Written Examination

Production Systems (PPU161)

Date:	Thursday 2025-10-30
Time:	8:30 AM – 12:30 AM (4 hours)
Examiner:	Professor Johan Stahre (+46 703 088 838)
Place:	SB H7 and H8, Johanneberg
Questions:	The examiner or course assistant will be available for questions on phone and on two occasions in the room.
Department:	IMS, Division of Production Systems
Review of exam:	Contact the examiner

EXAM RULES AND INSTRUCTIONS:

- Communicating and collaborating with others is strictly forbidden.

- Write clearly and legibly. Illegible text will be disregarded in the grading process.

- Clearly motivate your solutions to enable maximum points for each question.

- Answer only **one question per page**, sub-question may be answered on the same page.

- Write your exam code on each page of the exam and do not write your name on any of the pages.

- Do not use a red pen.

INFORMATION ON EXAM MARKS:

A maximum of 20 points can be obtained on this written exam.

Final marks are given according to the following scheme, which represents the total sum of points from the written exam and extra points from other deliverables of the course:

• Not passed	0 – 7 points
• 3 = passed	8 – 11 points
• 4 = very good	12 – 16 points
• 5 = excellent	17 – 20 points

We wish you the best of luck!

Production Systems (PPU161) exam

1 *Industrial revolutions – from traditional to digital systems* ***Total: (2p)***

Consider the following scenario: It is the year 1912 and you are leading the engineering and manufacturing management team of an automotive company. Your market goal is to produce medium quality, low price automobile for a mass market.

How you would design the production system that could produce the 1912 cars, given the available power sources, parts supply, state of the art production technologies, and semi-skilled work-force? (2p)

You would typically organize a mechanized production and assembly line, with standardized parts and standardized work tasks, in line with Tayloristic procedures. The production process machines in the line are driven by electricity rather than steam. You would train your (semi-skilled) workforce to perform specialized tasks and try to motivate them to reduce and minimize the time and cost needed for their respective work-task, to enable mass-market and low cost products. You will need a lot of quality control to be able to deliver good products to your customer. The supply-chain of companies mass-producing components and parts could be local, regional, or international.

2 *Sustainability Thinking* ***Total: (4p)***

Integrating sustainability in industrial development requires considerations for all dimensions of the **triple bottom line** (social, environmental and economic).

Note: Full points require the examples to be concrete, realistic, contextualised in production systems, and clearly explained.

2.1 Briefly describe how the **triple bottom line** applies to **production systems** with three examples, one for each dimension. The examples can be positive or negative. (2p)

Examples of possible answers with connections to *Sustainable Development Goals (SDGs)*:

Production can contribute to **economic sustainability** through productivity, competitiveness, and innovation (*SDG 9*) while ensuring that profit is made responsibly and ethically.
Concrete examples of economic contributions include: employment, decent work, fair wages (overlap with social sustainability), as well as circular economy transition and clean tech development (overlap with environmental sustainability).

Production can contribute to **social sustainability** by delivering goods and services to improve our quality of life, and by creating jobs and career opportunities (*SDG 8*).
Concrete examples of social contributions include: equal opportunities, decent work, fair wages (overlap with economic sustainability), as well as education, creativity and entrepreneurship which can enable green innovation (overlap with environmental sustainability).

Production can contribute to **environmental sustainability** by mitigating and reversing the ecological impacts (such as resource depletion, pollution, and climate change) from producing goods and services (*SDG 12* and *SDG 13*).
Concrete examples of environmental contributions include: resource efficiency (material, energy, water), no toxicity and safe work environment, product lifecycle management and waste management strategies for circular economy, clean tech development, low-carbon and renewable energy systems, green innovation, etc.

2.2 Briefly describe how **digital technologies** can affect the **triple bottom line**. Provide two examples: one synergistic for at least two dimensions and one presenting a trade-off/conflict between at least two dimensions. (2p)

Examples of *digital technologies* with **synergies** and **trade-offs** between dimensions:

ECONOMIC–SOCIAL
While *automation* requires high initial investments (**negative economic impact**), deploying it strategically can improve productivity and quality while reducing operating costs (**positive economic impacts**). It can also increase safety and wellbeing by assisting workers in physically and/or cognitively demanding tasks (**positive social impacts**). In addition, *automation* may displace low-skill jobs and cause unemployment in the short term (**negative social impact**), but it also creates demand for high-skill roles in robotics, data science, and systems engineering (**positive social impact**).

ECONOMIC–ENVIRONMENTAL
Digital solutions, such as *industrial IoT, smart sensors, and big data analytics*, enable more factors of industrial performance to be monitored and improved, such as multi-objective optimisation to simultaneously reduce cost, energy, and waste while improving quality and productivity (**positive impact on the economy and the environment**). However, these technologies also present trade-offs as they require high initial investments (**negative economic impact**). In addition, digital technologies and advanced computing with *machine learning and artificial intelligence* also increase energy consumption and related emissions (**negative environmental impacts**).

