factory (SMF) can move as the construction site progresses, shortening the transportation distances of prefabricated parts to the site (e.g. tunnel rings/segments), consequently reducing the environmental impacts. The paper is part of the research project Smart Mobile Factory for infrastructure projects (SMF4INFRA). In previous research activities, three different types of SMF were conceptualized: i) A concrete based SMF, ii) a wood based SMF and iii) a pneumatic based version of the SMF. In this research the main objective is to compare the environmental impact of the three SMF variants by performing a Life Cycle Assessment (LCA). As case study, the potential construction of a hyperloop track between Zurich and Geneva in Switzerland had been selected. As a result, the pneumatic based SMF showed the lowest environmental impacts, considering the transportation, assembly, disassembly and the material of the components of the SMF. Future research will focus on developing dynamic LCA, which encompasses the prefabrication and installation of infrastructure elements, incorporating the system also in a Digital Twin environment for an improved monitoring and control of the ecological footprint.

Exploring theoretical perspectives on the relationship between the reporting of circular economy initiatives and financial performance in the German context

Melissa Marques-McEwan, and Jannik Türnau

The relationship between circular economy (CE) implementation and financial performance is an emerging field of study. CE aims to mitigate environmental impact and enhance sustainability. Despite its growing adoption, however, the link between CE implementation and financial performance remains underexplored and inconsistent in empirical literature. This research explores the relationship between the self-reporting of CE policies and practices and financial performance, contrasting neoliberalism and legitimacy theories, particularly within the context of German manufacturing firms. We used quantitative data from financial and environmental reporting databases, for 28 small and medium publicly listed manufacturers in Germany, as well as supporting secondary qualitative data for 6 companies. Our results reveal no significant correlations between CE scores and various financial measures, such as ROA and profitability growth, challenging the neoliberal assumption that CE engagement is financially motivated. This study contributes to empirical research by suggesting that legitimacy theory, rather than neoliberalism, better explains why companies report CE initiatives. However, we suggest that legitimacy theory can be refined by accounting for how different stakeholders can influence the need for a company to seek legitimacy. In this study, we observed that factors such as having shareholders, company location, or size did not fully explain firm engagement with CE reporting, and we proposed that other factors might be relevant. This study provides insights for scholars and practitioners, emphasizing the importance of nuanced, context-specific analyses of the relationships between CE and financial performance. Practitioners and policymakers should note that the relationship between CE practices and financial performance requires careful consideration and individualized efforts.

Exploring the impact of circular strategies in manufacturing: Can they ensure sustainability?

Sundeep Tamak, Yasamin Eslami, and Catherine Da Cunha

This article explores the impact of circular strategies in manufacturing on sustainability, focusing on environmental, economic, and social dimensions. By analyzing various circular economy practices such as circular design, re-furbishment, remanufacturing, and recycling, the study assesses their effec-tiveness in promoting the triple bottom line of sustainability. While circular economy strategies offer promising environmental benefits, including waste reduction and energy conservation, they also present economic chal-lenges such as high initial costs. The article highlights the need to navigate trade-offs and address economic barriers to realize the full potential of circu-lar economy practices in achieving holistic sustainability. It underscores the importance of collaborative efforts among policymakers, businesses, and stakeholders to foster an enabling environment for sustainable manufactur-ing practices and drive positive change towards a circular and sustainable future.

Energy efficiency and improvement needs in Swedish manufacturing SMEs

Martin Kurdve, Zuhara Zemke Chavez, Niklas Ternström, and Gayathri Chandrasekaran

Energy efficiency is crucial for reducing the climate footprint, enhanc-ing green transformation and improving the economy and energy resilience. This paper aims to identify and demonstrate gaps between industrial practices found in empirical case studies and academic knowledge of industrial best practices for energy-efficient manufacturing design. The paper uses empirical cases where en-vironmental and energy-value stream mapping and Green Kaizen tools were used to analyse production operations, highlighting potential operational and design improvements in production equipment and systems, and showing there are still large opportunities for energy efficiency improvements in manufacturing opera-tions, which can save money and reduce environmental impact. Yet, several in-efficiencies are determined in the equipment and production system's design phase, which are challenging to change once the equipment is in operation. The secondary climate effect of energy savings in a Swedish context, where unused electricity can replace fossil-based electricity, is discussed. The paper contributes to theory by linking previous research findings with the current industrial chal-lenges and opportunities for energy and sustainability in operations management. The paper provides results and knowledge to help the industry improve energy efficiency in production.

Parallel Sessions 6.5

Digital Transformation Approaches in Production and Management - Part 3

Selver Softic, and Guven Gurkan Inan

Coordinating Digital Transformation: Exploring IT Organizational Adaptations in International Manufacturing Networks

Viktorija Badasjane, Anna Granlund, Mats Ahlskog, Jessica Bruch, and Barrett Sauter

Digital transformation is complicated in International Manufacturing Networks (IMNs), where factories are spread globally, and actions are interdependent. Adapting organizational structures is one way to handle the demands and expectations posed by digital transformation. However, research covering the adaptations to the IT organization is limited, and this paper's purpose is to explore adaptations of IT organizations within IMNs during digital transformation. A multiple case study was performed, studying two manufacturing companies' adaptations of the IT organization. The result reveals three phases of adaptations of the IT organization: the foundation phase, the mapping phase, and the coordinating phase. The phases are accompanied by the setup of a new operational IT function that works with digital transformation in the IMNs. Also, the interfaces and collaboration between the operational IT function and the factories in the IMNs are identified. Lastly, it highlights remaining challenges with the adaptations of the IT organization that need further research.

Building Digital Capabilities in Manufacturing SMEs

Guven Gurkan Inan

The Resource-Based View (RBV) posits that firms controlling and managing identical resources may exhibit divergent performance due to the development of distinct capabilities. These organisational capabilities, defined as an organisation's ability to utilise its tangible or intangible assets to perform tasks or activities that enhance performance, are pivotal in securing competitive advantages. Capabilities are bifurcated into two dimensions: capacity and maturity. Capacity pertains to the resources that an organisation manages and controls, while maturity denotes the proficiency in utilising the capacity for value creation that aligns with strategic objectives. In the contemporary business landscape, digitalisation has emerged as a significant avenue for Small and Medium Enterprises (SMEs) to carve out competitive advantages. However, it is noteworthy that 70% of digital transformation initiatives fail to contribute to business performance, underscoring the importance of successful digitalisation applications in streamlining business processes. Digitalisation capabilities, which refer to the ability to generate value from data produced, gathered, and stored by digital technologies in alignment with business strategy, can be cultivated through digital capacity and digital maturity. This research employs a theoretical framework to foster digital capabilities within organisations, the applicability of which was demonstrated via a longitudinal case study in a Turkish manufacturing SME. The findings reveal various strategies to adapt different digital technologies for value creation and business promotion within its industry. The journey of digitalisation in manufacturing SMEs presents several gaps that require attention, and it is crucial to align digital capabilities with the company's strategic objectives.

Dashboard Development for the Quality Department of a Company from the Automotive Industry

Mariana Mateus, and Sergio Sousa

The digitalisation of the automotive industry has led to an increase in the volume of data, making it difficult to analyse and interpret. To overcome this situation, managers have turned to dashboards that allow quick access to relevant information to support decision making. This study focuses on the development of a dashboard for the quality department of a company in the automotive industry. Through data collection, the performance indica-tors were identified, constraints were addressed and plans were developed. The dashboard, consisting of a main interface and three additional interfaces, was designed using Power BI. In addition to meeting the needs of the quality department, it forms the basis of a larger dashboard module in a manufacturing execution system (MES). Employees were involved in the process ensuring the relevance and effectiveness of the dashboard. In addi-tion, the dashboard is very cost-effective for the organization and will serve as a prototype for what the MES should produce automatically.

Digitalizing Smallholder Farmer Agri-Food Supply Chains: A Case Study from a Developing Economy

W. Madushan Fernando, Amila Thibbotuwawa, R.M. Chandima Ratnayake, and H. Niles Perera

Smallholder farming is critical to ensuring food security, employing over two billion farmers in developing countries, and alleviating rural poverty. Poor agricultural practices, supply chain inefficiencies, weather challenges, and market disruptions all diminish productivity in this sector. As modern technology and digitalization reshape agriculture, there is a significant augmentation of stakeholder connectivity within smallholder farmer Agri-Food Supply Chains (AFSCs). The progress of technology allows smallholder farmers to gain access to high-quality farming inputs while expanding their market reach. While there are proven benefits of digitally transforming smallholder farmer AFSCs, there is still a significant knowledge gap in effectively assessing the potential of digital technologies from a supply chain perspective. As the overall approach in this paper, we used the case study research method along with inductive reasoning. We combined the AHP and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methods to include both industry practitioners and academic perspectives in the decision-making process. The process involved using AHP to analyze supply chain inefficiencies, with a focus on their impact on yield, harvest quality, and farmer livelihood, and then using the TOPSIS method to prioritize digital solutions for the chosen case study. The case study revealed that 61% of inefficiencies arose in the early supply chain stages, notably in regulation (28.26%) and farm input supply (33.03%), emphasizing the critical need for prioritizing digital farm record keeping and registration for improved efficiency. This study emphasizes practical digital solutions for smallholder farming supply chains while integrating industry and academic perspectives, offering a systematic approach to prioritizing interventions.

Decision-Making for AI-Enabled Industry 5.0 - Part 1

Oliver Antons, and Vittaldas Prabhu

Analytical and Computational Models for In-Store Shopper Journeys

Korrawee Henprasert, Prakash Chakraborty, and Vittaldas Prabhu

Retailing is an important part of the supply chain, the link at which money is transferred from the consumer and flows to upstream trading partners. However, retailing has received very little attention from researchers in terms of developing quantitative models that are used in the rest of the supply chain. This paper proposes analytical and computational models based on queuing theory and discrete-event simulation, respectively, for in-store shopper journeys. Specifically, based on empirical data from retail stores, we propose a M\/G\/∞ and M_t \/G\/c queues in tandem to model the shopping process and the checkout process to characterize key aspects of shopper journeys. Such an analytical model is probably the very first of its kind proposed to mathematically characterize retailing and offers prospects for enabling better understanding and decision-making in this multi-trillion-dollar industry. A key advantage of such analytical models is that they can provide quick answers to questions such as average customer waiting times at checkout for different levels of staffing, which is an important issue in customer service vs staffing cost. A shortcoming of such analytical models is that they are based on assumptions therefore their output has limited accuracy, and these models cannot predict variance in the output. To overcome these shortcomings, this paper presents ShopperSim, which is a stand-alone discrete-event simulation software being developed using SimPy, a Python library, to simulate shopper journeys in a variety of store formats. To ensure practical relevance of these developments, ShopperSim has been programmed to statistically reproduce empirically observed shopping time, basket size, and store area covered – key attributes for shopper journeys. Tests indicate that ShopperSim can reproduce empirically observed statistics of key attributes for shopper journeys. Data generated from ShopperSim indicates that M\/G\/∞ and M\/G\/c, a much simpler and more tractable tandem queuing model may be adequate for the tested case of a convenience store. In the future, analytical and computational models developed here can be leveraged in several ways for education, training, and operational decision-making in stores, including gamification of these decisions.

Designing a New Dry Port-Seaport Logistics Network with a Focus on Industry 5.0 by Machine Learning

Shabnam Rekabi, Zeinab Sazvar, Alexandre Dolgui, and Reza Tavakkoli-Moghaddam

Dry Ports (DPs) are essential inland terminals that cover a variety of goods and are strategically established in select countries. According to the general structure of DPs across various countries, they play a major role in the field of multimodal transportation. Considering that some countries have wide beaches, they can earn non-oil income by using these beaches. Therefore, in this study, we are looking at the design of the Logistics Network (LN) for Dry Port-Seaports (DPSs), with an emphasis on multimodal transportation systems, by predicting demand utilizing a Machine Learning (ML) algorithm named Seasonal Autoregressive Integrated Moving Average (SARIMA). The mathematical model of this study includes three Objective Functions (OFs) (e.g., minimization of cost and environmental impact, and maximization of job opportunity and resilience). This work offers a mixed-integer programming model for set-ting up a viable LN by the Industry 5.0 (I5.0) dimension. Moreover, the Lp-metric, Goal Programming (GP), and Meta-GP (MGP) approaches are used to solve the developed model. Eventually, several quantitative illustrations are employed to evaluate the mentioned solution approach.

A literature review on the cross-domain usage of digital factory twins within design time

Adrian Schröder, Oliver Antons, and Julia C. Arlinghaus

In a globalized production environment companies are confronted with shortening product life cycles leading to shortening factory system life cycles. To overcome this issue, factories have to be (re-)built faster. The design time is a crucial phase in which many different disciplines of different domains have to work together in a major planning project. Currently, various experts in the respective domains of e.g. production system planning, automation and building are commonly working on their silo models resulting in different and sometimes contradictory information depending on the perspective of planning. While modelorientated, collaborative planning approaches like Building Information Modeling (BIM) have become familiar with the domain of factory planning, there is still a lack of combining the different factory data models holistically to connect all elements of production regarding information of products, processes and resources. Besides the BIM methodology several other forms of virtual factory descriptions, like the digital factory twin have emerged. In this work, a systematic literature review is conducted to present the current perspective on creating factory data models about a cross-domain usage and modeling approach. In analyzing the current use case definition of factory models the opportunity is seen to point out the importance of the combination of holistically linked factory data models with a multipurpose design. In doing so, a possibility is seen to overcome the mentioned obstacles of planning while raising the value of the created models. This demonstrates the need for a concept of modeling a digital factory twin, created for cross-domain usage.

Parallel Sessions 7.2

Risk Analysis and Sustainability in an Uncertain System in a Digital Era

Yasamin Eslami, and Martin Kurdve

An Exploratory Survey on the State of Supply Chain Visibility in Portugal

Eduardo e Oliveira, Pereira Teresa, and Guedes Alcibiades

Supply Chain (SC) visibility is becoming increasingly critical for supply chains to evolve, given the growing amount of disruptions and increase in SC complexity. In this study, we aim to understand what is the state of SC visibility in Portuguese companies, and what are the reasons for this state. We have conducted a survey that was answered by 57 Portuguese companies. We then conducted a quantitative analysis on the results. The results indicate that 65% to 80% of companies have some degree of visibility, but that, in most cases, this is not done in an autonomous way. Investment has been made on data collection and storage infrastructure, but not in its analysis. The reasons for this state are more technical in nature, such as low digitalization maturity. Companies would like SC visibility to allow for better planning and client relationships. However, little attention is paid to the potential of SC visibility for dealing with disruptions in the SC.

Instant Green Design event for emergency redesign

Emanuel Bengtsson, Niklas Schmidt, Trupti Borade, and Martin Kurdve

In times of crisis, urgency and lack of data, decision-making may drift away from long-term sustainability. This paper presents a case study of product and process design decisions, and description of an instant green design event workshop (IGDE-workshop). While informed sustainability decisions at best use thorough life cycle assessments, these take a considerable time. Results show that it may be possible to make reasonable environmental de-sign decisions fast in crisis situations with a design event focusing on green design and life cycle thinking. It requires a broad team with decision-making authority and with all available information at hand. The IGDE-workshop gave reasonable input for decision-making in crises regarding ecoefficiency and climate impact, although gaps in other impact categories not covered remains.

