

DE FABRIEK VAN DE TOEKOMST

DESIGN AND OPERATION OF NEXT-GENERATION MANUFACTURING SYSTEMS

SEBASTIAN THIEDE

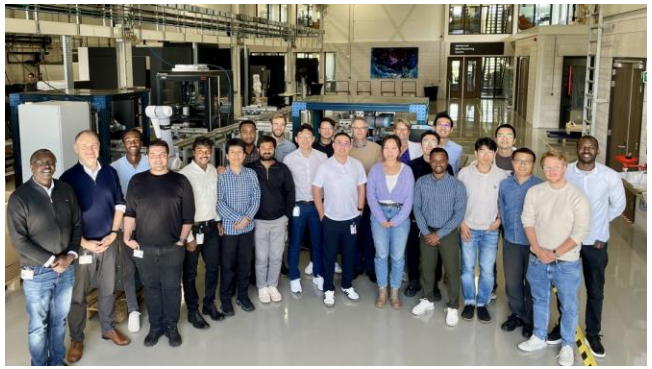
PROFESSOR OF MANUFACTURING SYSTEMS, UNIVERSITY OF TWENTE

S.THIEDE@UTWENTE.NL

DIGITALISERING & PRODUCTIVITEIT, AMERSFOORT, NOV 05, 2026

CHAIR OF MANUFACTURING SYSTEMS

TOWARDS FACTORIES OF THE FUTURE



Factory planning and operation
layouting, production planning and control, lean and quality management

Smart & flexible manufacturing systems
flexible/scalable/decentralised systems, intra-logistics, autonomous system design and control

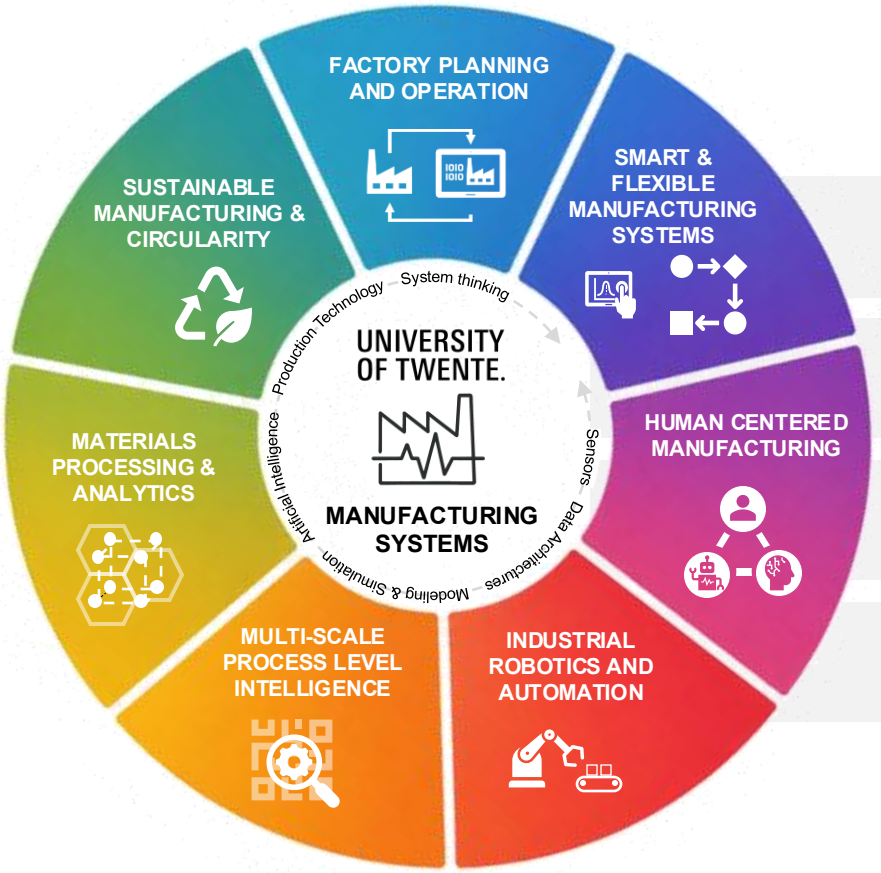
Human centered manufacturing
physical and cognitive assistance systems, occupational health and safety, workplace design

Industrial robotics and automation
advanced robotics, cobots, automation of complex tasks, robotic system design

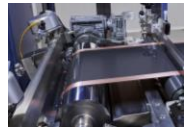
Multi-scale Process Level Intelligence
micro-/nano manufacturing, precision manufacturing, AI enabled quality control, vision technology

Materials processing and analytics
process-structure-property analysis, sustainable materials and system level implications

Sustainable Manufacturing & Circularity
environmental assessment, circular manufacturing, energy & resource efficiency and flexibility



Battery cell and module/pack manufacturing



High tech applications
(e.g. semicon, biomed, hydrogen)



Mechanical/mechatronic components and products



Mobility Sector
(e.g. heavy duty, aerospace, micro mobility)



TOPICS/FIELDS OF ACTION

APPLICATION AREAS

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MANUFACTURING SYSTEMS INFRASTRUCTURES@UTWENTE

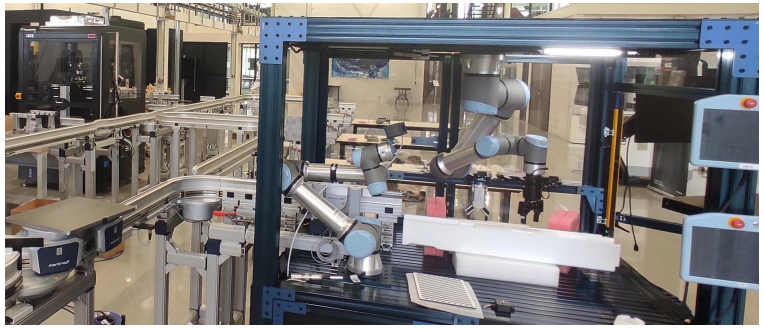
RESEARCH AND EDUCATION TOWARDS FACTORIES OF THE FUTURE

Learning Factory@CUBE



- human oriented workstations with diverse smart technologies, e.g. assistance systems, cobots, …
- testbed also for low/medium TRL
- flexible setup with diff. products
- throughgoing digital architecture
- focus on education and research

Advanced Manufacturing Centre



- higher TRL equipment, e.g. for battery module/pack assembly and additive manufacturing
- realistic and larger scale factory environment
- focus on industrial involvement and applied R&D

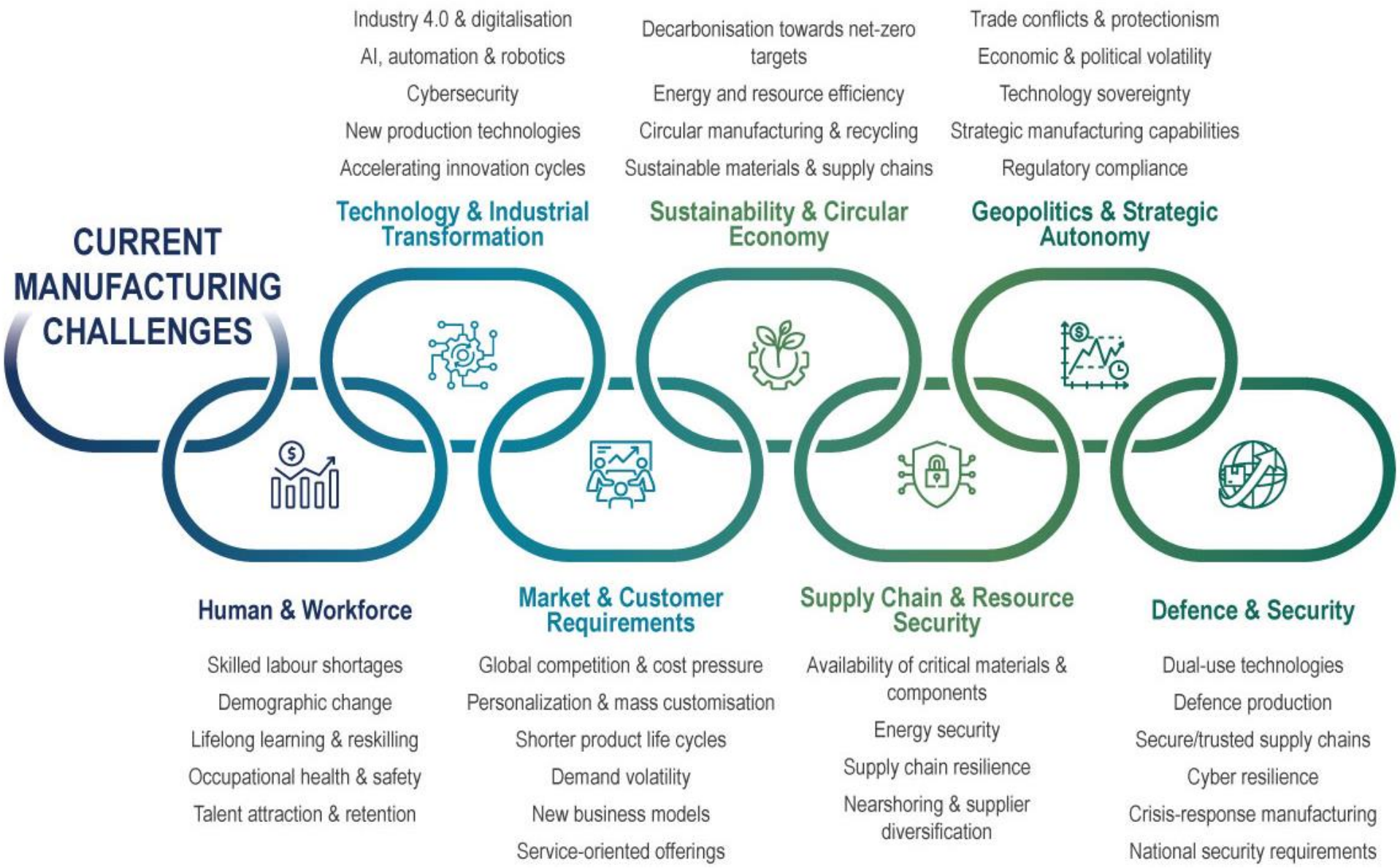
BATTFAB - Battery cell pilot line



- battery cell process chain including electrode manufacturing, cell assembly and formation
- manufacturing of pouch cells in reproducible quality
- Platform for research & education
- Smart industry architecture

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CURRENT CHALLENGES IN MANUFACTURING