SOCIAL-ENVIRONMENTAL
Circular economy calls for new ways to manage products through their entire life cycle. Digital solutions such as *Digital Product Passport (DPP), blockchain, carbon accounting and tracking software, and collaborative digital platforms,* enable material traceability and transparency to ensure responsible and ethical sourcing as well as enable circular solutions (**positive environmental and social impacts**).
Implementing circular strategies, such as repair, remanufacturing, and increasing the use of recycled materials, implies more variability and uncertainty in manufacturing operations. *Augmented Reality (AR)* can assist workers in complex tasks for circular manufacturing operations, such as disassembly, diagnostics, reprocessing, assembly, and quality control (**positive social and environmental impacts**). It can also be used to train workers on safety procedures, and equipment handling without exposing them to real-world hazards (**positive social impact**). However, the hardware and software also increase resource consumption and feed into the growing concerns about Waste Electrical and Electronic Equipment (WEEE) when these digital technologies are not deployed to fit into a circular economy (**negative environmental impacts**).

3 Digital Twins

Total: (4p)

3.1 Discuss the differences between Digital Prototype, Digital Model, Digital Twin, and Simulation Model. (2p)

- Digital Prototype: Greenfield scenario, no physical object exists, pre-step before building a digital model/twin

- Digital Model: Manual data flow only (a change in one object does not update the other object)
- Digital Twin: Automatic data flow in both directions (both objects update each other)
- Simulation Model: Virtual model for experimentation, simulations can take place in all steps (digital prototype-model-shadow-twin)

3.2 Discuss one challenge when implementing Digital Twins. (1p)

Main challenges are connectivity, data integration, keeping the model up-to-date over time, data quality, scalability, and model complexity

3.3 Discuss an example of how a Digital Twin could be used to improve sustainability in a production process. (1p)

Valid examples include discussing aspects related to energy optimization, waste reduction, resource efficiency, predictive maintenance, supply chain optimization, and product life cycle management.

4 XR in Manufacturing — ***Total: (2p)***

4.1 List and describe two pros and two cons of virtual training. (2p)

Mention at least 2 points of the following pros and cons.

Pros of virtual training:

- Reduced ramp-up
- Reduced lead time
- Cost-efficient
- Increased flexibility
- Improved learning
- Increased quality
- Reduced reworks
- Reduced non-value adding activities in live production
- Safer (like battery training)

Cons of virtual training:

- Physical connection missing
(weight, feeling, environment, motor skills...)
- Infrastructure for hardware and training material
- Cybersecurity
- Investment needed
- Resistance from operators and organization

5 Automation — ***Total: (4p)***

5.1 Provide an example of a product assembly process in which the operator is supported with both physical and cognitive automation.
Also, describe how this support is provided. (2p)

An ideal answer should include an example such as the assembly of doors for an automotive vehicle. In this scenario, the operator is supported by an automated nut tightener (physical automation) and receives instructions through light projections on AR/smart glasses (cognitive automation) indicating where the nuts should be assembled.

5.2 How can human-centred automation be effectively implemented on the shop floor? What specific tools and equipment should engineers utilise, and in what manner? (2p)

An ideal answer should demonstrate a clear understanding of human-centered automation and its principles. For instance, one could describe the use of collaborative robots to alleviate ergonomic strain and enhance both quality and utilization. Additionally, the implementation of power tools and XR technology can improve the operator's comprehension of the assembly process, thereby reducing both physical and cognitive demands.

6 Data — *Total: (4p)*

6.1 Design a data-driven project plan for a new predictive analytics initiative aimed at improving production line performance within a manufacturing industry. Structure your plan using the CRISP-DM (Cross-Industry Standard Process for Data Mining) framework. In your answer, clearly describe:

- The business problem or operational goal your project aims to address,
- The types and sources of data required for the analysis,
- The key tasks and deliverables within each CRISP-DM phase.

(3p)

One potential short answer:

Business problem: Improve production line efficiency by predicting machine downtime and quality issues.

Data required: Sensor readings, machine logs, maintenance records, production output, and quality inspection data.

CRISP-DM phases:

Business understanding: Define goals, e.g., reduce downtime, improve output.

Data understanding: Collect and explore production and sensor data.

Data preparation: Clean, integrate, and transform data for modeling.

Modeling: Apply ML models to predict failures and quality issues.

Evaluation: Assess model accuracy and business impact.

Deployment: Implement predictive system for real-time monitoring and decision support.

6.2 Artificial Intelligence (AI), Machine Learning (ML), Data Mining, and Data Science are key concepts in modern computing and analytics. The following definitions describe these concepts:

1) Extraction of interesting information or patterns from data in large databases.
2) A subset of Artificial Intelligence that develops algorithms that can learn from historical data.
3) A branch of computer science dealing with the simulation of intelligent behaviour in computers.
4) A multidisciplinary field that uses tools and techniques from data mining, AI, and ML.

The corresponding terms are:
a) Data Mining,
b) Machine Learning,
c) Artificial Intelligence,
d) Data Science.

Relate each definition (1-4) to the most suitable term (a-d), please motivate your answer. (1p)

Short answer:

1 → a) **Data Mining** – because it focuses on extracting patterns and insights from large datasets.
2 → b) **Machine Learning** – as it develops algorithms that learn from historical data.
3 → c) **Artificial Intelligence** – since it involves simulating intelligent behavior in computers.
4 → d) **Data Science** – because it integrates methods from AI, ML, and data mining to analyze data.
Motivation: Each definition aligns with the main purpose of the corresponding field: **Data Mining = pattern discovery**, **ML = learning from data**, **AI = simulating intelligence**, **Data Science = interdisciplinary data analysis**.

—— *END OF EXAM* ——