A correlated redefinition of the concept of resilience in a production system

Borzoo Pourabdollahian, Yasamin Eslami, Raphaël Chenouard, and Catherine Da Cunha

There are many definitions of resilience. Their common core is that it is a response to unexpected or unforeseen changes and disturbances, and a capacity to adapt and respond to these changes. In the literature, many different concepts were identified to accompany resilience and help define or measure a system's resilience. These include flexibility, vulnerability, rapidity and robustness. However, these concepts are sometimes used interchangeably with resilience as there is a lack of clarification among them. In addition, the role of "lessons learnt" and "learning" after a disruption is some-how neglected in existing studies of resilience and system performance. This article aims to position resilience regarding these concepts, taking into account the system's experience after several disturbances. Schematic presentation of resilience-related concepts such as flexibility, rapidity, vulnerability and robustness are proposed. Additionally, an updated definition of resilience in a production system while considering the correlated concepts like vulnerability, robustness, flexibility, rapidity is proposed.

Parallel Sessions 7.3	Time: 16:15 - 17:15	Room: Radix

Evolving Workforce Skills and Competencies for Industry 5.0 - Part 2

Alexandra Lagorio, and Greta Braun

Contemporary and Future Manufacturing – Unveiling the Skills Palette for Thriving in Industry 5.0

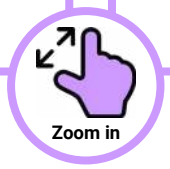
Marta Pinzone, Greta Braun, and Johan Stahre

When industry and society face major challenges, a strong and competent workforce is increasingly crucial. Throughout past crises and industrial revolutions, people have been at the core of supporting "business as usual", while simultaneously driving change. When industry is presently repositioning towards value-based sustainability, resilience, and human-centricity, contemporary work, tasks and skills are radically changed. The World Economic Forum claims that 44% of the employees' skill sets will have to change within the next five years, due to the current industrial transformation. However, there is a lack of understanding of which skills employees need to acquire to contribute to achieving a shift to Industry 5.0. This paper puts forth the concept of an Industry 5.0 Skills Palette, offering an overall understanding of the of skills needed by the future workforce. The Industry 5.0 Skills Palette is divided into four areas, i.e. Resilient Manufacturing, Green Industrial Transformation, Digital Human Work, and Technological Systems. This Industry 5.0 Skills Palette can be used by managers to assess their employees' skill needs, guiding their workforce towards learning the relevant skills. Also policymakers can apply the Skills Palette, especially when exploring incentives for upskilling initiatives. Finally, the Skills Palette helps education providers to develop curricula for Industry 5.0 skills.

A Methodology for Identification of Reconfigurability Enablers and Application in a Manufacturing System

Alessia Napoleone, Rasmus Andersen, Ann-Louise Andersen, Thomas Ditlev Brunoe, and Kjeld Nielsen

Manufacturing systems are continually challenged by evolving market de-mands, environmental constraints, and regulatory uncertainties. These sys-tems need to develop and implement the reconfigurability capability to rap-idly and cost-effectively adapt to new requirements throughout their life cy-cles. To this end, reconfigurability enablers —physical or logical factors that facilitate such adjustments— are needed. To support the identification and implementation of necessary reconfigurability enablers in existing factories, this study proposes a structured methodology to identify and select reconfig-urability enablers and applies it within a case study in a brownfield factory. The case study focused on understanding an existing configuration, includ-ing strategic requirements and anticipated trends, to identify and select re-configurability enablers. The findings underscore the necessity for systemat-ically designing reconfigurability enablers at various levels of detail, high-lighting how enablers at workstation and system levels influence each other. This provides a foundation for future research on the systematic design of reconfigurability enablers.



Parallel Sessions 7.4	Time: 16:15 - 17:15	Room: Vulcanus

Advancing Eco-Efficient and Circular Industrial Practices - Part 4

Jannicke Baalsrud Hauge, and Ralph Riedel

Smart Battery Circularity: Towards Achieving Climate-Neutral Electrification

Koteshwar Chirumalla, Erik Dahlquist, Moris Behnam, Kristian Sandström, Martin Kurdve, Anas Fattouh, Ignat Kulkov, and Ioana Stefan

The transition towards sustainable electrification, particularly in the context of electric vehicles (EVs), necessitates a comprehensive understanding and effective management of battery circularity. With a plethora of EV models and battery variants, navigating the complexities of circularity becomes increasingly challenging. Furthermore, efficient fleet management emphasizes the necessity for robust data collection and analysis across diverse EVs to optimize battery value throughout its lifecycle. Advanced digital technologies play a crucial role in bridging informational gaps and enabling real-time connectivity, intelligence, and analytical capabilities for batteries. However, despite the potential benefits, the integration of circularity and digital technologies in the battery sector remains largely unexplored. Both circularity and digital technologies in the battery domain are still emerging, lacking conceptualization on their integration. To tackle these challenges, this paper advocates for the concept of smart battery circularity, which amalgamates advanced digital technologies with circular economy principles. The purpose of this paper is to enhance the conceptualization of smart battery circularity and elucidate the key knowledge areas necessary to facilitate it. The study identifies three critical knowledge areas essential for enabling smart battery circularity: digitally-enabled circular business models, digital twin platforms for circular battery services, and smart battery performance monitoring. The sub-areas within each key knowledge area are also outlined. By delineating these knowledge areas, the study proposes an integrative framework, showcasing how these areas contribute to smart battery circularity both individually and collectively. The study offers insights to accelerate the development of initiatives aimed at establishing a sustainable and circular battery ecosystem, thereby advancing global efforts towards climate-neutral electrification.

Cybersecurity Integration in the Circular Economy: Maximizing Sustainability in Industry 4.0

Naiara Uriarte-Gallastegi, Beñat Landeta-Manzano, Waleska Sigüenza-Tamayo, Iker Laskurain-Iturbe, and German Arana-Landin

The integration of cybersecurity into the Circular Economy (CE) is essential to ensure the move towards circular practices in Industry 4.0. Although its im-portance is recognised, there is a gap in the literature on its direct influence on the CE. This study addresses this gap by investigating the relationship between cyber security and CE from economic, social, and environmental perspectives. A multi-case analysis methodology was used and the level of influence of cyber security on different indicators of EC was assessed. The results suggest a narrow and sec-tor-dependent application. Its influence on improving process control and reduc-ing uncertainty in industrial decision-making stands out. In addition, by protect-ing cyberphysical systems, it ensures safe operation of industrial systems, pre-venting physical damage to facilities and reducing risks to people. Although it is presumed that these measures can avoid risks of environmental pollution, our study does not confirm such effects and suggests a limited impact on environ-mental indicators.

Parallel Sessions 7.5

Digital Transformation Approaches in Production and Management - Part 4

Selver Softic, and Manuel Brunner

Let them eat data – a concept that allows us to share data from farm to fork (and back to the farm

Kyle Alves, Shaun West, Steve Brewer, Eugen Rodel, and Dominique Henri

This paper introduces an approach to augment the farm-to-fork value chain through thorough data consolidation and use case sharing. Capitalizing on cutting-edge data analytics and digital transformation strategies, the ap-proach seeks to mitigate predominant issues in the food supply chain, such as inefficiencies, waste, and sustainability. The ambition is to create a de-pendable data ecosystem akin to the financial sector's SWIFT network, en-hancing transparency, traceability, food safety, and operational effective-ness throughout the supply chain. Covering a broad spectrum of applica-tions from producing prepared foods to cultivating soft herbs, this paper il-lustrates the transformative potential of data-centric solutions in redefining food production, distribution, and consumption paradigms. The study delves into the benefits and challenges of data sharing and analytical tech-niques for fostering business innovation, system oversight, and regulatory frameworks in the food industry through collective endeavours. This work presents a benchmark for the imperative of empirical research via real-world implementations within the sector.

Simplifying data analysis: A visualization framework and practical application for complex BEV data

Daniel Niedermayr, Manuel Brunner, Shailesh Tripathi, and Herbert Jodlbauer

Effective data visualization for business applications is crucial in extracting meaningful insights from vast amounts of data generated from various sources. However, there is a need for more visualization tools that combine multiple features, such as complexity reduction methods through the principal component analysis with the data analysis method clustering and interactive visualization. The paper discusses the necessity for novel methods to handle complex and high-dimensional data. It proposes an innovative framework for a visualiza-tion tool that integrates complexity reduction, analysis methods, figural features, and various output possibilities. The proposed framework is further practically tested with a dataset of battery electric vehicles (BEV) from the German market. Lastly, the implications for research and practice are discussed, and further re-search avenues are proposed.

Parallel Sessions 8.1	Time: 17:30 - 18:30	Room: Terra

Decision-Making for AI-Enabled Industry 5.0 - Part 2

Oliver Antons, and Anja Brückner

AI-supported Shift Scheduling - Prototype of a Human-Centered Approach

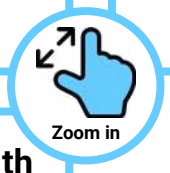
Christian Walter, Anja Brückner, and Sandra Schumann

Optimal shift planning can provide many benefits for companies, such as employee satisfaction and higher productivity. The use of artificial intelligence (AI) in shift planning has the potential to give particularly small and medium-sized companies a decisive competitive advantage. While various research results on the implementation of AI-based planning tools are already available, the individual satisfaction of employees is rarely considered. The focus of the presented paper is the development of an intelligent workforce planning system taking human-centered criteria into account. The approach includes the practical implementation of an AI-based application for shift planning in a mediumsized company in Germany. The development was carried out using a participatory approach together with the management, shift planners and affected employees. In future, the system, which was tested as a prototype for one shift, will be transferred to the entire shift system of the company. The approach provides indications of how human-centered shift planning can succeed in the manufacturing industry.

Fuzzy TOPSIS with Interval Data Based Possibility Measure Approach for Multi-criteria Group Decision Making: Application to Information System Selection Problem

Ryma Zegai, Imen Khettabi, Lyes Benyoucef, and Moncef Abbas

Supply chain partners increasingly make shared tactical and strategic decisions to achieve joint goals. Decisions include selecting partners, sites, machines, technologies, transportation modes, scheduling policies, etc. Effective selection needs considering multiple evaluation criteria. In this paper, we address the supply chain selection problem as a group, multi-criteria decision making. More specifically, a fuzzy TOPSIS with interval data based possibility measure approach is developed. Moreover, to demonstrate the applicability of the approach, a simple illustrative example dedicated to information system selection problem is presented and the obtained numerical results analysed.



Advancing Manufacturing with Interpretable Machine Learning: LIME-Driven Insights from the SECOM Dataset

Anna Presciuttini, Alessandra Cantini, and Alberto Portioli-Staudacher

This study introduces an interpretable machine learning (ML) framework tailored for the semiconductor manufacturing industry, with a strong focus on ensuring model transparency and understandability. In a domain where manufacturing efficiency and product quality are of utmost importance, our research introduces bespoke ML models designed to predict product quality with remarkable accuracy while elucidating the factors driving these predictions. Indeed, the pervasive challenge of model opacity impedes the manufacturing industry to fully leverage ML advancements for operational excellence. To address this critical gap, our study introduces an interpretable ML framework. This framework not only enhances model transparency and understandability but also ensures the precision of product quality predictions. Central to our approach is the application of LIME (Local Interpretable Model-agnostic Explanations), which demystifies the predictive mechanisms of ML models. By elucidating the underlying factors influencing product quality predictions, our methodology empowers operation managers with actionable insights for preemptive quality control and process optimization. Utilizing the UCI SECOM dataset, this paper exemplifies how interpretability in ML transcends conventional analytics, facilitating informed decision-making and fostering a culture of operational excellence

Parallel Sessions 8.2	Time: 17:30 - 18:30	Room: Aqua

Resilience management in supply chains

Michele Martignago, and Julian B. Maier

Forging Resilience Through Supply Chain Collaboration: Insights from the Chinese Automotive Industry

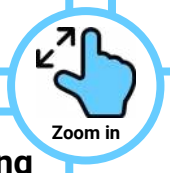
Weiyuan Li, Ming K. Lim, and James Wilson

This paper explores the pivotal role of supply chain collaboration in building resilience within the Chinese automotive industry amidst the new kind of disruption catalysed by the COVID-19 pandemic. Resource Dependency Theory (RDT) provides the theoretical foundation for this research, which used case studies and interviews to examine resilience strategies. The research found information sharing, resource sharing (supporting smaller suppliers), and adjustments (seeking external help) played key roles. This research highlights collaboration's importance in building supply chain resilience and offers practical guidance for navigating disruptions.

Anticipating VUCA by Utilizing the Potential of Technological and Logistical Degrees of Freedom

Julian B. Maier, and Hans-Hermann Wiendahl

Facing increased market volatility necessitates robustness and flex-ibility to mitigate short-term disruptions and transformability to adjust to long-term changes. The degrees of freedom available for (re-)acting in this environment are determined by product requirements, production system characteristics, and production control system flexibility. The often-found sequential and decoupled consideration of technological and logistical deci-sions provides a narrow action space, resulting in limited flexibility. Production control with integrated consideration of logistical and technolog-ical degrees of freedom has the potential to increase flexibility by opening up the decision space. So far, research in this context is focused on job shop environments. Aiming to extend this integrated consideration to production systems with other characteristics, this article proposes a method to identify available degrees of freedom and introduces an approach to quantify their potential to mitigate the effects of company-specific turbulence patterns through a daydreaming-enhanced digital twin.



Material shortages propagation: using network science to evaluate inventory efficacy

Michele Martignago, Martina Calzavara, and Daria Battini

The ability to manage the effects of supply chain (SC) disruptions has played a major role in industrial environments in recent years. Pandemics, natural disasters, and political tensions increased difficulties in procuring components, resulting in delays in delivering finished products and thus in lost sales, along with other relevant effects that strained companies' survivability (e.g. delayed financial flows). Companies have tried to avoid material short-ages by increasing inventory levels, with increased costs and further risks (e.g., inventory devaluation, obsolescence), but with hard-to-evaluate benefits. Efficient resilience requires these cost-benefit analyses: their computation is even harder in todays' complex and intertwined supply networks (SN), where it is also hard to align SC players with contrasting goals. In this paper, we aim to understand the effect of increasing inventory levels in two different network types. Hence, we simulate the shortages of materials propagating through the SN. For the first time in this area of study, we extend the common SIR (susceptible, infectious, recovered) model to a SEIR (susceptible, exposed, infectious, recovered) model, where the state 'E' helps in modelling the time-dependent effect of different inventory levels to preserve operations. This paper's practical value lies in offering a way for professionals to estimate the benefit coming from the investment in higher inventory levels, towards a choice that balances resilience and efficiency. On the theoretical side, we show that increasing inventory levels is more effective in SNs corresponding to scale-free network type (closer to automotive industry), compared to SNs corresponding to small-world type (typical of electronics industry).