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FLEXIBLE MANUFACTURING



FACTORY PLANNING / DESIGN

Next generation Manufacturing Systems

OPERATIONS MANAGEMENT

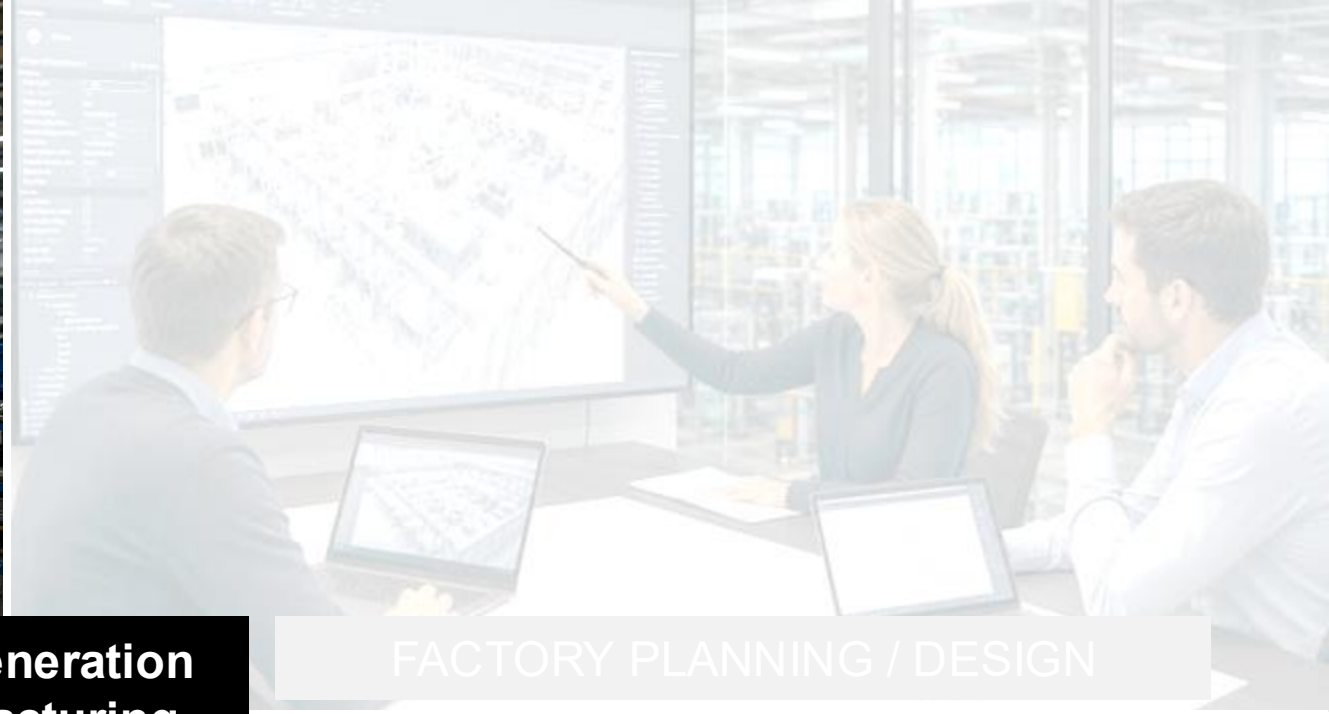


TASK EXECUTION / WORKER





FLEXIBLE MANUFACTURING



FACTORY PLANNING / DESIGN

Next generation Manufacturing Systems

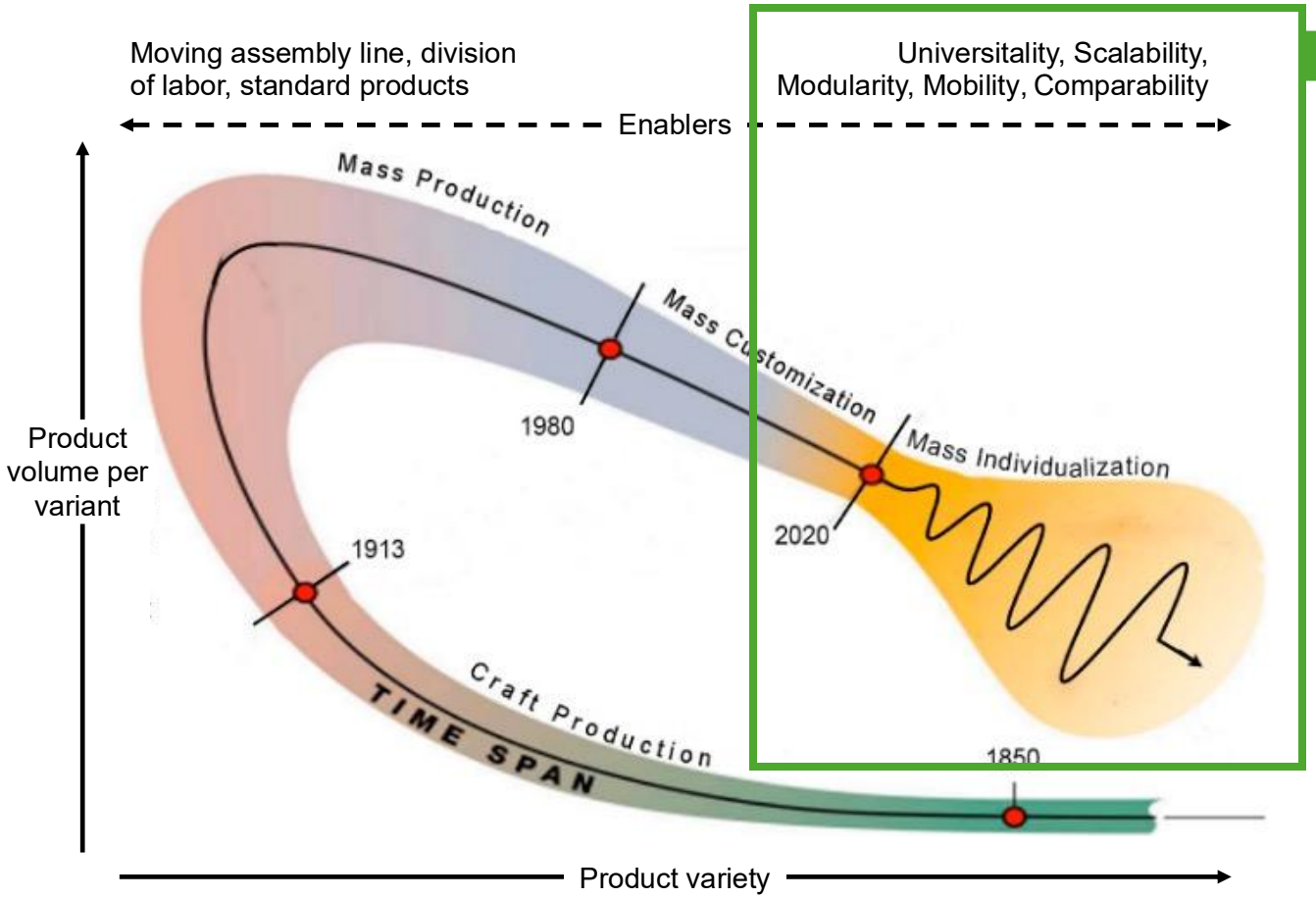
OPERATIONS MANAGEMENT



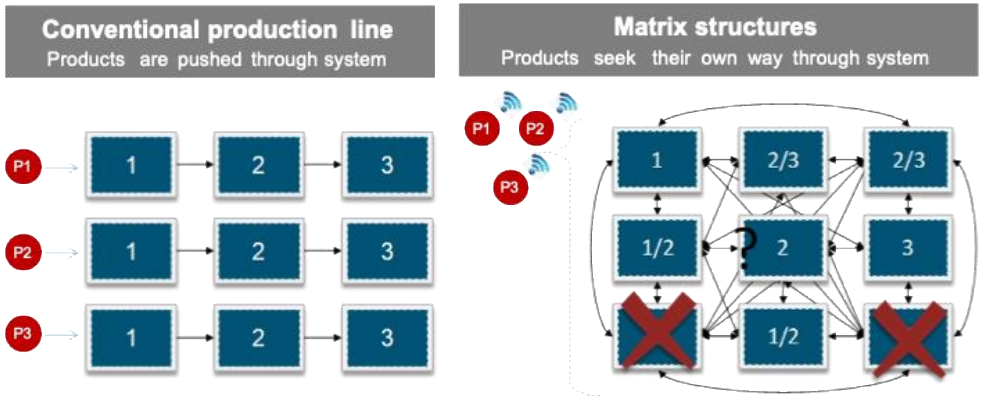
TASK EXECUTION / WORKER

FLEXIBLE AND SCALABLE MANUFACTURING SYSTEMS

MOTIVATION



Innovative production system concepts

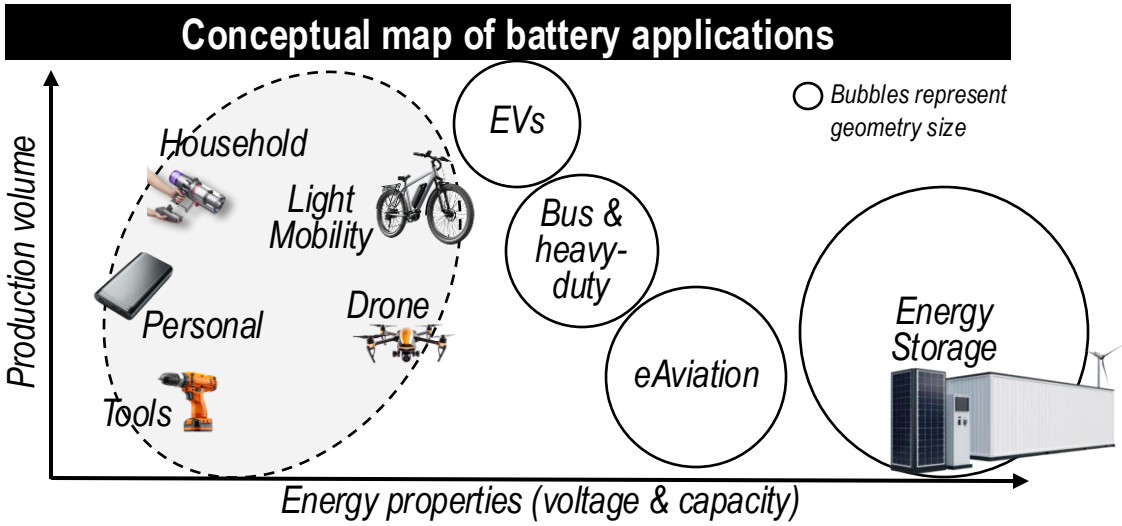


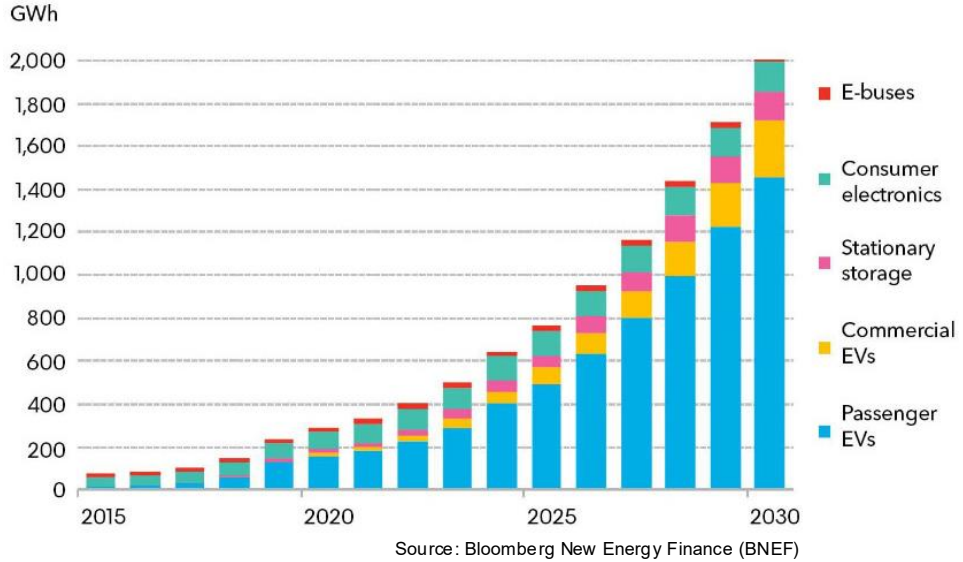
- highly flexible and scalable - synergetic use by different products
- resilient system design
- digital technologies are enablers

Koren Y (2010) The Global Manufacturing Revolution: Product-Process-Business Integration and Reconfigurable Systems. John Wiley & Sons; 2010.
Greschke P, Schönemann M, Thiede S, Herrmann C (2014) Matrix structures for high volumes and flexibility in production systems. Procedia CIRP