Parallel Sessions 8.3	Time: 17:30 - 18:30	Room: Radix

Human-centred Manufacturing and Logistics Systems Design and Management for the Operator 5.0 - Part 1

Chiara Cimini, and Tamas Ruppert

Exploring the cognitive workload assessment according to human-centric principles in Industry 5.0

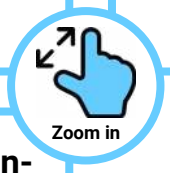
Ahmadreza Nadaffard, Ludovica Maria Oliveri, Diego D'Urso, Francesco Facchini, and Claudio Sassanelli

Industry 4.0 and 5.0 paradigms have been crucial for companies in employing digital technologies as an ally for men to free them from dangerous and routine tasks in favour of higher value tasks, putting humans at the centre of the organization as the decision maker. However, on the one hand, the new industrial systems shift to new tasks requiring more 'cognitive' than 'physical' efforts; on the other hand, the approaches to assess the cognitive workload and ensure the physical well-being of the operators are far to be considered easily applicable. For this reason, this research reveals current research trajectories and explores the cognitive workload using subjective and objective indicators. The discussion highlights cognitive ergonomics and advocates for a harmonious balance between human and machine capabilities. It identifies factors contributing to cognitive overload in manufacturing and maps their interconnections. The analysis of recent research trends reveals a growing adoption of new approaches requiring the adoption of physiological measurements (e.g., electrocardiogram (ECG), electroencephalography (EEG), Electromyography (EMG), etc.). Finally, this investigation offers insights into future research directions, urging a nuanced exploration of industrial activities and addressing cognitive workload across organisational layers in the context of Industry 5.0.

A Meta-Heuristic Approach for Industry 5.0 Assembly Line Balancing and Scheduling with Human-Robot Collaboration

Jingyue Zhang, Jinshu Zhou, and Shigeru Fujimura

Throughout the development of Industry 5.0 towards a paradigm prioritizing human-centricity and sustainability, the potential of assembly lines with human-robot collaboration (HRC) is substantial. In HRC environments, human and robot operators share the workplace and can perform tasks simultaneously and collaboratively, amplifying work efficiency and operators' welfare. This research investigates solutions to the assembly line balancing problem (ALBP) with HRC, where multiple human and robot operators work together. Using an adaptive simulated annealing (SA) framework for addressing ALBP with HRC, two innovative mechanisms are introduced—a new fitness value calculation method for roulette wheel selection and a pioneering heuristic approach. These mechanisms are devised to establish an innovative meta-heuristic approach based on SA for enhancing task allocation and resource management, improving productivity and operators' well-being through strategic workload balancing between human and robot operators, and minimizing cycle times and the total number of operators required. The computational results using actual production data show that these mechanisms significantly enhance the solution quality, particularly in the large-size case study involving collaboration between multiple humans and robots in each workstation.



Game-based design of a human-machine collaboration monitoring system

Mónika Gugolya, Tibor Medvegy, János Abonyi, and Tamas Ruppert

In a human-machine collaboration scenario, identifying a specific use case can be challenging due to the wide range of potential applications and interactions. Additionally, effective monitoring of the behavior of both human and machine agents during this collaboration poses significant challenges. The developed game-based process enables the analysis of the behaviours, leading to improved efficiency and collaboration. Indicators such as agent utilization and waiting times serve as valuable metrics to represent the quality of collaboration. This paper presents a setting in the Industry 5.0 laboratory, where monitoring and evaluation of humans and robots is possible. An experimental design is described and executed based on the developed game-based scenario, and exploratory analyses are performed based on the measured data.

Parallel Sessions 8.4	Time: 17:30 - 18:30	Room: Vulcanus

Transforming Engineer-to-Order Projects, Supply Chains, and Systems in Turbulent Times

Erlend Alfnes, and Jo Wessel Strandhagen

Exploring the Hydrogen Transition within the Maritime Value Chains

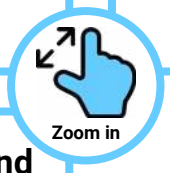
Francesca Bianchi, Monica Rossi, Margherita Pero, and Erlend Alfnes

The maritime industry is experiencing a transition towards the adoption of sustainable alternatives to traditional fossil fuels. The focus is on hydrogen due to its emergence as a feasible solution to the problem of pollution across the industry. The context comprises four value chains: those pertaining to the design, production, and management of fuel, ships and infrastructure (i.e., port and bunkering facilities); as well as the value chain associated with maritime operations (i.e., sea voyage between two ports). To successfully introduce hydrogen in maritime operations, the industry must be aligned in terms of the design and management of fuel, ships and infrastructure to accommodate the necessary changes. The study investigates the relationships within and between value chains, which can either support or hinder the transition. To this aim, a systematic literature review is performed. The analysis of 42 articles provides insights at the intersection of these value chains. The study identifies the decision variables that will have implications on the industry at large, including the storage form of the fuel and related requirements, the design of the ship and its fuel consumption, and the availability of suitable supporting infrastructure. Finally, the aim is to examine current research trends, highlight any shortcomings, and identify future research directions.

Application of Circular strategies for ETO products

Jenny Bäckstrand, and Malin Löfving

The circular economy (CE) concept seeks to minimize resource input, waste generation, emissions, and energy waste by slowing, narrowing, and closing ma-terial and energy cycles. Various circular strategies exist to reduce the consump-tion of virgin materials and minimize waste production. These strategies, often re-ferred to as "Rs" (e.g., Reduce, Reuse, Recycling, etc.) or R-frameworks can be described as different strategies to transition from a linear model to CE. The R-frameworks encompasses a range of options aimed at preserving the value of re-sources within the system. Even though there exists an abundance of literature about CE and the Rs, we have neither found a common definition of R-frameworks, nor a distinct adaptation of the Rs for an ETO context. The purpose of the paper is to explore how circular strategies can be applied to ETO products. To fulfil this purpose, illustrative cases are used to explore the application of cir-cular strategies, operationalized by R-frameworks, in two different ETO-contexts.



Yard Logistics: Framework and Classification of Yard Types

Jo Wessel Strandhagen, Marco Semini, and Erlend Alfnes

For shipyards and offshore construction yards delivering highly customized and complex products via an engineer-to-order (ETO) manufacturing approach, the importance of logistics performance is increasing. This is occurring because of lower profit margins and more challenging market environments, especially in the Norwegian yard industry. However, yard logistics has not yet received adequate academic attention, and there is a lack of knowledge on how to address the current need for more cost-efficient logistics at yards. Therefore, this paper aims to develop and structure knowledge on yard logistics. Via a multiple case study of eight Norwegian yards, this paper builds on empirical evidence to establish a definition and description of yards as logistics systems in ETO manufacturing. Specifically, the paper outlines the constituents and main activities of yard logistics and describes the key characteristics of yard logistics. Furthermore, a classification model is developed to differentiate between the logistics requirements of three main types of yards: fabrication yards, outfitting yards, and service yards. This classification helps in understanding the specific logistics needs and challenges faced by different types of yards, contributing to the academic literature and providing practical insights for practitioners to enhance yard logistics performance.

Wednesday
11 September 2024

Presentations

Parallel Sessions 9.1

Mechanism Design for Smart and Sustainable Supply Chains - Part 1

Hajime Mizuyama, and Nariaki Nishino

Utilizing the Shapley Value to Measure Individual Productivity in the Service Industry

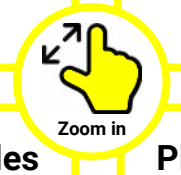
Sinndy Dayana Rico Lugo, Di Wu, and Nariaki Nishino

Measuring productivity, particularly at the individual employee level, has significant implications for organizational success, such as the standardization and guidance of employee behavior. Although various statistical methods have been applied to measure overall productivity, an alternative approach that considers intricate individual-organizational relationships and data availability to develop a robust measurement model is required. To address this gap, this study adopts the Shapley value concept from cooperative game theory to quantify individual productivity in the service industry. By treating the contribution to hourly revenue as the expected marginal contribution of each employee, two methods are proposed for the different data structures available. Through simulations, these methods are compared with other statistical methods. The results indicate the feasibility and efficacy of the Shapley value approach for accurately measuring individual productivity with satisfactory levels of accuracy, stability, and practicality.

A two-stage stochastic programming approach for energy-oriented lot-sizing

Ruiwen Liao, Franco Quezada, Céline Gicquel, and Safia Kedad Sidhoum

We consider an industrial plant equipped with an on-site power generation system based on intermittent renewable energy. We investigate the problem of simultaneously planning the industrial production and the energy supply in this plant on a short-therm horizon. We propose to handle the resulting energy-oriented lot-sizing problem by a two-stage scenario-based stochastic programming approach. We discuss two alternative models differing with respect to when the decision on the production quantities is made. Preliminary computational results aimed at assessing the value of the stochastic solution are provided for both models.



Ensuring Fruits and Vegetables Freshness in Sustainable Agricultural Supply Chain Networks: A Deep Learning Approach

Youness Bahaddou, Lahcen Tamym, and Lyes Benyoucef

Ensuring fruits and vegetables' freshness within a sustainable agricultural supply chain network (SASCN) is a critical and multifaceted challenge. This demands comprehensive solutions that integrate new technologies, sustainability philosophy, and effective management practices, to name a few. In this regard, computer vision (CV) and machine learning/deep learning (ML/DL) have increasingly been utilized in various sustainable agricultural areas, demonstrating significant efficacy in image analysis and processing. To this end, this research study proposes a novel approach leveraging advanced Deep learning techniques, including convolutional neural network (CNN) for fruit and vegetable quality detection and assessment throughout a SASCN. Therefore, an approach based on CNN is developed, utilizing a varied dataset that includes several types of fruit like Apples, Oranges, Bananas, and Grapes, alongside a single type of vegetable, namely Bitter-gourd. Notably, the proposed approach takes into consideration criteria, namely sustainability, and quality management thereby facilitating a holistic approach to fruit and vegetable quality control. The significant finding results in this study demonstrate the applicability of the developed approach for SASCN. After conducting thorough experimentation and assessment, the effectiveness of the developed approach attained an accuracy rate of 98.39%, indicating its high performance

Planning And Optimising Value Chains In Production Networks Of MSEs: A Lightweight Planner for Parallel Processes

Emad Aghajanzadeh, Julia Christina Markert, Matthias Kerzel, Stephanie von Riegen, Pascal Krenz, Lothar Hotz, and Jens P. Wulfsberg

With increasingly automated production and global competition, pricing pressure on micro, small and medium-sized enterprises (SME) from the trade sector is increasing. Cooperation with other enterprises could be part of the solution to allow them to continue providing their services in the form of made-to-order, customised products. With new challenges and changing circumstances, applying modern Information and Communication Technology and AI (Artificial Intelligence) to local production in networks could provide valuable opportunities. The construction of value chains is a complex planning problem with partial parallelism, as companies can work independently and in parallel, but are also often dependent on precursors from previous production steps. Utilising this partial parallelism is essential for finding production plans with a short duration. While heuristically guided planners can optimise for such a criterion, selecting a value chain is a multifactorial optimisation problem. Besides total production time, aspects like cost or transport can be significant. Moreover, if this choice is up to customers, they will require a quick, interactive generation of plans according to their preferences. A graph-planning-based approach for interactive multifactorial optimisation is presented. The approach is demonstrated and evaluated on examples from the production domain.

Parallel Sessions 9.2

Optimization - Part 1

Saadettin Erhan Kesen, and Hyeongoo Pyeon

A Cost Effective Two-step Exploration for Constrained Two-dimensional Packing Problems

Hyeongoo Pyeon, and SookYoung Son

A combinatorial optimization problem, an NP-hard challenge, aims to find an optimal solution within a discrete search space and it has been applied in diverse industries. However, it is common to have more various constraints in applying the optimization problem in a practical use-case. And as the search space expands, the problem becomes much more complicated due to the addition of various constraints. In order to address this issue, this paper presents a new methodology that efficiently solves two-dimensional bin packing problems with numerous constraints. We suggest a two-step exploration technique consisting of combination and permutation, and apply it to a practical design of LNG vessels. The proposed methodology not only enhances efficiency in search time and space but also enables finding global optimal solutions without additional exploration. As a result, we confirm a remarkable improvement in time and spatial efficiency compared to brute-force global searches. The methodology proposed in this paper is expected to lead to great technological progress in solving the combinatorial optimization problem.

Energy Conscious Bi-Objective Job Shop Scheduling: A New Formulation and Augmented ε-Constraint Method

Saadettin Erhan Kesen, and S. Hocine Bouzegag

This paper addresses a job shop scheduling problem in which machines can operate at varying speeds and different energy efficient strategies known as speed scaling and switching on/off are incorporated as well. When a machine runs at high-speed, the amount of time to complete the job shortens but energy consumed by the machine increases. Selection of different speed modes of machines for different jobs (i.e. speed scaling) generates compromise solutions. To save energy further, one must decide whether to shut down the machine during idle periods of consecutive jobs. One option is to turn off the machine whenever the idle period occurs regardless of its duration, which may result in machine breakdown due to excessive opening and closing. Alternatively, a threshold or time limit can be determined below which the machine is kept in standby mode by consuming very little energy. We aim to minimize two conflicting objectives, energy consumption resulting from usage while the machine runs at a particular speed or in standby state and total tardiness emanating from late completions. To this end, we developed a MILP formulation for the problem and Augmented ε-Constraint (Augmecon) method is implemented to find pareto optimal solutions. The experimental result reveals that energy consumption and total tardiness ob-jectives are conflicting. Based on payoff table, while the total energy consumed is 25000, total tardiness is 270. When energy consumption increases to 32186, total tardiness reduces to 36. Between the two, Augmented ε-Constraint (Augmecon) method provides non-dominated optimal solutions based on 11 grid points.

Routing heuristics for in-house transportation in assembly systems

Ebenezer Olatunde Adenipekun, Veronique Limère, and Nico André Schmid

This research addresses routing challenges in high-variety mass customization environments, focusing on in-house transportation problems involving traversal between supermarket cells and consecutive assembly stations. Supermarket cells are organized separately from assembly stations in parallel rows, each cell having a designated pickup point and each assembly station a drop-off point. The routing problem aims to establish an efficient path, starting from the depot and visiting all pickup and drop-off points exactly once before returning. This study introduces a range of heuristic methodologies tailored to address the problem. These heuristics, such as nearest neighbor, S-shape, modified S-shape, and combined heuristics, are characterized by practical implementability, offering practitioners defined guided rules to navigate the shop floor. Artificial problem instances of varying sizes, characterized by the number of cells and pickup/drop-off points, are analyzed, comparing heuristic performance against an optimal benchmark solution. Results indicate that heuristics perform better in larger problem sizes, particularly with 100 rows, showing average gaps below 11.48% and 1.02% for 7-row and 100-row instances, respectively.