Schönemann M, Herrmann C, Greschke P, Thiede S (2015) Simulation of matrix-structured manufacturing systems. J Manuf Syst 37

FLEXIBLE AND SCALABLE MANUFACTURING SYSTEMS

EXAMPLE BATTERY MODULE/PACK MANUFACTURING





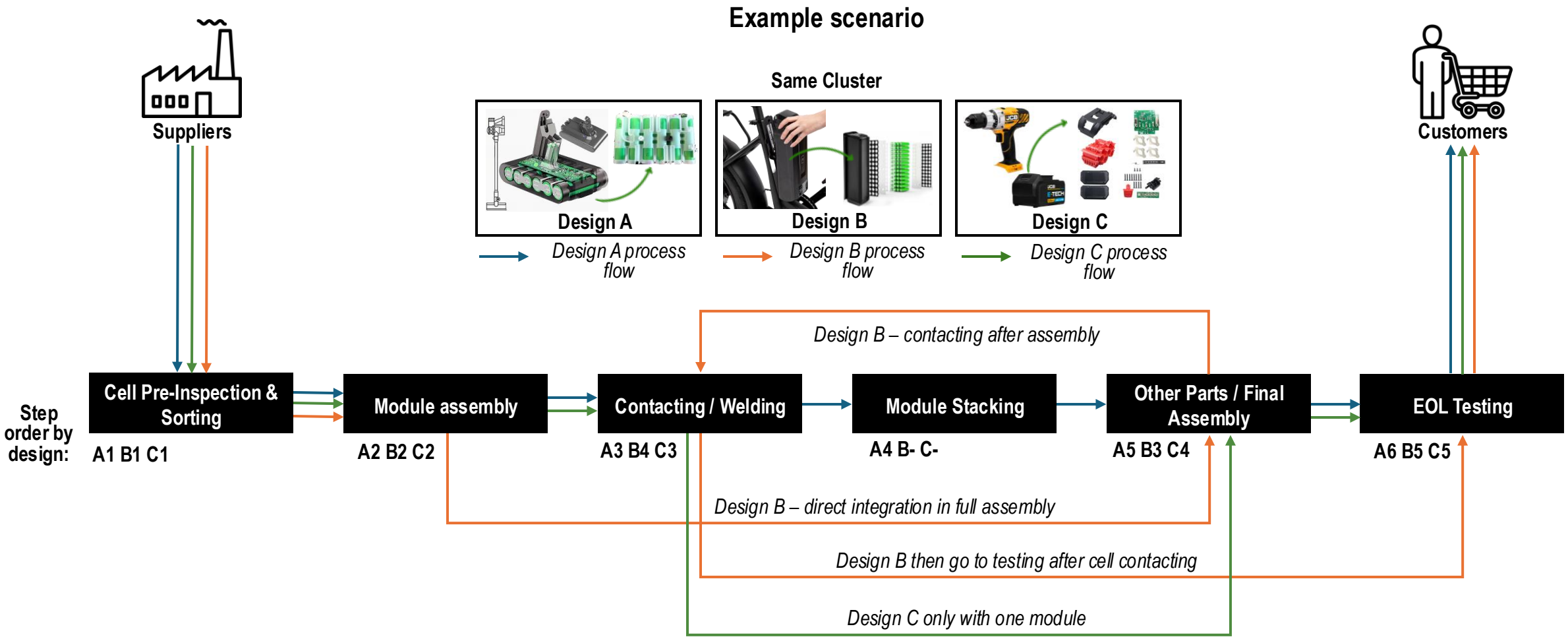
Cell Pre-Inspection & Sorting | **Module assembly** | **Contacting / Welding** | **Module Stacking** | **Other Parts / Final Assembly** | **EOL Testing**

- *(non-EV) battery module/ pack applications as interesting case*
- *diverse applications, uncertain volumes and variety, dynamically evolving technology*
- *economies of scale and scope through integration in one production system*

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FLEXIBLE AND SCALABLE MANUFACTURING SYSTEMS

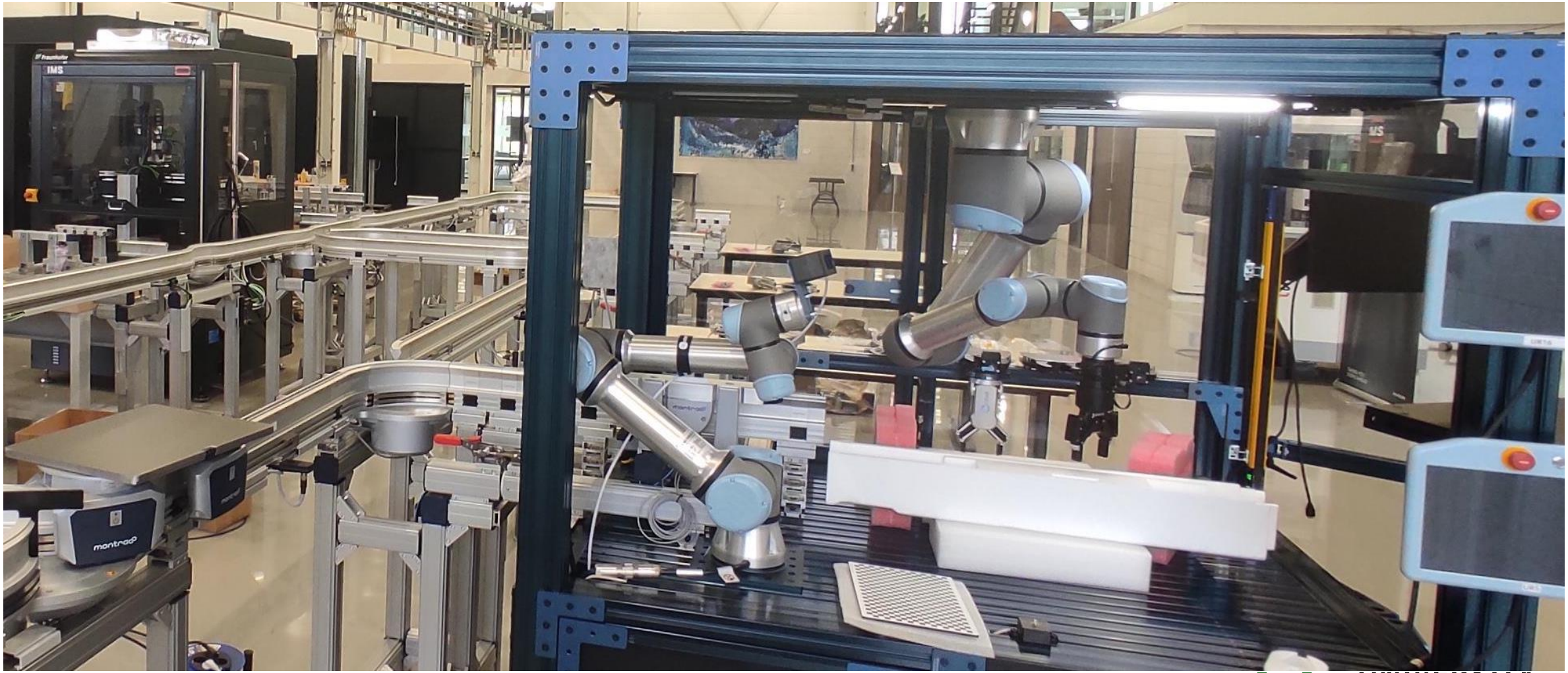
EXAMPLE BATTERY MODULE/PACK MANUFACTURING



- *similar processes but differences in specific assembly, sequence, cycle time, setup, etc.*
- *potential integration of different variants in one production system but flexibility for machines and logistics necessary*

FLEXIBLE AND SCALABLE MANUFACTURING SYSTEMS

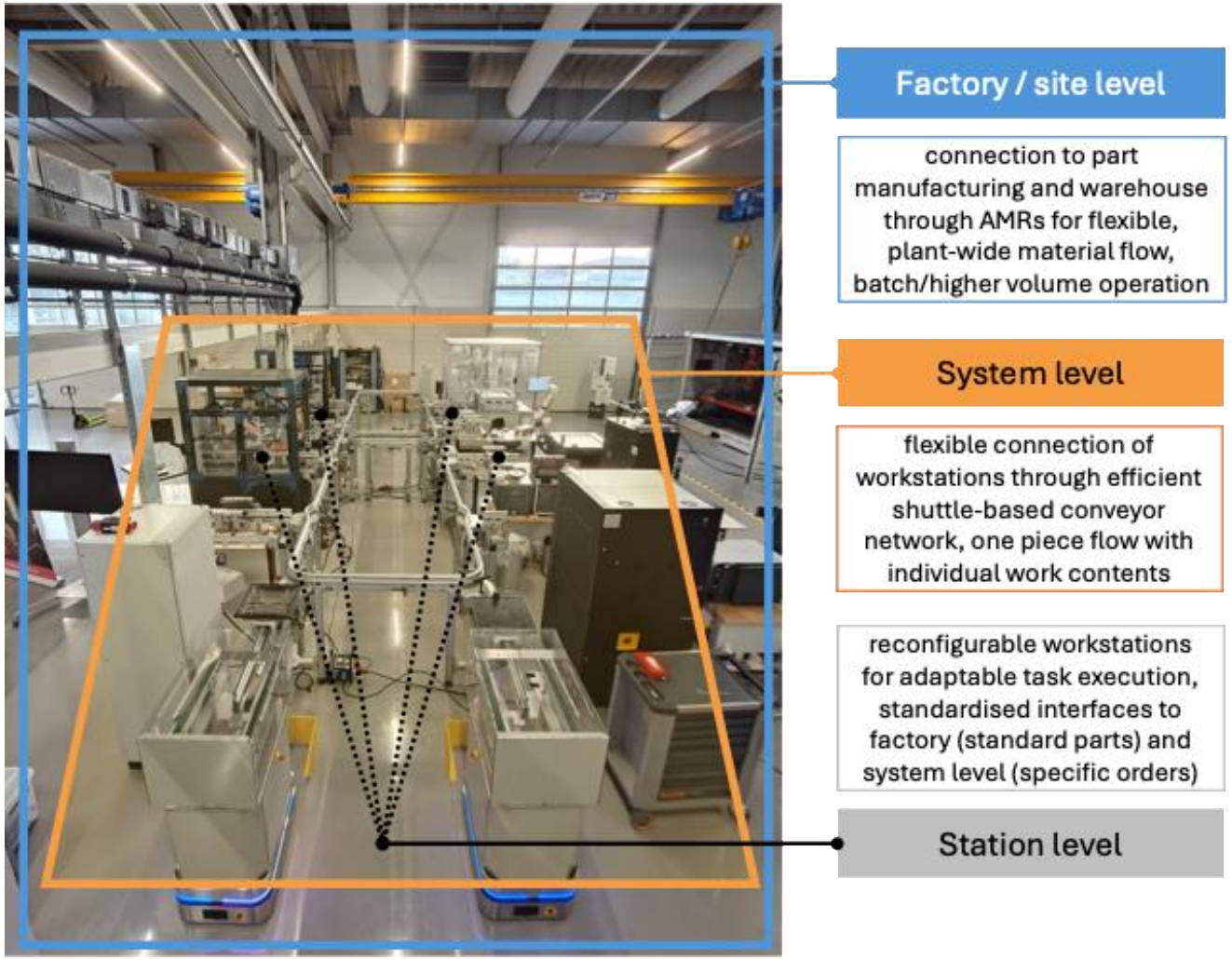
MULTI SCALE MATRIX PRODUCTION SYSTEM



Thiede et al. (2026) Multi scale matrix production system: concept and implementation for circular battery pack manufacturing, CIRP CMS 2026.

FLEXIBLE AND SCALABLE MANUFACTURING SYSTEMS

MULTI SCALE MATRIX PRODUCTION SYSTEM





Thiede et al. (2026) Multi scale matrix production system: concept and implementation for circular battery pack manufacturing, CIRP CMS 2026.



FLEXIBLE MANUFACTURING



FACTORY PLANNING / DESIGN

Next generation Manufacturing Systems

OPERATIONS MANAGEMENT

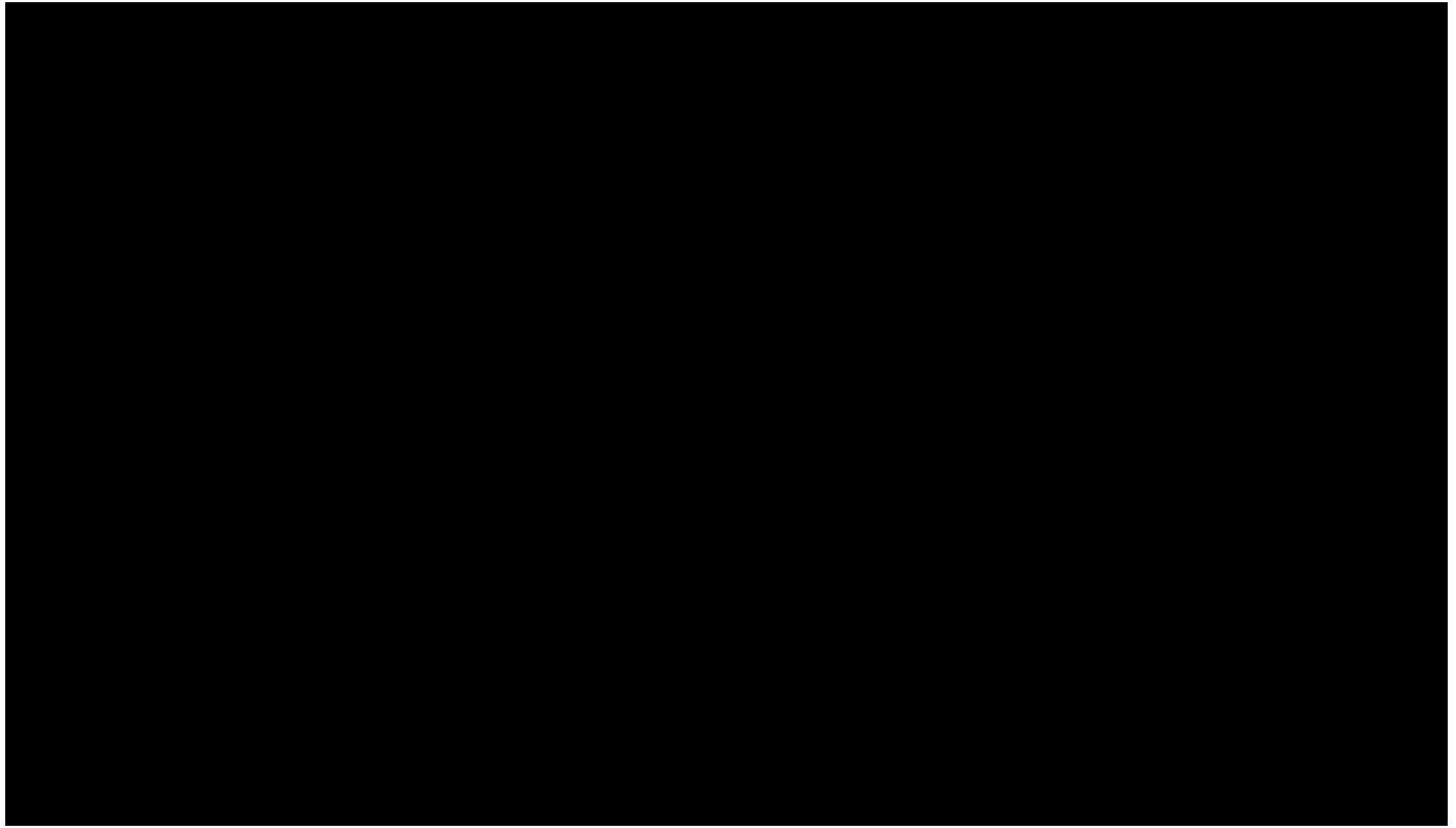


TASK EXECUTION / WORKER



AI SUPPORTED FACTORY PLANNING

UTILISATION OF GENERATIVE DESIGN APPROACHES

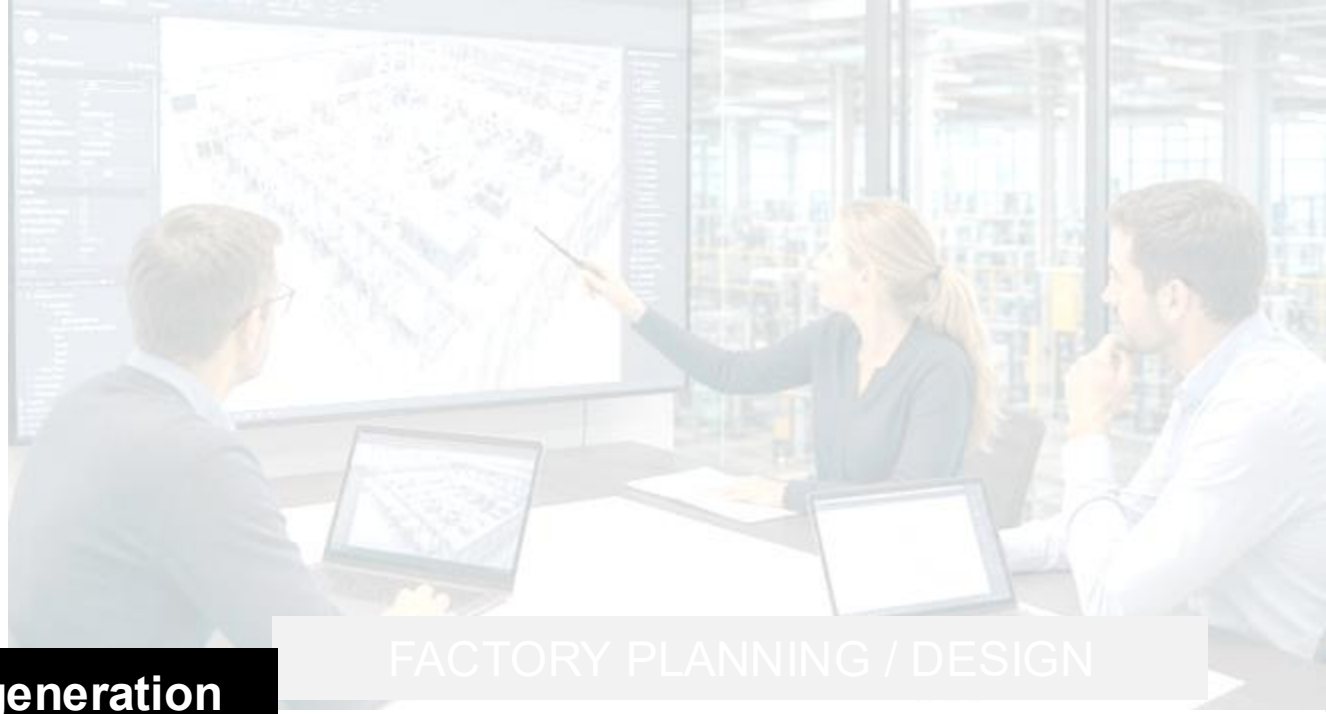


- complex planning problem with various stakeholders
- digital solution supports with automated generative of scenarios and calculation of KPIs
- human input for requirements and multi-criterial decision making

Thiede, S., & Liu, S. (2026). Generative design for sustainability-oriented factory planning. *Journal of Cleaner Production*, *552*, 147893.