A Flexible Job Shop Scheduling Problem Involving Reconfigurable Machine Tools under Industry 5.0

Hessam Bakhshi-Khaniki, Reza Tavakkoli-Moghaddam, Zdenek Hanzalek, and Behdin Vahedi-Nouri

The rise of Industry 5.0 has introduced new demands for manufacturing companies, requiring a shift in how production schedules are managed to address human-centered, environmental, and economic goals comprehensively. The flexible job shop scheduling problem (FJSSP), which involves processing operations on various capable machines, accurately reflects the complexities of modern manufacturing settings. This paper investigates the FJSSP involving re-configurable machine tools with configuration-dependent setup times, while integrating human aspects like worker assignments, moving time, and rest periods, as well as minimizing total energy consumption. A mixed-integer programming (MIP) model is developed to simultaneously optimize these objectives. The model determines the assignment of operations to machines, workers, and configurations while sequencing operations, scheduling worker movements, and respecting rest periods, and minimizing overall energy consumption. Given the NP-hard nature of the FJSSP with worker assignments and reconfigurable tools, a memetic algorithm (MA) is proposed. This meta-heuristic evolutionary algorithm features a three-layer chromosome encoding method, specialized crossover and mutation strategies, and neighborhood search mechanisms to enhance solution quality and diversity. Comparisons of MA with MIP and genetic algorithms (GA) on benchmark instances demonstrate the MA's efficiency and effectiveness, particularly for larger problem instances where MIP becomes impractical. This research paves the way for sustainable and resilient production schedules tailored for the factory of the future under the Industry 5.0 paradigm. The work bridges a crucial gap in current literature by integrating worker and environmental impact into the FJSSP with reconfigurable machine models.

Parallel Sessions 9.3

Human-centred Manufacturing and Logistics Systems Design and Management for the Operator 5.0 - Part 2

Chiara Cimini, and Alexandros Bousdekis

Assessing Trustworthy Artificial Intelligence of Voice-enabled Intelligent Assistants for the Operator 5.0

Alexandros Bousdekis, Gregoris Mentzas, Dimitris Apostolou, and Stefan Wellsandt

The concept of Trustworthy Artificial Intelligence (TAI) focuses on the establishment of trust in AI systems' development, deployment, and use. In this realm, the European Commission (EC) developed the Assessment List for Trustworthy Artificial Intelligence (ALTAI) in order to enable the assessment of trustworthiness in the AI systems under development. Since this is an emerging topic, there is little evidence on how to apply ALTAI. In this paper, we pre-sent the application of ALTAI on a Digital Intelligent Assistant (DIA) for manufacturing. In this way, we aim at contributing to the enrichment of ALTAI ap-plications and to the drawing of remarks regarding its applicability to diverse domains. We also discuss our responses to the ALTAI questionnaire, and pre-sent the score and the recommendations derived from the ALTAI web application.

A Bibliometric Perspective of Integrating Labor Flexibility in Workload Control

Alireza Ahmadi, Alessandra Cantini, and Alberto Portioli Staudacher

In an era assessed by quick technological advancement and shifting work paradigms, the integration of labor flexibility within Workload Control (WLC) systems presents a critical yet underexplored facet of industrial operation. This research embarks on a comprehensive bibliometric and systematic literature network analysis crossing a decade of studies from 2014 to 2024, uncovering pivotal contributions and identifying prevalent themes in labor flexibility and WLC. Although our inquiry reveals an intensifying interest in this field, particu-larly during the COVID-19 pandemic, it discloses a noticeable research shortfall in empirical explorations of labor flexibility's role within various order release methodologies. Addressing this gap, the study brings to light the growing im-portance of human dynamics, such as learning curves and worker heterogeneity, in optimizing WLC. Synthesizing the most significant scholarly works, the paper points out the urgency of adopting cross-disciplinary approaches to enrich future research attempts.

Experimentation and evaluation of the usability of an AR-driven zero defect manufacturing solution in a real life complex assembly setting

Joao Soares, Jerome Martins, Emrah Arica, Robert Schmitt, Jochen Wacker, Christoph Rettig, Daryl Powell, and Manuel Oliveira

This paper reports the outcomes of a case study on evaluating the usability of AR-driven quality control solution conducted in real life production setting with highly complex, high value production characteristics. The AR solution has been evaluated by the production personnel from every organizational level, with main emphasis given to operators and process engineers. The results clearly indicate a significant usability of the solution in avoiding the quality defects in the assembly line driven by manual operations.

Parallel Sessions 9.4

New Horizons for Intelligent Manufacturing Systems with IoT, AI, and Digital Twins - Part 1

Anna Presciuttini, and Jiayi Song

Dynamic pricing for fashion supply chain with blockchain supported value authentication

Wenjie Wang, Jiayi Song, and Yazhou Liu

The fashion industry is facing a challenge in pricing seasonal fashion products. Our study explores the dynamic pricing strategy for fashion supply chain that blockchain technology is employed to enhance fashionably designed value perceived by customers and identify heterogeneous fashion-sensitive customers. We propose pricing models on game theory in the presence of blockchain supported value authentication. Our research indicates that blockchain adoption could enhance the perceived fashion value of customers and further increase the customers' willingness to buy and consequently profit. We compared basic priding (SF) and blockchain common pricing (CP) strategies that heterogeneous fashion-sensitive customers are differentiated by blockchain driven fashion value authentication data. Our results demonstrate that the equilibrium price in blockchain pricing model CP is higher than basic SF. And, the blockchain could increase the expected profit of fashion supply chains.

An Explorative Study of AI Applications in Composite Material Extrusion Additive Manufacturing

Austin Harper, and Thorsten Wuest

Additive Manufacturing (AM) is on the forefront of innovative advance manufacturing techniques leveraging Artificial Intelligence (AI) and Ma-chine Learning (ML) to improve processing capabilities. This study was conducted to i) survey the current state of the art for AI/ML applications within Material Extrusion Additive Manufacturing (MEX-AM) and ii) study the intersection of AI applications and use of Carbon Fiber-Reinforced Polymers (CFRP) as a MEX-AM material. It was found that while discontinuous CFRPs are featured in several experimental studies, there was a noticeable lack of research involving continuous CFRPs among the collected research. Additionally, it was found that the most common ML Solution for quality Problems in MEX-AM was the Artificial Neural Network Feed Forward Supervised Learning Back Propagation (ANN-FFNN-SL-BPN) Solution.

Explainable Artificial Intelligence in Manufacturing Operations: a bibliometric analysis

Anna Presciuttini, Alessandra Cantini, and Alberto Portioli-Staudacher

This paper presents a bibliometric analysis of explainable artificial in-telligence (XAI) within the manufacturing sector, with a focus on the critical ar-eas of quality, maintenance, and production. Despite the increasing integration of XAI in industrial applications, a bibliometric exploration of its impact across these specific dimensions remains uncharted. Our study fills this gap by employ-ing bibliometric methods to map the landscape of XAI research in manufacturing, analyzing publication patterns and thematic evolutions. Understanding this land-scape is crucial, as it not only highlights the current state and trajectory of XAI applications in manufacturing but also identifies key areas where further innova-tion and investigation can significantly enhance efficiency, transparency, and de-cision-making processes in the industry. Utilizing the Bibliometrix R-package and data from the Scopus database, we analyze 109 publications from 2019 to 2024. We chart the intellectual trajectory of XAI, delving into predominant themes and observing a research progression from foundational machine learning to its sophisticated applications, culminating in Industry 4.0 innovations. The analysis reveals an academic landscape where explainability is increasingly in-tertwined with the technological advances of smart manufacturing, spotlighting key topics and their evolution that reflect the field's dynamic nature. This inves-tigation offers a novel lens on the bibliometric trends shaping the development of transparent, intelligent systems within the manufacturing sector.

Pre-Post Analysis on Multi-Skill Development using Flow Line Data at Expressway Service Area Facilities

Takeshi Kurata, Akihiro Sato, Satoki Ogiso, Karimu Kato, Satoshi Nakae, Ryosuke Ichikari, and Takeshi Shimmura

This paper mainly reports on a case study of pre-post analysis of multi-skill development at commercial facilities in an expressway service area, together with the results of grasping the current work patterns of the site. A work pat-tern analysis method that does not depend on site-specific detailed infor-mation using geospatial intelligence (GSI) technology was applied to the fa-cilities, and a matching analysis with site-specific detailed information was also conducted. In the facilities, 16 work patterns were extracted that are close to the actual situation. In addition, it was confirmed that the number of work areas that can be handled has increased as a result of multi-skill devel-opment. The median number of employees per day was reduced by one after multi-skill development, and its standard deviation was also reduced. This implication is that the site became more flexible to handle daily tasks. In contrast, walking distances and work hours per employee increased. Further improvement in efficiency and automation will be desirable to absorb the re-duction impact in the number of employees without increasing the burden on each individual. In this case study, the analysis method developed for a manufacturing line was applied to the service site. This provided a prelimi-nary validation of the versatility of this analysis method and its applicability to larger sites.

Parallel Sessions 9.5

Applications of artificial intelligence in manufacturing - Part 1

Rida Kheirallah, and Torsten Munkelt

Anomaly Detection in a Production Line: Statistical Learning Approach and Industrial Application

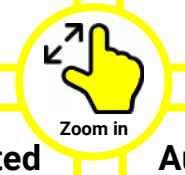
Rida Kheirallah, Anis Hoayek, Frederic Grimaud, Mireille Batton-Hubert, and Patrick Burlat

This paper explores industrial engineering, particularly focusing on discrete pro-cesses and emphasizing real-time control of production lines within these pro-cesses. A critical component of this control involves the incorporation of a dash-board system, essential for providing workshop managers with valuable insights into the estimated time required for each Production Order (PO) to progress through the remaining stations in the production chain. The key contribution of this work lies in the conception and development of a mathematical model applied to the dashboard system, capable of detecting anomalies within the production line, which are defined as deviations from expected timeframes. Constructed us-ing statistical learning techniques and information theory, the model can be inte-grated within the dashboard framework, offering prompt identification of anoma-lies within the production line and ensuring optimal performance and efficiency of the production process. The research offers practical solutions for enhancing productivity and streamlining operations in discrete manufacturing environments.

Leveraging LLMs for Information Extraction in Manufacturing

Marvin Matthes, Oliver Guhr, Martin Krockert, and Torsten Munkelt

In this paper, we present an approach using open-source Large Language Models (LLMs) for structuring free-text fields in the context of manufacturing. Our process involves three main steps: (1) creating prompts that extract information from free text fields, (2) converting the extracted information into a structured format accessible to computational analysis, and (3) evaluate the accuracy of the extraction by comparing the structured output with a predefined ground truth. We present the approach using a case from an actual manufacturer: We apply the process to texts from free text fields containing problems and solutions from quality control. Using LLMs, we extract quality problems and their solutions from the text, cluster the quality problems and identify common quality issues. Our findings demonstrate the potential of LLMs to automate knowledge extraction and the time-consuming manual pre-processing of text necessary for subsequent analytics and machine learning.



Development of Automated Negotiation Models for Suppliers using Reinforcement Learning

Ga Hyun Lee, Byunghun Song, Jieun Jung, and Hyun Woo Jeon

During a negotiating process in the supply chain, the negotiating parties try to maximize their interests while presenting a reasonable proposal that the counterpart may accept. Human negotiators, however, can have difficulties in making the optimal negotiation proposal or decision due to various limitations related to time, cost, and information processing capabilities. To deal with these issues, this study proposes artificial intelligence-based models to automate the negotiation process for a supplier in the supply chain. Specifically, we focus on the sell-side perspective as this area has not been studied comprehensively. To deal with the insufficient amount of data, we generate data on quantity (Q), price (P), and delivery lead time (D) by analyzing the correlation among these three variables from the available real transaction data. Then, more than 23,000 negotiation episodes between a buyer and a seller are simulated with correlated Q, P, and D. For learning the optimal negotiating strategy through simulated episodes, we apply the reinforcement learning models based on the Q-learning algorithm. We present two negotiation models: (i) a P negotiation model dependent on Q and (ii) a P negotiation model dependent on D. Our results show that the proposed structure of the automated negotiation model with correlated Q, P, and D can be applied to various negotiation environments by helping sell-side agents.

Autonomous Vehicles: Technological Evolution and Obstacles to Implementation from a Brazilian Perspective

Daniele dos Santos Ramos Xavier, João Gilberto Mendes dos Reis, Daniel Laurentino de Jesus Xavier, and Gabriel Santos Rodrigues

Autonomous vehicles have been announced as innovative solutions for transport with the potential for changes in the transport of cargo and passengers. The ob-jective of this paper is to analyze the challenges of vehicle automation adoption considering an analysis in the Brazilian scenario. To do so, a literature review was conducted, and the implications were verified in the light of the Brazilian case. The results suggest that the country has great potential to benefit from the implementation of autonomous vehicles since it has a large number of traffic ac-cidents caused by human error, such as distraction, tiredness, and recklessness, among others. However, the literature indicated that the barriers to the implemen-tation of autonomous cars refer to; the need for improvements in obstacle detec-tion by autonomous vehicles; users' perception regarding the adoption of this technology; questions about the interaction between pedestrians and drivers; cost competitiveness of vehicles; as well as the need of improvement in road safety and reduction of accidents.

Parallel Sessions 9.6

Time: 08:30 - 10:50

Room: Ventus

Digital Track - Part 1

Emanuel Bengtsson, and Per Solibakke

Link: https://eu02web.zoom-x.de/j/66235628809?pwd=JVbbDG6hrKT5G8kI0eoFP5KrMtyTrl.1

Sustainability Evaluation of Electronic Components: A Case Study of a Swedish Temperature-Sensing Solutions Manufacturer

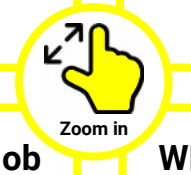
Trupti Borade, Zuhara Zemke Chavez, and Emanuel Bengtsson

The electronic industry faces increasing pressure to enhance product sustainability across the supply chain. Understanding the sustainability impact of electronic devices is vital for informed decision-making and meeting customer demands for eco-friendly products among growing environmental concerns and regulatory pressures. This paper evaluates the sustainability impact of a Swedish electronic component manufacturer, TSS AB, specializing in temperature-sensing solutions, considering both the company's and their client's perspectives. Employing a life cycle assessment (LCA) and LCA software tools, we comprehensively analyze environmental impacts. Through a cradle-to-grave assessment, we evaluate production processes, reverse logistics, refurbishment, reuse, and disposal, identifying hotspots for improvement. Additionally, we explore the influence of regulatory frameworks on incentivizing sustainable product development. Our findings contribute to the electronics sector's growing emphasis on sustainability, offering insights for companies aiming for net-zero emissions and circular product lifecycles.

Developing a Robust Multi-objective Optimization Model for Reverse Logistics of Electric Vehicle Batteries

Roozbeh Yaghoubi, Aysan Mahboubi, Mina kazemi miyangaskary, and Samira Keivanpour

In response to the damaging impacts of greenhouse gas emissions, Electric Vehicles (EVs) have emerged as a sustainable alternative. However, the rise of EVs creates the challenge of disposing numerous retired batteries. Hence, designing and optimizing Reverse Logistics (RL) for Electric Vehicles Batteries (EVBs) can be an effective approach. Existing uncertainties, however, cause a gap between the outputs of exact optimization models and real-world conditions. Addressing this, the present study develops a robust multi-objective optimization model that incorporates uncertainty such as the return rates of retired batteries. making it more applicable to real-world scenarios. This research compares the relative performances of deterministic and the proposed robust optimization models and validates the model by calculating violation probabilities within a robust optimization framework. This validation is conducted by allocating a specific budget for robustness to ensure that the model remains effective under various uncertain conditions. Additionally, this study explores adjusting the level of conservatism in decision-making by applying the price of robustness approach to manage conservatism in our decision-making process. Highlighting the importance of innovative sustain-able practices, this work offers a practical route for stakeholders to collaboratively mitigate the challenges associated with the end-of-life management of EV batteries, thus contributing to environmental sustainability and re-source efficiency in the BEV industry.



Integrated Dynamic Flexible Job Shop and AIV Scheduling: Multi-agent Deep Reinforcement Learning Approach Considering AIV Charging and Capacity Constraints

Arman Hosseini, Mohammad Feizabadi, and Zakaria Yahouni

Scheduling Automated Intelligent Vehicles (AIV) in Dynamic Flexible Job Shops is a challenging problem due to its high level of stochasticity and dynamic nature. Various heuristic and exact methods have proven effective when the complexity of the problem is relatively low. Moreover, in the past decade, machine learning algorithms, particularly reinforcement learning, have been applied to sophisticated scheduling tasks and demonstrated their efficiency in solving such problems. In this study, a hierarchical multi-agent deep reinforcement learning approach is proposed to address the integrated Dynamic Flexible Job Shop and AIV scheduling. Aimed at optimizing two objectives—total tardiness of jobs and total energy consumption of AIVs—the study takes into account the limitations of AIV transporters, such as charging consumption and loading capacity. To validate the proposed method, a case study is designed, and our approach is compared with a combination of existing heuristics. The method surpasses the heuristics and showcases robust scalability and generalization to increasingly complex problems.

WEEE Flow for Magnets

Kyriakos Bitsis, Alexandros Spanos, Konstantinos Kaparis, and George Zois

The recovery of Waste from Electrical and Electronic Equipment (WEEE) poses a significant challenge in the realm of solid waste management. With the global urgency to develop innovative disposal methods for WEEE, the creation of value chains that facilitate the recovery of valuable secondary raw materials is crucial. This paper explores a value network formulated specifically for the recovery and reuse of magnets from WEEE. To this direction, we introduce a holistic Mixed Integer Linear Programming (MILP) model, capable to optimise the material flows and the total cost incurred within the value network. Interestingly, our model integrates the proposed policies and directives of the European Commission (EC), aiming to devise a strategy that efficiently blends secondary and virgin magnetic materials to minimize total energy costs. We validate our modeling approach through a set of computational results, applying sensitivity analysis to assess the robustness of the proposed solutions under specific fluctuations in the energy cost. We conclude with the introduction of a two-stage stochastic model that extends the deterministic framework of the MILP, offering broader applicability and resilience in planning.

Parallel Sessions 9.6

Time: 08:30 - 10:50

Room: Ventus

Digital Track - Part 1

Emanuel Bengtsson, and Per Solibakke

Link: https://eu02web.zoom-x.de/j/66235628809?pwd=JVbbDG6hrKT5G8kI0eoFP5KrMtyTrl.1

Integrating AI with lean manufacturing in the context of industry 4.0/5.0: Current Trends and Applications

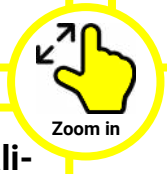
Aze-eddine Mohammed Boursali, Hichem Haddou Benderbal, and Mehdi Souier

This article presents an examination of the integration of Artificial Intelligence (AI) within lean manufacturing processes across the transformative phases of Industry 4.0 and Industry 5.0. The study focuses on how AI intersects with smart manufacturing, sustainability, metaheuristics, human factors, industry 4.0, and digitalization. It highlights the significant applications of AI in improving maintenance optimization, production efficiency, and quality improvement within lean manufacturing settings. The researchers conducted a swift overview of literature using the SCOPUS database to identify relevant articles through structured keyword searches. The results, presented in a comprehensive table, ad-vocate for more research on integrating sustainable and human-centered manufacturing practices to ensure that technological advancements benefit both productivity and the well-being of human workers.

A Digital Twin framework for Flexible Manufacturing System

Mokhtar Nizar Sid Lakhdar, Hichem Haddou Benderbal, and Mehdi Souier

In the era of digitalization and automatization, several technologies and manufacturing paradigms emerged and became popular and attracted the interest of both researchers and industrials. Flexible Manufacturing System (FMS) that is one of these paradigms is a production system able to switch between tasks easily making it adaptable to varying production needs. Furthermore, the concept of Digital Twin—a virtual counterpart of a tangible object— emerged and gained widespread popularity across diverse domains. Despite the focus of several research studies to develop these concepts, there is still a lack of work on an integrated and comprehensive framework that encompass a Digital Twin for Flexible Manufacturing System with a focus on smart manufacturing. Thus, this paper provides an attempt to propose a detailed Digital Twin framework for Flexible Manufacturing System with a focus on smart manufacturing and outlining various components and information.



Construction logistics conceptualization: a comprehensive framework and existing challenges

Uyen Ngo, Erlend Alfnes, Fabio Sgarbossa, and Marco Semini

Playing a key role in the nation's infrastructure development, the construction industry has been studied extensively for several decades. However, there is a need of systemizing knowledge on construction logistics – a crucial element in improving performance of the industry. Combining multiple case study and literature review methods, this research offers a comprehensive framework for construction logistics with construction logistics activities positioned throughout construction project phases. Additionally, it explores practical challenges in onsite and prefabricated construction logistics operation, through which offering valuable insights and suggesting improvement ideas for practitioners and policymakers in construction and similar Engineer-to-Order industries.

Parallel Sessions 10.1

Mechanism Design for Smart and Sustainable Supply Chains - Part 2

Hajime Mizuyama, and Ryuichiro Ishikawa

Mechanism Design as Collaborative Production Systems

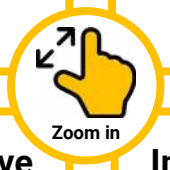
Ryuichiro Ishikawa, Hideyasu Karasawa, Sangjic Lee, Hajime Mizuyama, Nariaki Nishino, Kohei Nishiyama, Shigeru Ono, and Shota Suginouchi

This paper discusses a platform in which customer participation shapes product development in a collaborative production system such as LEGO IDEAS. By employing `mechanism design' developed in economics, our objective is to build a production system in which the platform takes into account the potential demands of the customers. In general, customers' potential needs are private information and it is difficult to gather adequate information even through marketing surveys. Therefore, we provide a framework in which the members of the platform propose their alternatives and let customers vote based on them. The choices offered by the platforms are necessarily limited to those that can be produced by their production systems. This allows for the collection of information on highly feasible products. In addition, a scoring rule is introduced to determine how well the suitability of the proposal matches the needs of the consumer, and multiple proposals are evaluated under that rule. Finally, we also propose a method to implement platform exploration and exploitation guidelines through natural language analysis of descriptive responses from customers.

Real traffic analysis around large-scale shopping mall using game theory

Mizuki Kobayashi, Ayato Kitadai, Uta Sato, Masanori Fujita, and Nariaki Nishino

This study quantitatively evaluates the impact of a new transportation policy, especially in areas surrounding large-scale shopping malls that suffer from chronic traffic congestion, from the perspective of game theory. This congestion not only impedes mobility and disrupts transportation services, but also leads people to lose opportunities, hinders the provision of commercial services by institutions, and reduces customer satisfaction. Therefore, this study focuses on the East Saitama area, Japan, where such problems are widespread and various construction projects to solve them are already underway. We regard this transportation planning as a form of mechanism design and game-theoretically formulated the traffic situation based on real data to derive an equilibrium solution. The results revealed that the new expressway has a traffic congestion mitigation effect. This cutting-edge study tackles the congestion problem from both empirical and theoretical perspectives, offering scientific insights that help policymakers determine the most effective measurement.



Partner Selection in Additive Manufacturing Networks

Xiaoli Chen, Yen Mai Thi, Julia Sprigode, Ralph Riedel, and Pierre Grzona

Considering the special features of additive manufacturing networks, and with the aim to realize a more efficient functionality of these networks, this work focuses on the issues of partner selection. Based on an in-depth litera-ture review encompassing more than 170 papers, 61 criteria clusters are listed as a general basis. A horizontal and vertical classification of criteria is further conducted, attempting to cover different situations of partner selec-tion in additive manufacturing networks. Here, economic, social, environ-mental and resilience perspectives are composed as the horizontal view. Key stages of additive manufacturing processes serve as the vertical one. A math-ematical algorithm model is further developed to facilitate partner matching. Within the algorithm model, motivations and their relative priorities are con-sidered. This work contributes to enhancing the reliability of partner selec-tion processes, which in the end improves the efficiency of networks' func-tionality.

Impact of Wholesale and Retail Limits on Supply Chain Decision Strategies: Insights from Serious Gaming Experiments

Mizuho Sato, and Hajime Mizuyama

Tight wholesale and retail limits are often considered as major contributors to food loss in Japan. However, relaxing these limits can have complex impli-cations because they are influenced by the operational decisions of key sup-ply chain actors, such as manufacturers and retailers. Game theory analysis offers a systematic approach to characterizing decision-making processes; however, defining a concise strategy space is crucial. To facilitate this, our study conducted an exploratory analysis using data from serious gaming ex-periments, specifically the "Milky Chain Game," to characterize player strat-egies. Our findings suggest that safety-stock levels and initial pricing are key strategies for both manufacturers and retailers. Additionally, eliminating wholesale limits increases manufacturers' stock levels, resulting in shorter milk carton lifespans for retailers, and potentially counteracting the intended effects of relaxation. Future research directions should include conducting deeper analyses with larger sample sizes.

Parallel Sessions 10.2

Optimization - Part 2

Reza Tavakkoli-Moghaddam, and Stavros Vatikiotis

Makespan minimisation in Hybrid Flexible Flowshops with buffers and machine-dependent transportation times

Stavros Vatikiotis, Ilias Mpourdakos, Dimitrios Papathanasiou, and Ioannis Mourtos

Hybrid Flexible Flowshop Scheduling (HFFS) is the problem where a set of jobs must be processed in a given sequence of stages and each stage has a set of (typically identical) parallel machines. The flexibility of HFFS allows a job to skip some stages. Modern production environments, e.g., assembly lines, exhibit additional structure, namely limited-capacity buffers and transportation times between subsequent stages, while the layout also imposes that such times are machine-to-machine dependent. We propose two formal models, namely a Mixed-Integer Linear Program (MILP) that incorporates transportation times but not buffers and a Constraint Program (CP) that handles both, given a sequence of all jobs per machine. This sequence is provided by the MILP or constructive heuristics or a Genetic Algorithm (GA). The scalability and performance of all methods is evaluated computationally on large-scale real-life instances of about 500 jobs on 15 stages with up to 5 machines per stage and 30 machines in total.

Multi-Depot Electric Vehicle Routing Problem with Half Open Routes and Rotations: A mathematical formulation

Hakan Erdeş, and Saadettin Erhan Kesen

The electrification spreads all around the world with the goal of global net zero emission, especially in transportation sector. As a natural consequence of this phenomenon, many countries and organizations announce their targets relating to the Electric Vehicles (EVs). Although shifting from fossil-fuel towards EVs is a major step forward, there are other precious actions to be taken, one of which is to integrate EVs into scientific studies along with the routing improvements. To this end, we introduce the Multi-Depot Electric Vehicle Routing Problem with Half-Open Routes and Rotations (MDEVRP-HORR) as an extension of the MDEVRP where the rotation refers to set of all routes assigned to an EV. EVs can be recharged at the depots or at the recharging stations along the route with full recharging strategy. The problem is formulated as a 0-1 mixed integer linear program (MILP) and existing procedures are applied to improve the model. The proposed model relaxes the restriction that the departure depot of the first route and arrival depot of the last route of an EV must be the same. It also avoids from creating dummy nodes for recharging stations and replenishment depots. We conducted experimental studies by using small-sized instances from the recent literature due to problem intractability. Out of 36 instances, results reveal that inclusion of half-open routes leads to a cost reduction for 20 instances. Besides, inclusion of both half-open rotations and half-open routes results in cost re-duction for 28 instances.

The Generalized One-to-One Pickup and Delivery Vehicle Routing Problem

Nurşah Yılmaz, and İsmail Karaoglan

Vehicle Routing Problem (VRP), one of the most important problems in the logistics industry, aims to find the most suitable route for vehicles that meet the demands of customers. VRP is examined under various variants, and one of these variants, the Pickup and Delivery Problem, deals with the pickup demands as well as the delivery demands of the customers. This problem is divided into three main categories according to demand type and route structure: one-to-many-to-one problems, many-to-many problems, and one-to-one problems. In one-to-many-to-one problems, there are goods at the depot to be delivered to customers as well as goods at customers to be carried back to the depot. In many-to-many problems, one node can be the origin or destination point for a good, and multiple nodes can be the origin or destination point for each good, while in one-to-one problems, there is a single origin and a single destination point for each unique demand. Within the scope of this study, a general case of one-to-one problems is introduced, in which multiple vehicles are allowed to leave the depot with goods and return to the depot with undeliverable goods, and a customer can be both a pickup and delivery node at the same time. A mathematical model is developed for the problem to obtain the optimal solution for the test instances. The model is tested on 45 randomly generated test instances. The results show that 40 out of 45 instances were solved using a commercial solver within one-hour computation time limit.

A Multi-objective Model in a Sustainable Manufacturing System under Reliable Constraints: An AUGMECON2VIKOR Method

Reza Shahabi-Shahmiri, Reza Tavakkoli-Moghaddam, Alexandre Dolgui, Mohammad Ghasemi, and Seyed Ali Mirnezami

Recognizing suitable manufacturing methods for goods can consider a crucial manufacturing task resulting in the optimization of activities. It has gained significance in the food industry owing to the distinct limitations and assump-tions posed by perishable as well as non-perishable goods in this issue. There-fore, this research presents a novel mathematical formulation based on knowledge discovery and an assignment model for the optimization of manu-facturing systems for perishable as well as non-perishable tailored to satisfy their unique features. In the proposed formulation, three objectives of mini-mizing the makespan, the production costs, and the energy consumption are considered. Two numerical examples considering both small and medium sizes are applied to appraise the performance of the AUGMECON2VIKOR method. The sensitivity analysis represents the positive reliable constraint impacts, in-fluencing objective functions.