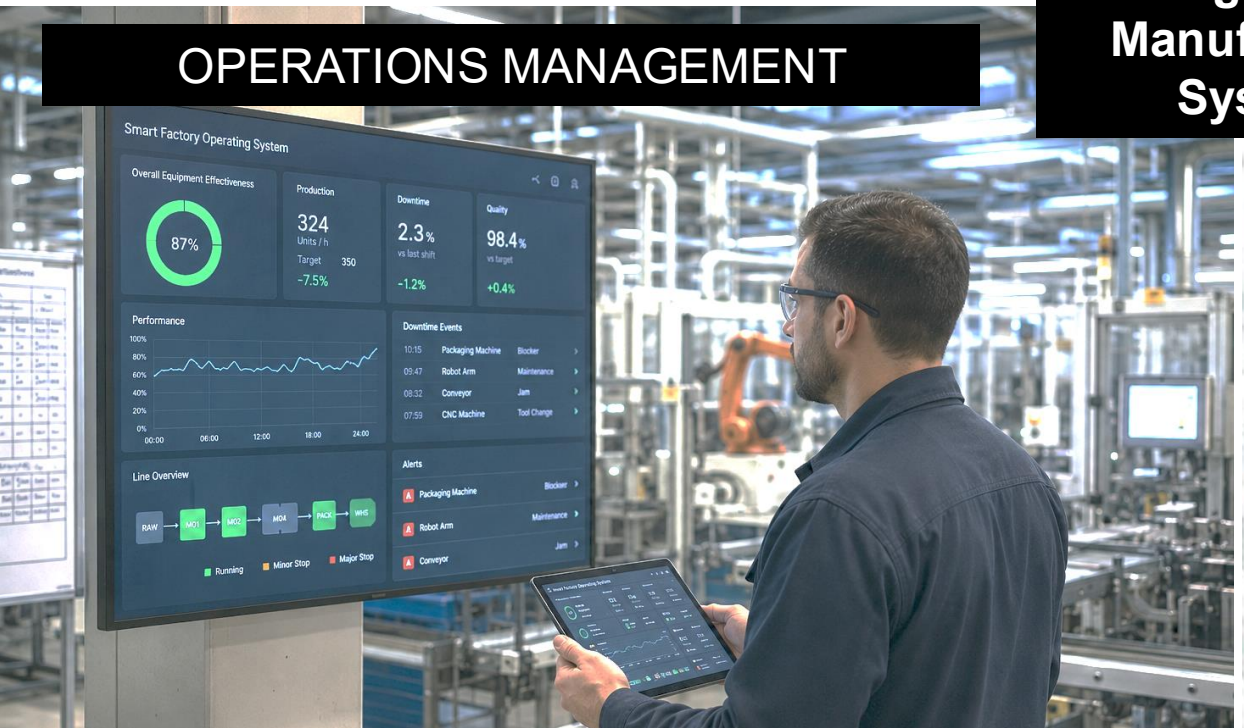
FLEXIBLE MANUFACTURING



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TASK EXECUTION / WORKER



DECISION MAKING FOR FACTORY OPERATIONS

MULTI-DIMENSIONAL DATA INPUT AS BASE FOR BROAD UTILISATION

AI enabled user interaction

Digital models/twins and agent-based services

Consistent and scalable data middleware / data backbone

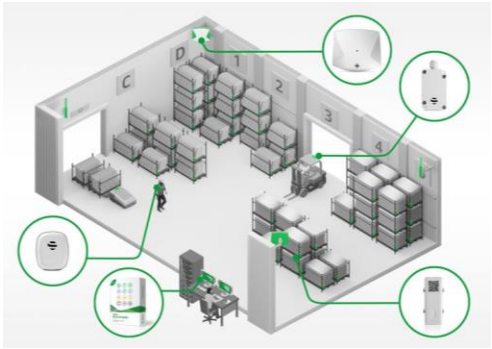
Machine and system data



source: symmedia.de

Machine states, processing parameters/state variables, order data from ERP/MES

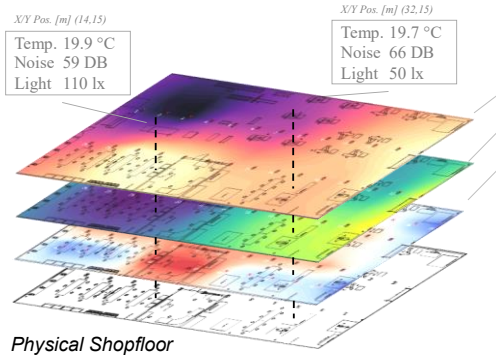
Real time locating systems (RTLS)



source: Sewio

Position tracking of factory objects (e.g. forklifters, products/order, tools, …)

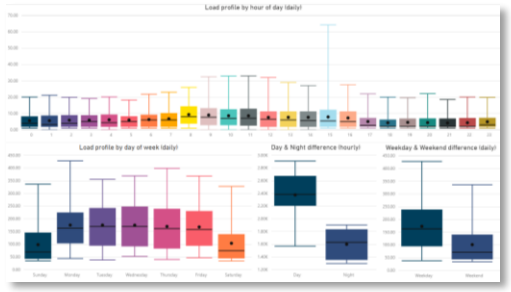
Environmental sensors / ambient data



Thiede et al. 2025

Ambient conditions in production environment, e.g. temperature, humidity, noise, …

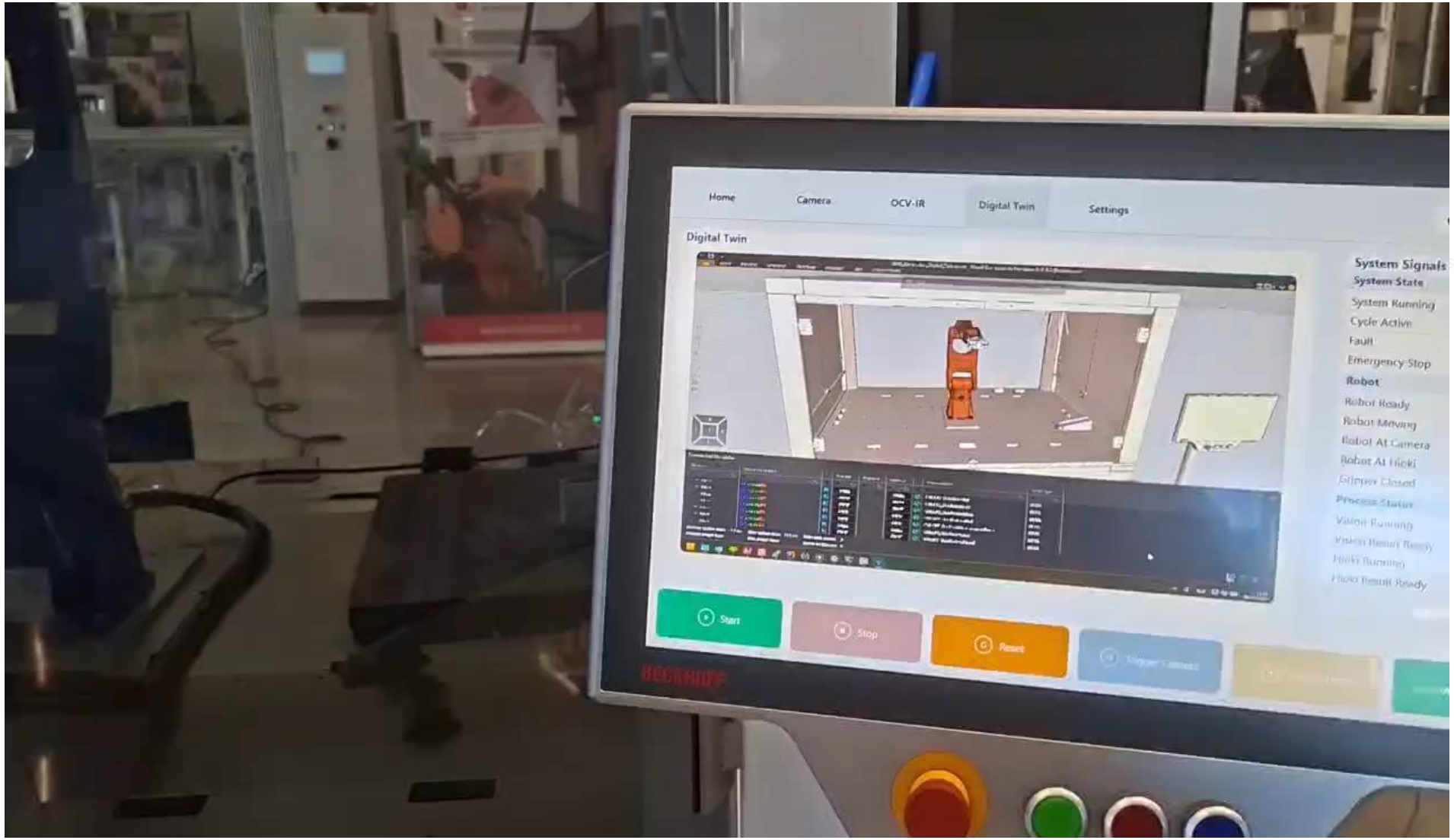
Energy monitoring



Energy demand of factory system and individual elements

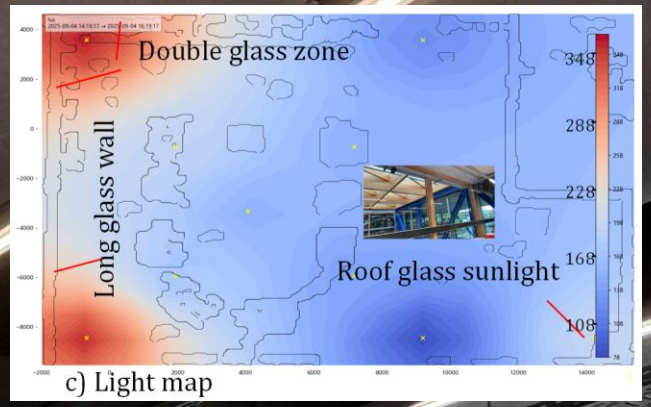
USE CASE: (MACHINE) DIGITAL TWINS

FOR MONITORING, VIRTUAL COMMISSIONING, CONTROL, ….



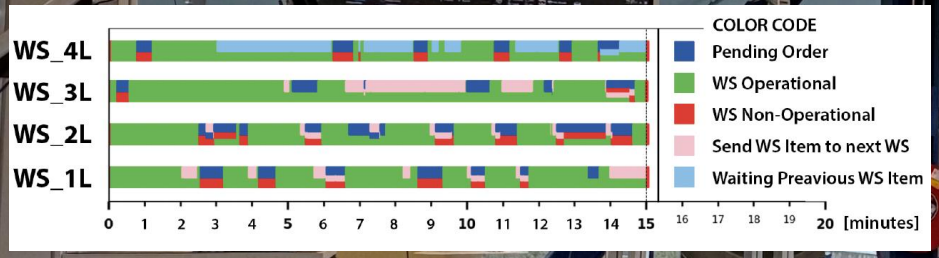
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EXAMPLE: MANUAL ASSEMBLY SYSTEM

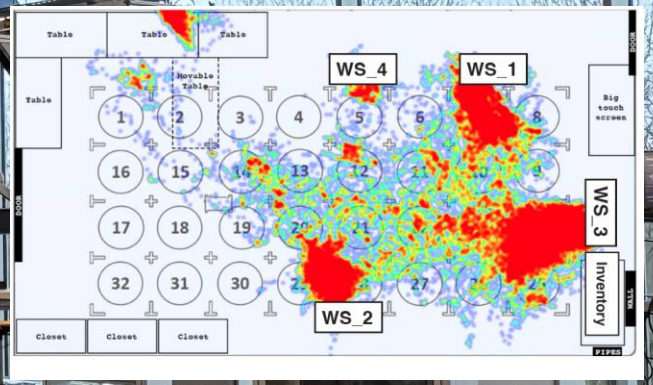


Ambient data (e.g. noise, light, temperature, connectivity)

Ordering and Inventory management system (OIMS)



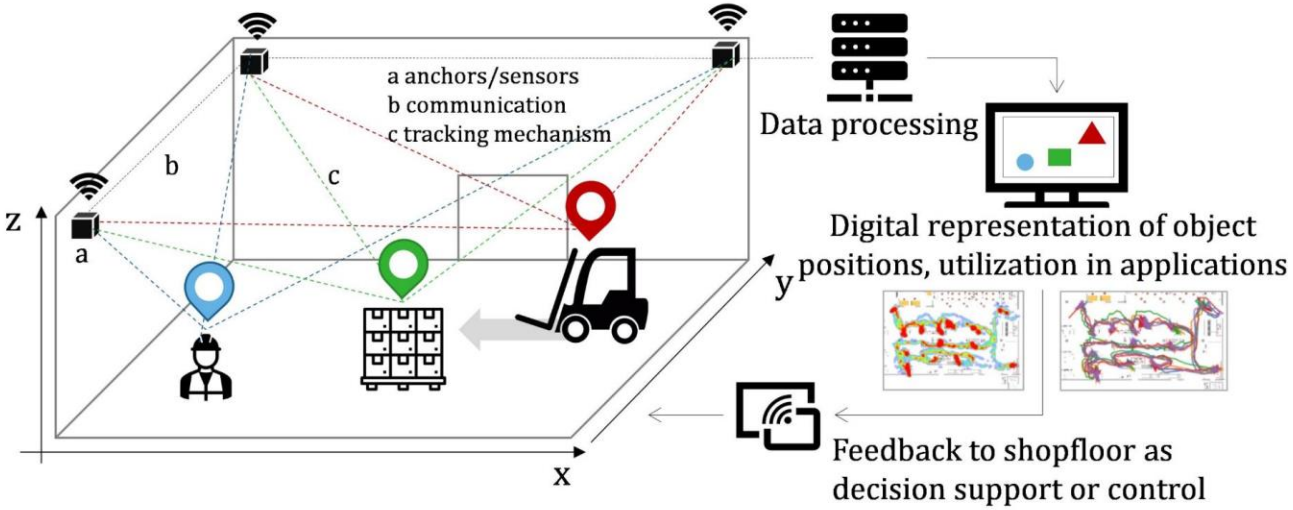
Real time location systems (RTLS) & Ambient data monitoring

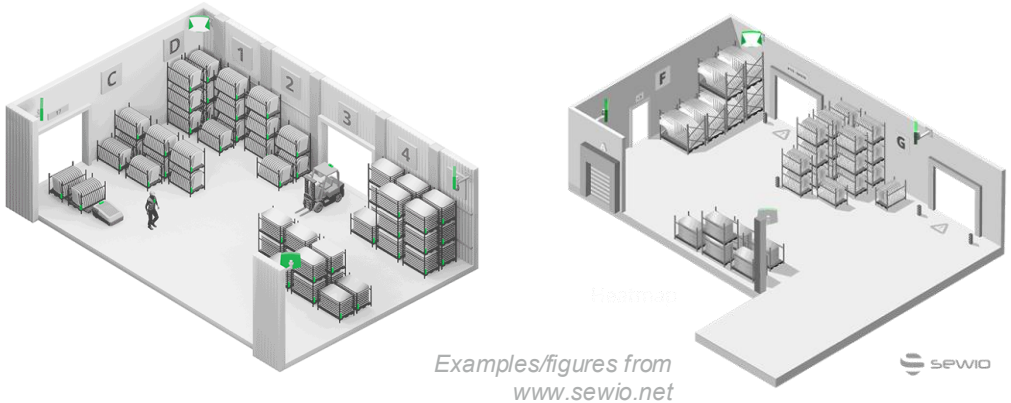


- *input for improving productivity, costs, occupational health and safety, sustainability*
- *but how to deal with this huge amount of data in meaningful, efficient and effective, way?*

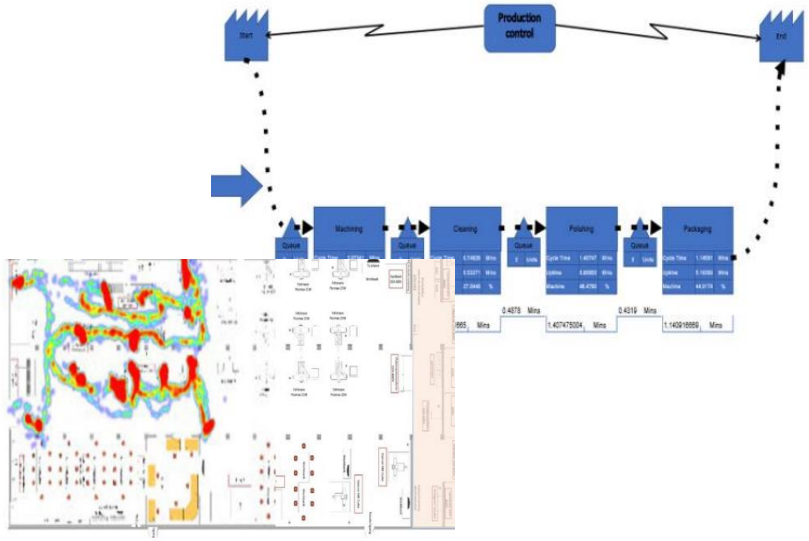
USE CASE: „LEAN 4.0“

COMBINING LEAN METHODS WITH DIGITAL CAPABILITES, E.G. DIGITAL VALUE STREAM MAPPING





Examples/figures from www.sewio.net



- *diverse (tracking) technologies and vendors available, e.g. UWB, Bluetooth, optical, ultrasonic, potentially 5G - technologies differ in terms of their capabilities and requirements*
- *applicability in variety of manufacturing system use cases, e.g. tracking of objects and tools, occupational health and safety, continuous value stream mapping*

Thiede, S., Sullivan, B., Damgrave, R., & Lutters, E. (2021). Real-time locating systems (RTLS) in future factories: technology review, morphology and application potentials. *Procedia CIRP*, *104*, 671-676.

Sullivan, B. P., Yazdi, P. G., Suresh, A., & Thiede, S. (2022). Digital value stream mapping: application of UWB real time location systems. *Procedia CIRP*, *107*, 1186-1191.

USE CASE: AUTONOMOUS FACTORY INSPECTION

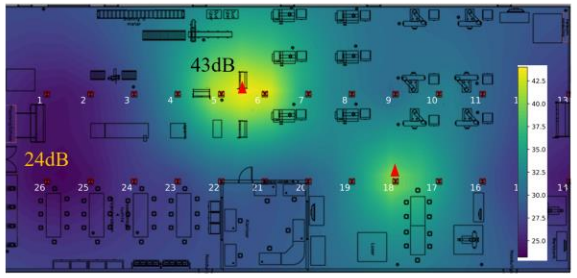
LARGE LANGUAGE MODELS (LLM) FOR NATURAL INTERACTION WITH DATA



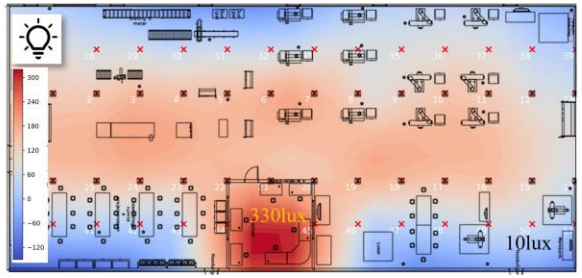
- relevant data for various applications, e.g. energy demand, occupational Health and Safety, auditing
- combination of spatial data with ambient data and and spatial mapping algorithms