Parallel Sessions 10.3

Human-centred Manufacturing and Logistics Systems Design and Management for the Operator 5.0 - Part 3

Chiara Cimini, and Tamas Ruppert

Enriching scene-graph generation with prior knowledge from work instruction

Zoltán Jeskó, Tuan-anh Tran, Gergely Halász, János Abonyi, and Tamas Ruppert

With the current focus on human resources in Industry 5.0, analysing the work movements of industrial operators is the important first step in optimising labour performance. Thanks to the popularity of camera sensors, vision-based Human Activity Recognition models have become useful engines for real-time monitoring tools, in which scene-graphs play an important role. Traditional scene-graph generation methods rely primarily on visual data for perception, neglecting a valuable source of process-oriented prior knowledge: the work instruction. Therefore, an extension of the scene-graph paradigm by integrating ground truth elaborated on elements from the work instruction is elaborated to complement and enhance the understanding of human activities in industrial environments, and improve the tracking capability with micro and repetitive movements. This conceptual paper discusses the basic design of this approach with potential applications in industrial environments, which is validated by a simulated use case of an electronic assembly process. Based on the proposed extension, the Human Activity Recognition model can be lightweight and robust. Further integration of multi-modal sensory inputs beyond visual cues, such as environmental and human-centric data, can enrich scene interpretation and provide a more comprehensive understanding of work behaviour, paving the way for more effective labour utilisation and improved productivity.

Designing augmented reality assistance systems for Operator 5.0 solutions in assembly

Chiara Cimini, Francesca Tria, Alexandra Lagorio, Tamas Ruppert, and Sandra Mattsson

Industry 5.0 emphasises how technology may benefit humans and marks a move towards a socio-technical paradigm. This study looks at how Augmented Reality (AR) can be integrated into human-centered smart manufacturing systems to improve operator performance, especially when it comes to assembly and disassembly work. Relevant AR applications in manufacturing are found through a methodical assessment of the literature, emphasising the necessity of human-centered design methodologies. The paper then offers basic recommendations for integrating AR systems into manual workstations in an efficient manner with the goal of enhancing operator productivity and welfare. The background, motivation and methods are discussed. The main findings include specific considerations for supporting the AR design in assembly, discussing the relevance of targeting group of users, choicing the suitable devices according to the usability and developing effective instructions.

A Study on Production Scheduling Methods for Ready-Made Meal Industries

Hinari Hamada, Fujii Nobutada, Shunsuke Watanabe, Soh Takehide, Ruriko Watanabe, Kohei Nakayama, Yuji Mishima, and Kazuo Yoshinaga

In ready-made meal industries, which are the focus of this study, maintaining freshness is just as important as meeting delivery deadlines due to the handling of fresh ingredients. To prevent deterioration in freshness, it is necessary to reduce the time from the start of processing to shipping. In this paper, a production scheduling method that simultaneously considers maintaining freshness and due date adherence, is proposed are verified the effectiveness of the proposed method through computational experiments.

Parallel Sessions 10.4

New Horizons for Intelligent Manufacturing Systems with IoT, AI, and Digital Twins - Part 2

Alexandros Bousdekis, and Alexander Albers

Human – Data Analytics Interaction through Voice Assistance in Electric Vehicle's Battery Testing

Mattheos Fikardos, Alexandros Bousdekis, Umair Haider, George Aristofanous, Katerina Lepenioti, Federica Mandreoli, Stefan Wellsandt, Enrico Taglini, and Gregoris Mentzas

Voice assistants, alternatively mentioned as conversational agents or Digital Intelligent Assistants (DIA), represent a new form of interaction between humans and machines, providing fast, intuitive, and potentially hands-free access to systems through voice-based interaction in order to increase the efficiency of certain activities. However, the literature has mainly focused on general applications of voice assistants in diverse industries. Their potential in manufacturing is underexplored, although the manufacturing sector is a key driver for employment and plays a critical role in economic growth. Further, enabling human workers to interact with data analytics insights through voice interfaces is key to realize a human-system symbiosis in an Industry 5.0 context. However, there is limited literature regarding the data analytics potential integrated to voice assistants and related implementations due to, among others, the challenges of translating analytical results into easy-to-understand information for humans. In this paper, we present a voice assistant integrated to data analytics functionalities in order to support human-machine interaction when there are data analytics insights that are communicated to the user in Electric Vehicle's (EV) battery testing use cases.

Information Modeling for Data-driven Digital Twin Simulation: Insights from Case Studies of Port Logistics and Urban Traffic Systems

Harry Lim, Hyoung Seok Kang, and Duck Young Kim

A digital twin creates virtual replicas of physical entities, enabling the simulation of changes over time to predict outcomes and reduce risks. Despite its significance, many organizations still face uncertainties about the information and methodologies required for digital twin development. Recent international standards, such as ISO 23247, provide a foundation for digital twin architecture, and data exchange in manufacturing. However, there's a need for clearer guidelines on simulation components to support decision-making beyond simple monitoring. Our study outlines essential elements and processes for implementing data-driven simulation models for digital twins, illustrated through case studies in port logistics and urban traffic systems. In further studies, we aim to advance the discussion on information modeling frameworks and methodologies to enable the efficient implementation of digital twins in manufacturing and beyond.

Lenses on Data: Toward an Application Perspective on Data in Manufacturing

Alexander Albers, and Torbjørn Netland

Data is becoming increasingly important in manufacturing, enabling visions like cyber-physical production systems and digital twins. However, companies still struggle to effectively leverage data to drive process improvements and productivity gains. One reason is that there are many implicit assumptions and perspectives on what data fundamentally represents. This paper explores five distinct lenses through which data can be viewed, drawing from the fields of information theory, information systems, accounting, management theory, and economics. While each lens offers valuable insights, we argue that manufacturing requires a more application-oriented understanding of data that accounts for the sociotechnical nature of factories. We discuss six key attributes of data from a manufacturing perspective, including cost, coverage, fidelity, timeliness, accuracy, and accessibility. We argue that rather than pursuing an all-encompassing digital replica, the focus of manufacturers should be on collecting just enough relevant data to enable specific manufacturing applications while prioritizing coverage of the entire shop floor.

Evaluating the Use of Blockchain-Enabled Federated Learning for Smart Manufacturing: A Bibliometric Review

Prince Waqas Khan, Khizar Abbas, and Thorsten Wuest

The combination of blockchain technology, federated learning, and smart manufacturing has gained significant interest due to its potential for data sharing, security, and collaborative learning in industrial environments. This article presents a bibliometric review that provides a thorough examination of the use of blockchain-enabled federated learning in the context of the Industrial Internet of Things and smart manufacturing. We performed a comprehensive literature search across multiple academic databases, including Scopus and Web of Science (WoS), using tailored search strings. After data preprocessing and duplication removal, a final set of 225 peer-reviewed journal articles was included for analysis. For the visualization, we have used VoSViewer and Python data science libraries. Bibliometric techniques, including publication trend analysis, author productivity analysis, journal impact assessment, and network visualizations, were employed to quantify and explore the research areas. The results revealed an upward trend in publications, with a surge in recent years, indicating growing interest in this domain. Influential authors, institutions, and countries contributing to the field were identified, shedding light on potential research collaborations and knowledge hubs. Additionally, we performed a content analysis to highlight emerging research themes, challenges, and future directions. To the best of our knowledge, this is the first bibliometric study that evaluates the use of blockchain-enabled federated learning for smart manufacturing.

Parallel Sessions 10.5

Applications of artificial intelligence in manufacturing - Part 2

Shailesh Tripathi, and Sascha Meckler

Comparison of bipartite graph community detection algorithms for reducing variant diversity in production planning and control

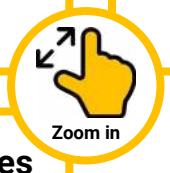
Shailesh Tripathi, Wolfgang Seiringer, Sonja Strasser, and Herbert Jodlbauer

In production planning and control, discrete-event simulation (DES) is commonly used to address optimization challenges. DES using {\it{simgen}} generally begins with data preprocessing, parameterization, and experiment design. However, due to the complexity of manufacturing environments, DES models require careful parameterization, with empirical experiments designed to ensure efficient execution. This parameterization involves optimizing parameter settings for different materials based on routing, bill-of-materials complexity, and other production process-related features. To achieve optimized parameterization within expected timeframes, reducing variant diversity to eliminate redundant materials is necessary by using data-driven approaches. In this study, to identify representative materials, a network-based approach with five community-detection algorithms is compared for their efficiency in execution time and efficient module detection by constructing bipartite networks of material and routing features for identifying similar material groups and representative materials. The results show that communities and subcommunities identify representative materials by significantly reducing the initial number of materials with a faster approach that can be used for DES parameterization.

Vibration-Based Operating Status Monitoring of a Production Line with Low-Cost IoT Devices

Sascha Meckler, Rene Dorsch, and Peter Filipp

Many production lines still in use today have been designed without provisions or machine interfaces for data recording and data analysis. An efficient solution for generating operation metrics for these brownfield lines is smart retrofitting with Internet of Things (IoT) devices. We present a cost-efficient, nonintrusive IoT solution for monitoring the operating status of modules of an assembly line based on the measured background vibrations. In contrast to existing solutions which often examine a single machine or process step, our solution monitors entire production modules with many moving components on a higher, business-focused level. The vibration is measured by a wireless network of low-cost IoT devices. A middleware software processes the sensor data for later analysis with unsupervised machine learning. Experiments at an assembly line have proven that low-cost IoT solutions are capable of identifying normal operation, state transitions, and standstill of production modules from the background vibrations. The monitoring of the actual operating status is necessary for deriving key indicators for business questions or maintenance optimization.



An Overview of Cloud-Based Services for Smart Production Plants

Auday Al-Dulaimy, Leo Hatvani, Moris Behnam, Anas Fattouh, and Koteshwar Chirumalla

Cloud computing is a game-changer model that opens new directions for modern manufacturing. It enables services and solutions that help improve the productivity and efficiency of smart production plants. The main objective of the paper is to provide a summary of the various cloud-based manufacturing services currently being offered to manufacturers or that could be offered in the future. Additionally, the paper aims to discuss the various enabling technologies used to support the integration of cloud manufacturing in the manufacturing industry. Furthermore, the paper categorizes the different services based on their functionalities and maps them to four levels of production such as plant level, production line level, machine level, and process level. The categorization of services and mapping them to appropriate levels in production can enhance efficiency and productivity in the manufacturing industry. The study advances the discussion on cloud-based manufacturing from the types of services and enabling technologies perspective.

Parallel Sessions 10.6

Time: 11:10 - 12:30

Room: Ventus

Digital Track - Part 2

Ali Fradi, and Egon Lüftenegger

Link: https://eu02web.zoom-x.de/j/66235628809?pwd=JVbbDG6hrKT5G8kI0eoFP5KrMtyTrl.1

Exploring the Intersection of Artificial Intelligence and Machine Learning in Supply Chain Management: A Structured Literature Review

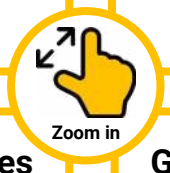
Sotiris P. Gayialis, Evripidis P. Kechagias, Nikolaos A. Panayiotou, Georgios A. Papadopoulos, and Achillefs Papaioannou

The purpose of this paper is to identify the contributions and applications of Artificial intelligence (AI) and Machine Learning (ML) algorithms to Supply Chain Management (SCM) through a systematic review of the existing literature. Scopus was the database used for the literature review and relevant papers were analyzed in depth to review conducted research and highlight future research directions in this specialized field. A structured selection process was followed to select the papers and provide an insight to the AI and ML techniques integration into the SCM practices. Also, four critical research questions were set. The selected papers were deeply analyzed both in a qualitative and a quantitative manner. The quantitative analysis involved performing numerical distribution analysis of publications as well as bibliometric analysis and network visualization. The qualitative analysis aimed to answer the research questions and provide valuable information for future research efforts. The research identified the most prevalent AI and ML techniques as well as the general research trends of AI and ML applications in SCM. Also, eight major SCM processes, that involve AI and ML techniques were identified and analyzed. Finally, the research revealed the tasks of SCM that have high potential for further development and improvement using AI.

Multi-Project Scheduling Problem with Limited Preemption and Ordinary Feeding Precedence Relations

Ali Fradi, and Maha Benali

Many companies operating in an Engineering-to-Order environment are under constant pressure to manage the complexity of production planning. This paper deals with the case study of a company offering highly customized products that are modular buildings. To support tactical production planning and capacity allocation, this paper formulates the production planning problem as a Preemptive Resource Constrained Multi-project Scheduling Problem and proposes two mathematical formulations to solve it. The first presented formulation performs preemption using continuous activity splitting whilst the second permits discontinuous energy distribution. With the presented formulations we aimed to curtail resultant makespans and delays of all set projects. Resource capacities are defined as accumulated weekly working hours of available and similar skills. We evaluated the performance of the proposed formulations, in terms of solving time and makespan, using three real-world datasets. Our findings indicate that the formulation using discontinuous energy allocation outperforms the formulation offering more control on the sub-activities.



Artificial Intelligence Reshapes Supply Chain and Lean: Key Insights and Challenges

Anne Zouggar, Kathryn Cormican, and Diego Ruiz-Hernandez

Smart manufacturing leverages various Industry 4.0 technologies to enhance the operational performance of manufacturing systems, strengthening their recon-figurability and resilience within Supply Chains (SC). Artificial Intelligence (AI) stands out as one of the most potent technologies driving these advance-ments, fundamentally reshaping SC behaviors. Concurrently, Lean production methodologies are employed to optimize manufacturing systems, synergizing with AI to reinforce technological efficiency. Recognizing the necessity of AI across diverse SC domains such as production, maintenance, logistics, supply, and quality, becomes imperative to comprehend its utility, applicability, and relevance. This paper tries to elucidate the role, limitations, and application framework of AI within Supply Chain Management (SCM), shedding light on its integration into contemporary SC paradigms. By updating existing knowledge on AI applications in SCM and sustaining Lean Processes, the au-thors address the evolving landscape of SC dynamics. Embracing this new era, the authors aim to delineate the boundaries of AI in SCM and articulate a framework for its prudent inclusion in the modern world. The Supply Chain Operations Reference (SCOR) model is utilized to contextualize the vast poten-tial of AI, opening a rapidly evolving collaborative network facilitated by AI applications and decision support tools.

Guiding Process Mining Projects with the IPMM Framework: A Case Study with a German Manufacturer

Egon Lüftenegger, and Florian Obersteiner

Process mining is a transformative approach that utilizes event data from various information systems to discover enhance performance, and ensure regulatory compliance of business processes. Bridging the theory-to-practice gap, particularly for newcomers, is a pressing concern. To tackle this issue, we developed our Integrative Process Mining Management (IPMM) framework consisting of a method and tools to offer companies a concise overview of existing process mining methods, their pros and cons, and alignment with the current maturity level. Within our method, we present our management tool: The Process Mining Maturity Level Cheat Sheet. This process mining management tool outlines potential objectives for each maturity level. The IPMM framework provides a structured solution. Our framework emphasizes the importance of customizing Process Mining techniques to match a company's maturity level. Finally, we apply our framework in a German manufacturing company.