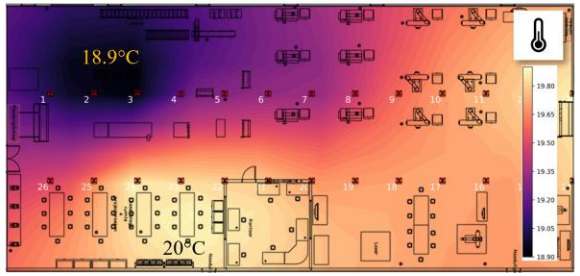
a) Hangar factory



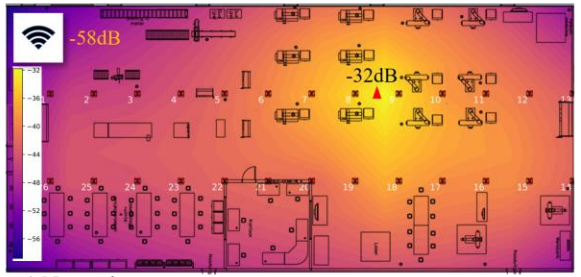
b) Ultrasonic map



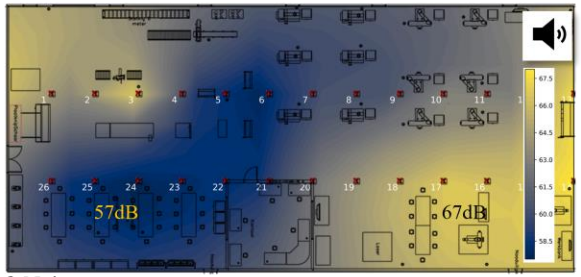
c) Light map



d) Temperature map



e) Network map



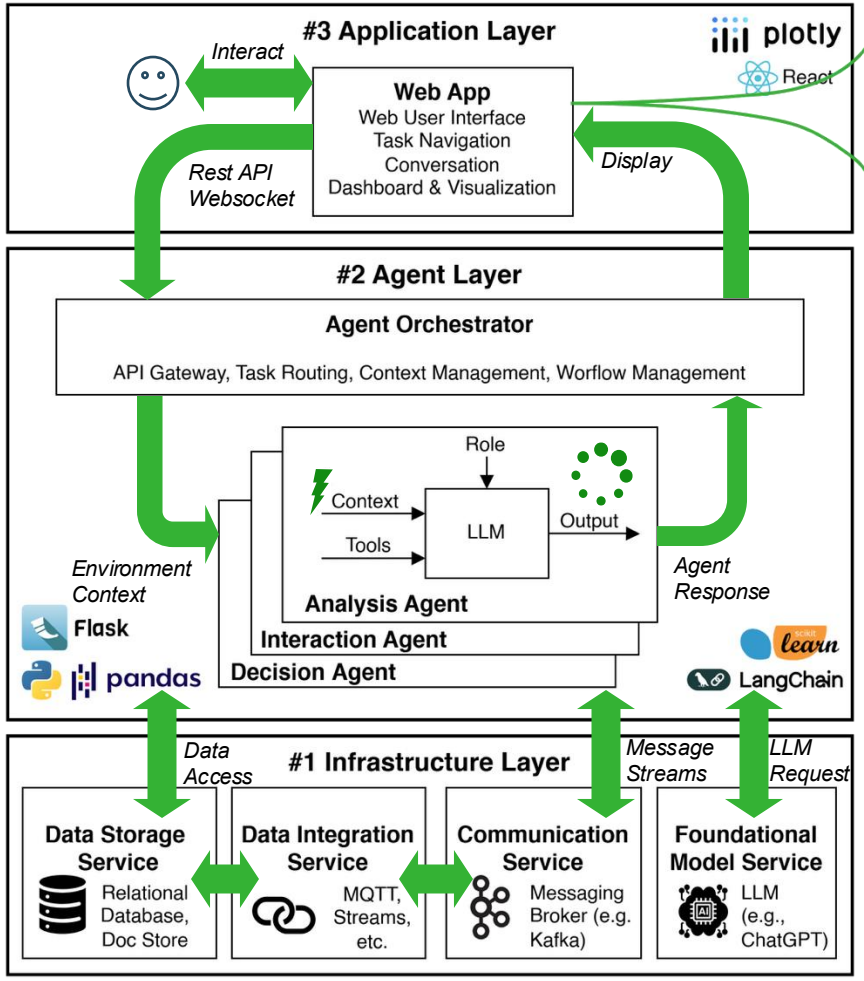
f) Noise map

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Thiede, S., Xiao, L., & Ghafoorpoor Yazdi, P. (2025). Autonomous spatial mapping and analysis of heterogeneous ambient sensor data in factories. *Production & Manufacturing Research*, *13*(1)

USE CASE: DECISION SUPPORT FOR FACTORY OPERATIONS

LARGE LANGUAGE MODELS (LLM) FOR NATURAL INTERACTION WITH DATA



System Architecture



Web App Interface

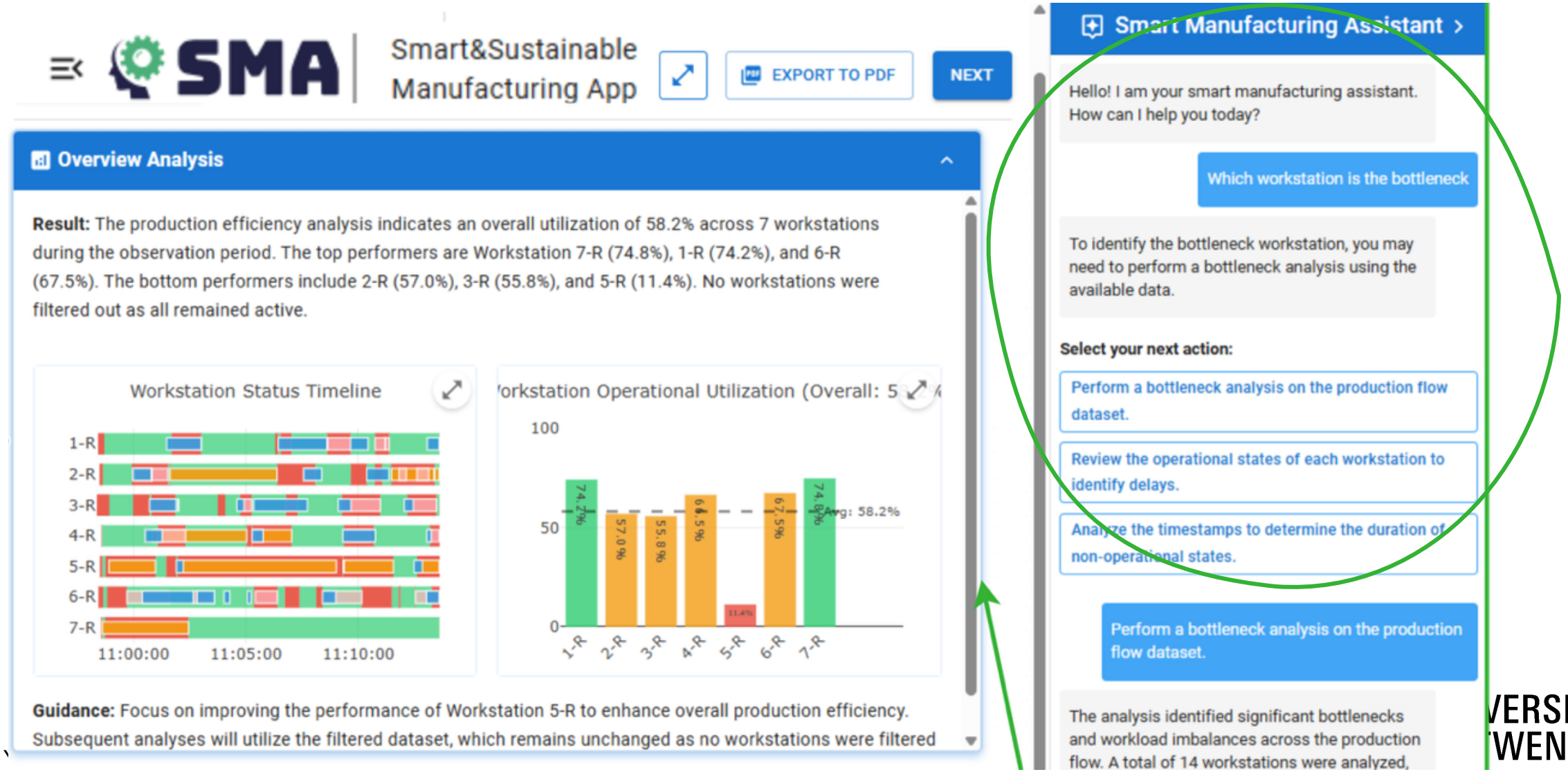
End-to-end Analytics with human in the loop

Yang, Z., Yazdi, P., Thiede, S. (2026) Operational Decision Support In Learning Factories Through Autonomous Data Analytics And Large Language Models, *Conference on Learning Factories 2026*

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USE CASE: DECISION SUPPORT FOR FACTORY OPERATIONS

LLM WITH VARIOUS ROLES AND PURPOSES (HERE "ANALYST")



Models, *Conference on Learning Factories 2026*

VERSITY
TWENTE.

USE CASE: TRAINING FOR FACTORY OPERATIONS

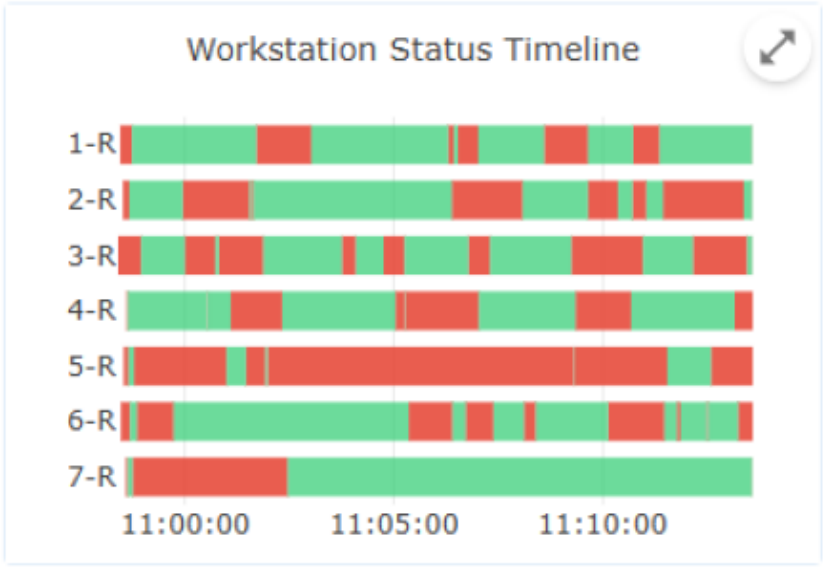
LLM WITH VARIOUS ROLES AND PURPOSES (HERE "TEACHER")

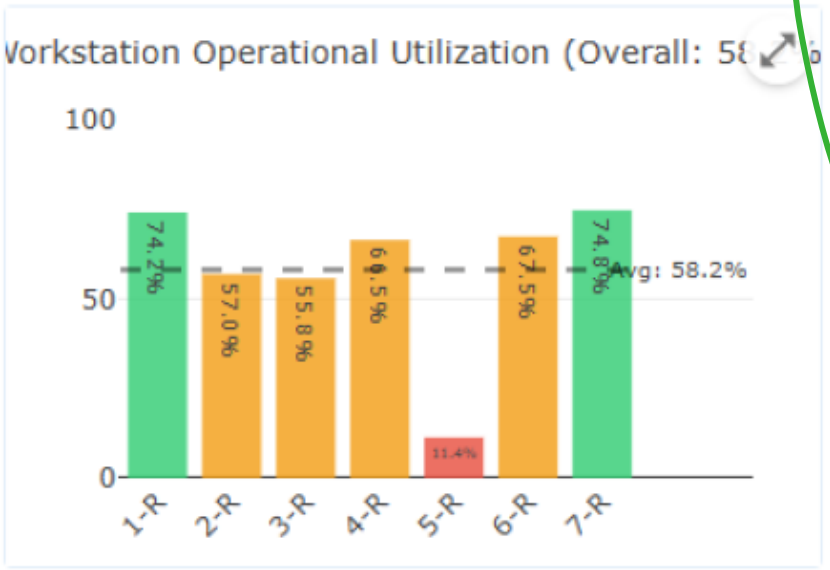
Utilization Analysis

Result: The production line is running at 58.2% utilization. See the red? That's all wasted time!

Tooltip: Utilization means how busy a workstation is.

Question: Can you find the bottleneck?





Smart Manufacturing Assistant

Can you find the bottleneck?

Bottleneck is workstation 5-R

You found the bottleneck! But what should we do about it?

Select your next action:

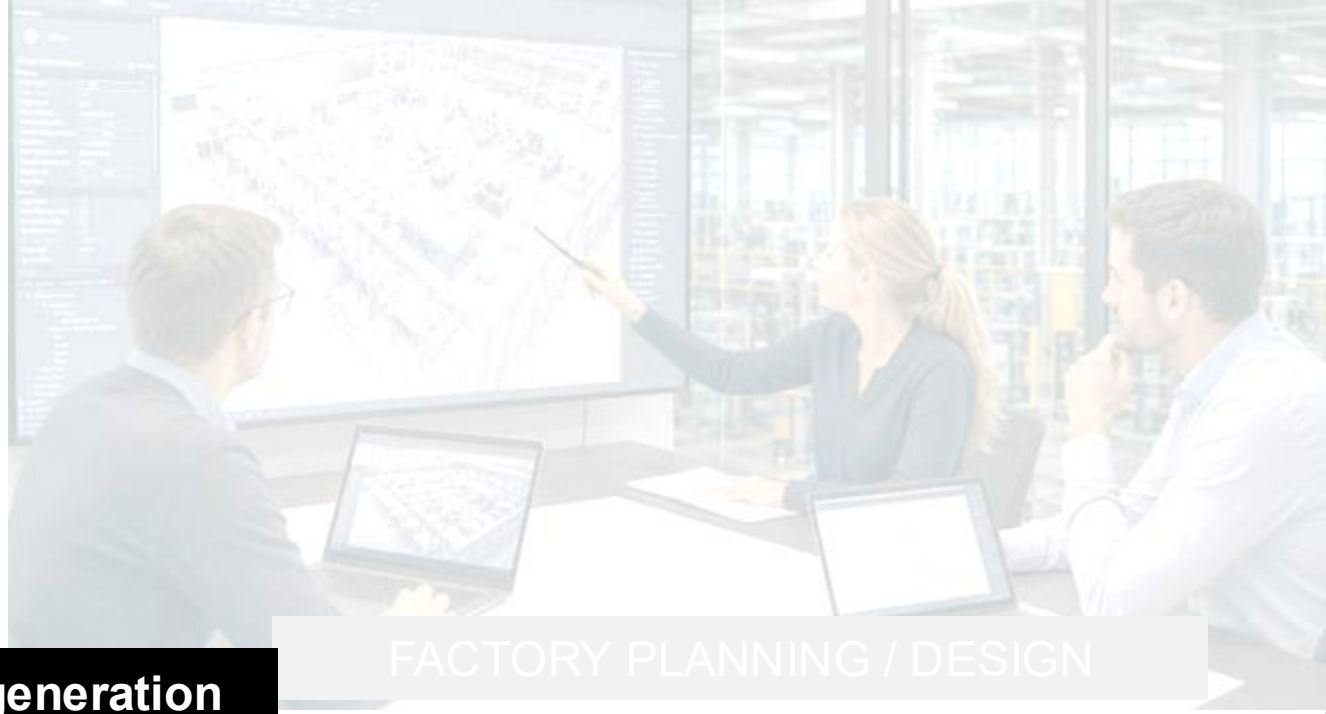
- Add Another Workstation
- Spread the Work More Evenly
- Reduce Wasted Movement

Type a message...

Yang, Z., Yazdi, P., Thiede, S. (2026) Operational Decision Support In Learning Factories Through Autonomous Data Analytics And Large Language Models, *Conference on Learning Factories 2026*



FLEXIBLE MANUFACTURING



FACTORY PLANNING / DESIGN

Next generation Manufacturing Systems

OPERATIONS MANAGEMENT



TASK EXECUTION / WORKER



HUMAN CENTERED WORKPLACES

SMART INDUSTRY TECHNOLOGIES FOR HUMAN OPERATORS









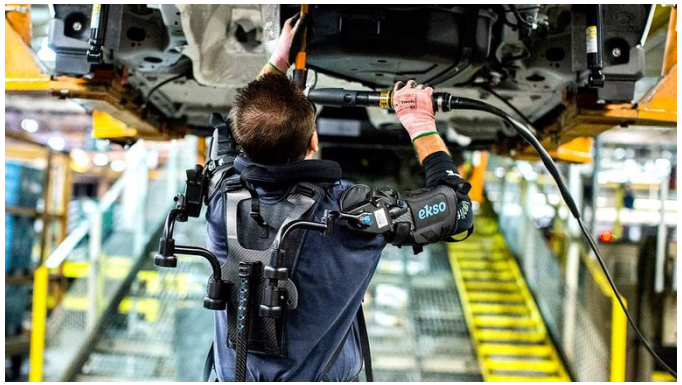


- *manual working tasks are still an important cornerstone in manufacturing (and will be)*
- *changing work profiles and demographic change as challenges*
- *occupational health and safety is an important topic in this context, e.g. ergonomics*
- *digitalisation with opportunities but also challenge to workers*

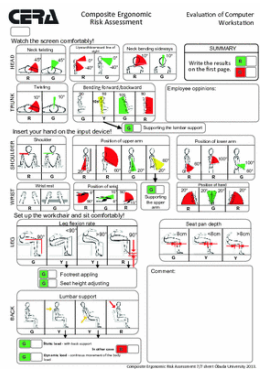
Pictures
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https://unsplash.com
https://indianindustryplus.com/2017/11/17/indian-auto-industry-in-changing-world-order/
https://www.rolandberger.com/nl/Insights/Publications/Automotive-manufacturing-requires-human-innovation.html

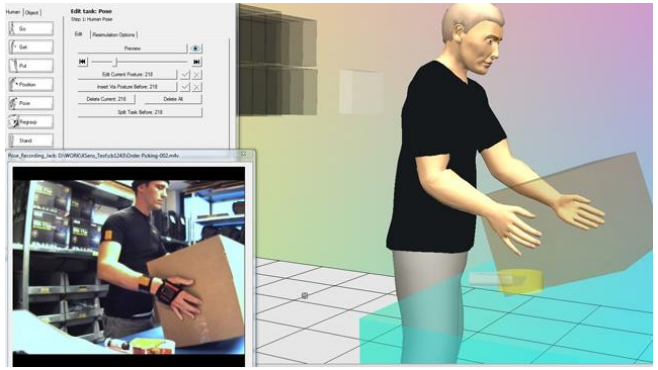
HUMAN CENTERED WORKPLACES

SMART INDUSTRY TECHNOLOGIES FOR HUMAN OPERATORS













State of the art (in good case)

Reduction of ergonomic loads as much as possible, avoid harm to workers

- *guidelines for workplace design*
- *ergonomic assessment sheets*
- *capturing of movements and/or virtual simulation and planning*
- *support technologies for workers, e.g. exoskeletons*

Observations

is less bad sufficient?

Snapshot observations

often separated task/discipline

not dynamic and not personalised

Pictures

https://www.plm.automation.siemens.com/global/pl/products/manufacturing-planning/ergonomics-human-performance.html
https://www.newequipment.com/research-and-development/article/22059887/ergonomics-in-the-production-line
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HUMAN CENTERED WORKPLACES

SMART INDUSTRY TECHNOLOGIES FOR HUMAN OPERATORS





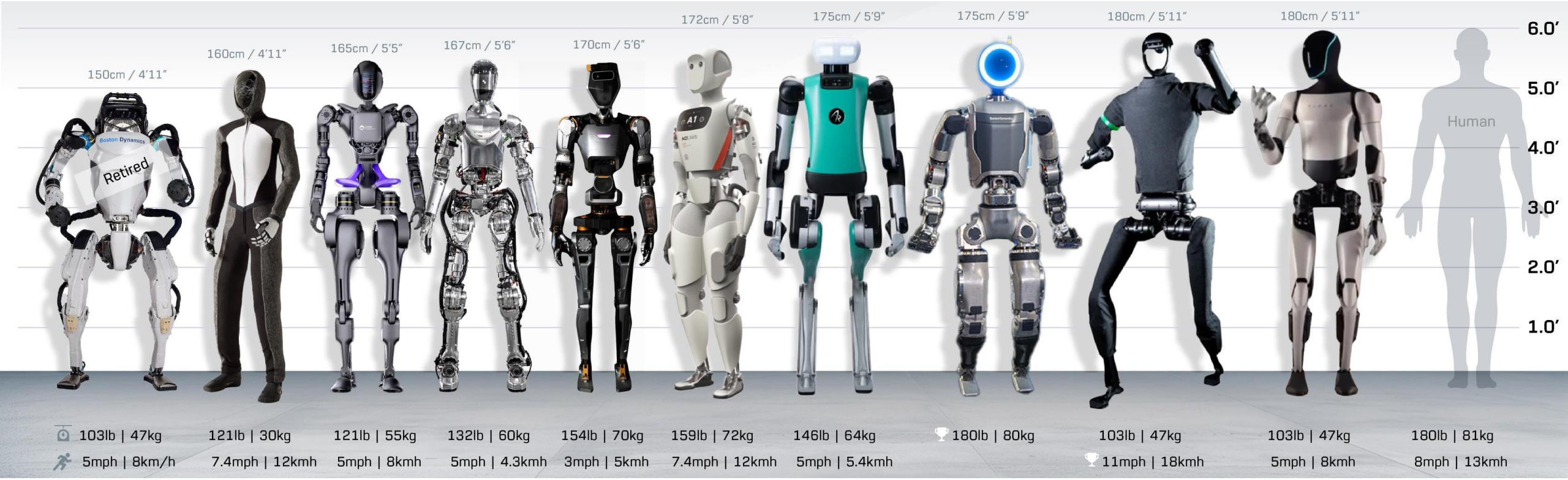




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HUMAN CENTERED WORKPLACES

RISE OF HUMANOID ROBOTS?



- development of meaningful and feasible use cases for direct collaboration
- assessment in terms of ergonomic, productivity and job quality dimensions

Visualisation by Harrison Schell from madevisual.co

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HUMAN CENTERED WORKPLACES

RISE OF HUMANOID ROBOTS?

https://www.future-robotix.eu





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DE FABRIEK VAN DE TOEKOMST

DESIGN AND OPERATION OF NEXT-GENERATION MANUFACTURING SYSTEMS

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