Parallel Sessions 11.1

Mechanism Design for Smart and Sustainable Supply Chains - Part 3

Hajime Mizuyama, and Shota Suginouchi

Mechanism Design for Agricultural Machinery Sharing

Yumeto Mino, Shota Suginouchi, and Hajime Mizuyama

The decline in agriculture owing to the reduction in the number of farms, has been countered via the adoption of advanced technologies aimed at in-creasing scale. However, in Japan, despite the use of such technologies, the unique topographical features render scale-up difficult. To achieve high productivity in small and medium-sized farmers, effective farmers collabo-ration must be implemented. Agricultural machinery sharing (AMS) has at-tracted attention in this regard. Although top-down services for AMS are provided by large companies, there remain several small-scale but scattered niche demands, certain of which are solved via a bottom-up sharing practice under a prerequisite of trust between participating farmers. As the depend-ence on precarious trust renders the spreading of such a practice challenging, this study proposed an AMS mechanism for replacing trust with monetary incentives. Moreover, the impact of weather uncertainty on the machine use schedule was also considered. To cause the schedule to respond to uncer-tain weather in the ex-ante stage, the mechanism utilized certain rules. Three rules: order rule, release date rule, and period rule, were proposed and their characteristics were analyzed through computational experiments. The re-sults revealed that the order rule was heavily dependent on the participating farmers. Although the release date rule and period rule provided similar re-sults, the former facilitated farmers in using the machine more frequently and the latter tended to equalize the revenue of the farmers.

Balancing High Social Welfare and Short Waiting Times: Determining a Reasonable Buyout Price in Auction-Based Restaurant Reservation Systems

Shota Suginouchi, Shoma Kanesaka, and Hajime Mizuyama

This study proposes an auction-based dynamic reservation system, the "synthetic scheduling auction" (SSA), to maximize social welfare through restaurant services. Each potential customer group submits 3-tuple bids to the restaurant, including the meal starting time, meal selection, and number of people in the group. After receiving these bids, the restaurant offers a buyout price to the group. To calculate the buyout price, the restaurant conducts an auction with synthetic customer agents who intend to book the restaurant within the reservation period. These agents are generated based on the restaurant's past customer statistics data. The buyout price is the "expected nuisance fee" based on the money transfer function determined by the VCG mechanism applied for static auctions. By conducting an auction with synthetic customers, the restaurant determines the buyout price without waiting for actual future reservation applicants. Therefore, SSA achieves an increased social welfare than the First-Come-First-Served (FCFS) reservation system, current standard, and a decreased waiting time for each customer group compared with the static auction mechanism. Computer experiments were conducted on a fictitious restaurant to compare the social surplus and seat occupancy rates when the restaurant uses the SSA and FCFS system. The results demonstrate that the SSA is superior in both metrics, that is, social surplus and seat occupancy rates.

Managing Handling and Transport in Furniture E-commerce Shop using the Dropshipping Model

Miguel Renon, João Gilberto Mendes dos Reis, Kennya Vieira Queiroz, and Fabrício Henrique do Nascimento da Silva

The exponential growth of e-commerce, especially in the furniture and homeware sector, has been driven by the adoption of dropshipping. In this practice unitiza-tion on pallets plays a crucial role in optimizing logistics processes. This research aims to investigate and analyze the challenges and opportunities linked to the handling and transport in furniture and homeware e-commerce, using the drop-shipping model. A case study in a Furniture E-commerce was conducted. Through the proposed study, it was possible to identify all the critical loading and unloading points in a dropshipping system. In this way, this article proposes so-lutions to mitigate the problems and optimize the respective processes, through management systems and unitization of bulky items. Understanding the details of handling and transport in the e-commerce of furniture and homeware via drop-shipping allows companies to develop strategies to optimize operations, improve customer satisfaction, and remain competitive in the market.

Parallel Sessions 11.2	Time: 13:30 - 14:50	Room: Aqua

Intralogitics

Kasuni Vimasha Weerasinghe, and Elouan Blanchard

Dynamic multi-objective opti-state decision-making method for intermittent synchronized production operation system

Kai Zhang, Honglin Yi, Ting Qu, Meihua Zeng, Lin Ma, Congdong Li, and George Q. Huang

In the era of escalating customer demands for tailored products, advancements in intelligent manufacturing technologies and the proliferation of diverse production and operational models, production-logistics systems face heightened internal and external disruptions. This work contributes a novel dynamic mul-ti-objective opti-state decision-making framework and method to address the complex decision-making challenges that arise from such disruptions. It delves into the re-decision-making requirements for maintaining optimal state performance in production-logistics systems amidst disturbances, focusing on operational objectives. The proposed method employs intelligent algorithms for local sub-models, utilizing the gray target theory to determine the best dynamic multi-objective optimization strategy. To demonstrate its practicality, the method is instantiated as an intermittent synchronized production operation system, with a case study in the context of enterprises with intermittent production, validating the effectiveness of the proposed approach.

Planning the tasks of an autonomous mobile robot fleet for internal logistics of production systems

Elouan Blanchard, Cyrille Briand, Mohamed Amine Abdeljaouad, Gregoire Milliez, and Arthur Bit-Monnot

The problem of planning the activities of a fleet of autonomous mobile robots in the context of performing a production plan is tackled in this paper. Three kinds of tasks are considered: the ones related to supplying workstations with the components or tools that are used in the operations, the ones related to the evacuation of empty containers or garbage collecting, and the latter ones that aims at moving semi-finished production from workstations to others. This paper shows that the planning of these activities can be modeled homogeneously as a particular pickup-and-delivery problem with time windows. In order to solve the latter problem, we propose a greedy heuristic as well as mixed-integer linear programming approach. An illustration of the interest of the approach is provided in a production context, demonstrating its validity and highlighting its advantages and limitations..

Model-based system engineering approach to design customized puzzle-based movable rack systems

Kasuni Vimasha Weerasinghe, Fabio Sgarbossa, and Andrei Lobov

The Puzzle-Based Movable Rack (PBMR) system is a new type of warehouse storage system that combines the features of both Puzzle-based storage (PBS) systems and robotic mobile fulfillment (RMF) systems. Thanks to the partnership between Norwegian company Wheel.me and the NTNU Logis-tics 4.0 Lab, this system with a new configuration where racks can be moved using autonomous wheels was explored. The PBMR system has a compact configuration with few empty locations and the storage racks can be autonomously moved through the autonomous wheels. Various storage and movement policies are employed to optimize system performance, enhancing both density and throughput. To implement the proposed storage solution, we consider the PMBR system from an engineering-to-order (ETO) perspective. In this study, we investigate the design process of the PBMR system considering it as an ETO product with the support of a model-based system engineering approach. Utilizing methods and tools from the system engineering discipline facilitates defining warehouse functions, systems, and the necessary resources for system implementation. This enables comprehensive documentation of all stages of warehouse design. Furthermore, these ware-house models can seamlessly integrate with various analyses and existing domain knowledge, thereby bolstering warehouse design decisions. Further, There are the necessary technical and theoretical foundations in place for reliable PBMR design, which also offer insights into how the other ETO products and related system designs could be implemented.

Parallel Sessions 11.3

Modelling supply chain and production systems - Simulations

Lucas Alves, and Mingze Yuan

A Worker-Centric Order Release Method based on Workload Control: An Assessment by Simulation

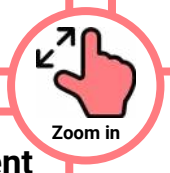
Lin Ma, Mingze Yuan, Ting Qu, Lei Liu, Kai Zhang, Congdong Li, and Matthias Thürer

This study presents a novel paradigm of production planning and control by in-troducing a worker-centric workload control order release approach, which is particularly suitable for the manufacturing shops involving robots and workers, such as the human-machine collaborative production system. Specifically, a production order in the real-life production process may consist of multiple operations. Some of these operations are exclusively performed by machines and others necessitating collaboration between workers and machines. This will make it more difficult for managers to balance the workload on the shop floor, even deteriorating the available capacity of workers and machines. Therefore, this study first classifies the production orders into two kinds of tasks (i.e., independent tasks and collaborative tasks) based on their processing attributes before holding them in a pre-shop pool. Subsequently, we give prior-ity to releasing the workload of collaborative tasks (i.e., triggered by the work-ers) and subsequently release independent tasks (i.e., triggered by the inde-pendent machines) to balance the workload across machines at the order re-lease stage. The experimental results demonstrate that prioritizing worker workload balance can significantly improve the shop performance in terms of throughput time and tardiness time. Furthermore, we observe that prioritizing workers' workload also mitigates tardiness typically associated with high load periods when expediting the processing of urgent orders. In other words, priori-tizing workers' workload to some extent diminishes the disparity between high load and low load periods due to this is conducive to avoiding premature idle or overload of small capacity resources, therefore leading to a more balanced workload on the manufacturing shops.

Dynamic Dispatching of DDMRP Replenishment Orders

Lucas Alves, Maha Benali, and Pierre Baptiste

The Demand Driven Material Requirements Planning (DDMRP) is a production control system originally tailored for the VUCA world. Despite research increasingly focusing on the dynamic aspects of this production control system, it has failed to address important execution aspects. This study bridges the literature gap by focusing on Demand Driven Planning and Execution, particularly the dispatching rules. The use of static dispatching rules, such as the one proposed in DDMRP, does not respond to the volatility and uncertainty of the VUCA world. Through the simulation of a six-machine flow shop, we investigate several dispatching rules to assess their impact on the system stability and service level. Our findings reveal that, when compared to a static dispatching rule, the use of a dynamic dispatching rule in the DDMRP execution significantly improves the service level and reduces the number of stockouts and the time to fulfill backorders.



Management of measuring equipment for quality assurance in manufacturing processes: a decision-making support system

Isabel Silva Lopes, Claudia Regina Pires, and Tiago Alão

This paper aims to present a decision-making support system for the efficient management of measuring equipment in Manufacturing plants, providing support for condition analysis and calibration interval definition, a missing functionality in current computerized systems. For the same equipment, ex-isting methods for defining the calibration/verification interval give very dif-ferent results. The proposed solution for management of measuring equip-ment includes a developed approach for the selection of the method that best suits the equipment, considering its characteristics and condition of use. Since unpredictable situations, such as falls, shocks or misuse can change the behavior of measuring equipment, an additional approach for unpredict-able behavior identification is included, using EWMA and I-MR charts. The approaches were developed and tested with data of measuring equipment of a cork company. This solution brings cost savings to companies since, by help-ing to adjust calibration or verification intervals, allows avoiding the use of inapt equipment for quality control of manufactured products.

Parallel Sessions 11.4

Modelling supply chain and production systems

Volodymyr Alieksieiev, and Sven-Vegard Buer

De-politicised in court: The interaction of democracy with innovation projects

Atle Martin Christiansen, Kenn-Steger Jensen, and Kenneth Vidskjold

This study explores the interaction of politics and innovation. We discuss how entrepreneurs and innovators face policies, legislation, governmental rules and public opinion when compiling innovation projects. This paper highlights the power of politics in a democracy, emphasising the principle of checks and bal-ances. We also touch upon the concept of deliberative democracy and how it should ideally function. Since the authors argue that excessive politicisation may hinder innovation, they seek to test this theory. The aim is to provide insight for overcoming undesired political influence, thereby helping those working on in-novation projects to lower or mitigate risk. This study underlines the need to un-derstand the implications of political leadership on innovation projects and statu-tory amendments. Further, it discusses the potential impact of political constraints on innovation, emphasising the need for strategies to influence policymakers ef-fectively. The authors not only acknowledge the existence and need for political leadership in a democratic society, but also are interested in understanding the implications of such leadership on innovation. A two-sample case study is con-ducted with mixed methods research. Literature reviews and interviews are com-bined with theory in an iterative process to test the following hypothesis: If gov-ernments and departments become too politicised this may impede innovation. Results from our two cases vindicate our assumption. This study encompasses the maritime and marine sectors, mainly within ports, transport and logistics.

Assembly Line Design for Industrialized Electrolyser Production

Sven-Vegard Buer, and Lars Skjelstad

The electrolyser industry is under rapid development, where manufacturing companies seek opportunities to develop industrialized solutions for electrolyser production. However, electrolyser production implies major logistical challenges related to for instance product characteristics (expensive and fragile components, rare materials), the stack assembly process (precise alignment of cells and pressure), the supply chain (immature, limited supplier base, quality issues, delivery constraints), and the production equipment (immature). Designing a high efficiency electrolyser assembly line is thus a challenging task. This paper presents results of a study with the aim to assess design alternatives for electrolyser stack assembly with focus on logistics and flow efficiency. Design elements such as the number and locations of buffers and quality inspection are considered. A discrete-event simulation model is developed and tested based on scenarios reflecting situations related to for instance poor quality yield of incoming components and equipment downtime. Data from an empirical case involving the design of a new assembly line, are used to set up the model. Based on the findings from the simulations, recommendations for the design of industrialized electrolyser assembly lines are formulated. This study contributes with insight to critical aspects and guidance to design decisions for efficient electrolyser assembly lines. Moreover, it shows how simulation can support assessment of different design alternatives in the development of efficient stack assembly lines.

Modeling of logistics objectives at rail-road inland transshipment terminals

Volodymyr Alieksieiev, Rafat Beigpoor Shahrivar, Carlos Jahn, and Hermann Lödding

The logistics performance of inland transshipment terminals, such as rail-road container terminals, is crucial for establishing a reliable combined transport and for accomplishing sustainability goals. Main logistics objectives, such as high output rate and short throughput times, cannot be achieved simultaneously, creating an objective conflict. Modeling the interdependencies between the objectives can support terminals in determining an optimal operation point depending on their goals. Previously, these interdependencies have been analyzed primarily using complex simulation or optimization models. This paper presents an approach to model these interdependencies using Logistic Operating Curves (LOCs) and validates it using simulation.

Parallel Sessions 11.5	Time: 13:30 - 14:50	Room: Vigor

Industrial Product Service Systems

Mike Freitag, and Tomomi Nonaka

Understanding Part Complexity: A Novel Approach for the Identification of Complexity-Influencing Part Characteristics

Greta Tjaden, Nick Große, and Anne Meyer

Machine tool manufacturers must understand the requirements of their customers to survive in challenging markets, e.g. by understanding their customers' order characteristics. We want to explore part complexity as a measure to fill this gap of data-based customer information. This paper presents the procedure that we developed for part complexity assessment and is centered around expert consultation and the results from implementing this procedure at our industry partner, a machine tool manufacturer for sheet metal processing. Our contributions are (1) a literature review on part complexity and assessment approaches, (2) a definition of part complexity, (3) a tried-and-tested procedure for the assessment of part complexity including an online tool, (4) 80 sheet metal processing geometries, (5) codebooks containing the relevant part characteristics to assess part complexity of an exemplary production unit, (6) detailed explanation of the labeling results for three geometries, and (7) refinements for enabling transferring the labeling results to new geometries using a classification algorithm.

Covariance Structure Analysis on the Collaboration between Local Enterprises and Local Governments for Value Creation and Value Communication of Local Brands

Yu Fujii, Tomomi Nonaka, Fumihito Oura, and Seiko Shirasaka

The establishment of regional brands is indispensable for revitalizing local areas, yet advancing such initiatives necessitates collaboration with a diverse array of stakeholders. This research focuses on local enterprises, which are pivotal stakeholders in regional branding strategies, and aims to elucidate the impact of their collaboration with local governments and the degree of brand penetration on their willingness to engage in regional branding efforts. We define regional branding as comprising two types: "comprehensive regional branding", which involves branding the region, and "resource-based regional branding," which pertains to branding specific local products and services. We propose a hypothetical model suggesting that the depth of collaboration with local governments influences local enterprises' engagement in regional branding. We conducted a questionnaire survey among local businesses in Fukuyama City, Hiroshima Prefecture, Japan, and verified the hypothetical model by covariance structure analysis using the survey data. The results revealed a moderate correlation between the willingness to participate in regional branding and the extent of collaboration with local governments. Furthermore, we identified factors that influence local enterprises' deepening relationships with local governments and factors that enhance brand penetration among local enterprises, specifically impact of the degree of understanding of local culture and the attractiveness of the brand.

Developing 3D Production Simulation Models in Industrial Production Systems

Akshay Goyal, Ioanna Aslanidou, and Yuji Yamamoto

This research presents a comprehensive framework for the development, integration, and formulation of 3D simulation models within industrial pro-duction systems. It aims to provide the required guidelines for utilizing 3D simulation technology, improving system productivity, assisting with decision-making, and furthering system optimization. The research highlights the considerable influence of 3D simulation technology on production systems, starting with developing and evaluating the system current state and its potential in manufacturing industries. The framework includes elements related to collecting data, the creation of 3D production simulation models, validation, and verification phases; setting objectives for the integration of 3D simulation; and the choice and advancement of customized simulation technologies that meets specific industry demands. The framework is developed with the help of a case study where the authors present the steps and information necessary to facilitate the modelling of the current state version within 3D production simulation model. Through the case study presented, this research illustrates the practical application of this framework, aiming to serve as an exemplary guide for academic and industrial practitioners.

From Product-Service-Systems to smart Product-Service-Systems. A survey about German Companies and practical implications

Christian Schiller, Mike Freitag, and Oliver Hämmerle

This text discusses a study conducted in Germany on smart product-service systems and their adoption among companies. The study examines the current state of smart product-service systems implementation, the importance of digital technologies, motivations for adoption, challenges faced, and the need for support. The findings show that 40% of surveyed companies are preparing to use or al-ready have applications for smart product-service systems. Large companies and those in the industrial sector are more likely to have implemented smart product-service systems. Companies with experience in smart product-service systems prioritize digital technologies such as the Internet of Things. Motivations for adoption include leveraging data, increasing competitiveness, meeting customer requirements, and creating new value. Challenges vary between experienced and inexperienced companies, with the former facing issues related to data protection, security, and costs, while the latter struggle with strategies, concepts, and human resources. System and solution providers have the highest adoption rate, followed by product providers, with service providers lagging behind. The study provides valuable insights for companies considering the implementation of smart product-service systems, offering guidance on technology integration, motiva-tions, challenges, and the need for support.

Parallel Sessions 11.6

Time: 12:50 - 14:50

Room: Ventus

Digital Track - Part 3

Uyen Ngo, and Adriana Saraceni

Link: https://eu02web.zoom-x.de/j/66235628809?pwd=JVbbDG6hrKT5G8kI0eoFP5KrMtyTrl.1

Robust Novel Defect Detection with Neuro-symbolic AI

Spyros Theodoropoulos, Georgios Makridis, Dimosthenis Kyriazis, and Panayiotis Tsanakas

Detecting novel product defects whose classes have not been seen at all during training time, is an important aspect of practical automated visual inspection in manufacturing. Without proper handling it is possible that these unknown defects will remain unnoticed causing production quality to deteriorate. Collecting more and more defect data is also not a solution as defects occur rarely in production and the rampup time of the AI-driven quality inspector becomes significantly slower. Since traditional machine algorithms are not always designed for handling these challenges, this paper applies an innovative approach based on Neuro-symbolic AI. Specifically we use a Logic Tensor Network that expresses the outputs of an unsupervised out-of-distribution detector as symbolic rules and uses them to drive the training of a neural network classifier. The resulting algorithm shows improved results in comparison to other related methods, especially in terms of defect recall, meaning that few defects remain undetected even if completely novel.

Digital Twins (DT) applied to the customization of 3D printed Scara robots using intelligent manufacturing

William Lopes, Adilson Rusteiko, Cleiton Mendes, Nicolas Honorio, and Marcelo Okano

The study presented the successful development of a digital twin using Blender software, the BlendixSerial library and a Scara robot built by 3D printing and controlled by an Arduino Uno R3 microcontroller. Choosing open-source tools not only reduced costs by eliminating the need for costly licenses, but also allowed efficient customization of the system to meet spe-cific project needs. The results obtained demonstrated the ability of the digi-tal twin to operate satisfactorily, enabling precise synchronization of move-ments between the physical robot and the virtual model through a low-cost project. Using the BlendixSerial library, efficient communication was estab-lished between the microcontroller and Blender, allowing control of the ro-bot's motors directly from the 3D simulation environment. During the tests, it was observed that the Scara robot, with two 180º MG996R servomotors for the X and Y axes, and one 360º MG966R servomotor for the Z axis, could perform fluid and precise movements. However, some intermittent failures were identified in the processing of servomotors by the Arduino Uno R3 due to limited hardware processing capacity. The work significantly contributes to advancing research into low-cost digital twins by providing an affordable and effective framework for simulation and analysis of physical systems. With continuous improvements in the hardware and software used, digital twins are expected to become an even more powerful tool in industrial and educational applications.

Smart Port Sustainability: A Business Intelligence Framework for CO2 Reduction in Cargo Truck Operations

Marco Hegger, and Adriana Saraceni

In the decade of sustainable focus, markets, and governments demand organizations participate in the sustainable transition by creating more sustainable operations. In this case, ports are essential performers in the sustainable transition because of their enormous volumes of worldwide logistics. Additionally, in recent years Business intelligence tools are developed and applied in several markets worldwide. Furthermore, the importance of smart ports or the industry 4.0" (4IR) concept is discussed to support the sustainable transition. Despite previous papers having researched different BI tools or the importance of sustainable performance at ports, no research explains which BI tools are needed to reduce CO2 emissions at port, especially for the loading process of cargo trucks. Therefore, this research aims at investigating how to assist European ports in the decision-making of business intelligence tools to reduce the CO2 emission of cargo trucks. Thus, several scientific papers are analyzed during this research, and BI tools are selected based on sequence and integration. Thereafter, this research conducted interviews with field experts to discuss the selected BI tools and broaden the knowledge for this research. Furthermore, it was possible to contact several European ports to acquire insights into the current port operations and the desire to introduce such tools. A performance dashboard prototype, created with simulated data through R, was demonstrated to the respondents during the questionnaire. Finally, a BI framework has been developed to assist European ports in the decision-making of business intelligence tools to reduce the CO2 emission of cargo trucks.

Material intensity of growing wind turbines

Per Solibakke, and Nina Pereira Kvadsheim

This study evaluated the material intensity (i.e., the raw material requirements) of growing wind turbines by analyzing the correlation between wind turbine capacity and head weight. The research is based on a compositional evaluation of wind turbines using available literature and publicly available data. To determine the material intensity in relation to capacity, three best fit approximations, namely average, linear, and power were utilized. The results show that as the capacity of wind turbines increases, so does the material intensity. However, further analysis suggests that in the 2-4 MW capacity range, the material intensity remained unchanged and might even decrease, while at larger capacities (6+MW) the material intensity clearly increases. The study emphasizes the importance of defining system boundaries and the need for a larger dataset to both improve accuracy and conduct further classifications. Overall, this research provides valuable insights into the material intensity of wind turbines and highlights the potential impact of capacity growth on resource utilization.

Parallel Sessions 11.6

Time: 12:50 - 14:50

Room: Ventus

Digital Track - Part 3

Uyen Ngo, and Adriana Saraceni

Link: https://eu02web.zoom-x.de/j/66235628809?pwd=JVbbDG6hrKT5G8kI0eoFP5KrMtyTrl.1

A Simulation Study For Integrating Library Material Handling with Autonomous Mobile Robots

Niloofar Jefroy, Chiara Lepre, Fabio Sgarbossa, and Teresa Murino

Libraries have served customer, so-called patrons, as a cultural and educational arena for many decades. Although there is a trace of attempts for incorporating advantageous technologies into the library environment, efficient operation of the library is still an underinvestigated topic which deserves scholarly efforts in the realm of material handling. Thus, this study seeks to contribute to the improvement of the library material handling by taking advantage of mobile robot solutions. A case study at the Trondheim Public Library of Norway is primary employed in order to capture the material flow of books within a library and to study the challenges of material handling in this context. The literature review assists in exploring the recent technologies that have contributed to the material handling. In pursuit of improving the moving processes, a simulation analysis is then considered to examine the utilization of autonomous mobile robot (AMR) under two layout configurations: centralized and decentralized. The simulation analysis is accomplished under the influence of two automation strategy, consisting semi-automated and fully-automated. Given the impact of two layout configurations, four scenarios were examined throughout the simulation, and the results demonstrate that an exhaustive technological upgrade of the material handling in the library does not necessarily yield the optimal performance. In this regard, the semi-automated approach in conjunction with the decentralized layout configuration demonstrated the highest performance with respect to two key performance indicators (KPIs), namely time in the machine and time for moving/emptying the bins.

Understanding co-opetition dynamics in manufacturing value networks: A system dynamics based causal loop diagram (CLD) modelling approach

Aziz Kemal Konyalioglu, Aylin Ates, Steve Paton, and Tugce Apaydın

The concept of "co-opetition" in manufacturing value networks involves firms engaging in both collaboration and competition simultaneously This approach, while aiming to leverage the benefits of both, inherently intro-duces a paradox concerning value creation and capture. Within a value net-work, co-opetition involves various entities such as suppliers, distributors, subcontractors, and even competitors working together to enhance overall value. Despite a surge in research on co-opetition, there remains a disjoint-ed understanding, with limited exploration of its dynamics within manu-facturing contexts. To address this gap, our study constructs a system dy-namics model using causal loop diagrams (CLD) derived from an in-depth literature review within the manufacturing sector. Our aim is to comprehen-sively elucidate the factors influencing co-opetitive relationships and dy-namics in manufacturing value networks and business ecosystems. Fur-thermore, existing literature emphasizes the need for a multifaceted perspec-tive on co-opetition in manufacturing Our model, developed through con-sultation of extensive manufacturing and business literature and CLD ap-plication, identifies key factors driving co-opetition dynamics in manufac-turing and business ecosystem contexts. It represents the first comprehen-sive content analysis of co-opetition dynamics within manufacturing and business ecosystems, serving as a valuable resource for scholars and profes-sionals in the manufacturing and management field. By examining interconnected elements in a causal loop framework specific to manufacturing and business ecosystems, our study reveals how dynamic factors influence co-opetitive outcomes in these ecosystems. We explore various manufacturing-related aspects, such as supply chain dynamics in coopetition, technological innovations, and market dynamics, all impacting co-opetitive interactions. This comprehensive approach fills a literature gap, offering insights into critical factors affecting the co-opetitive process within manufacturing and business value networks. Our study's methodology, employing causal loop diagrams tailored to the manufacturing domain, stands out in the literature, providing a unique perspective on co-opetition dynamics within manufacturing and management contexts.

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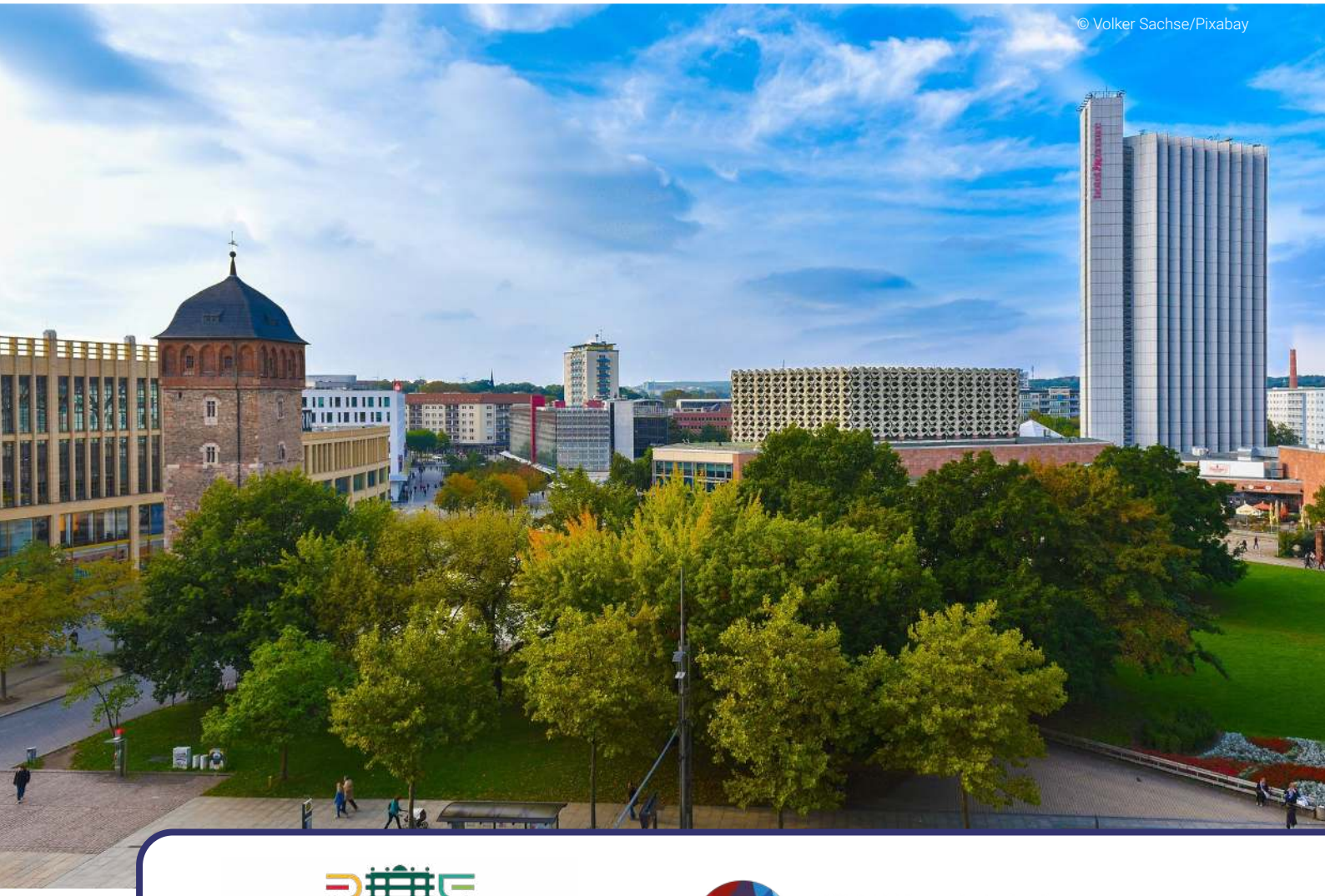

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