Public Summary

AI IMPLEMENTATION IN MANUFACTURING: AN APPROACH TOWARDS A VISUAL ROADMAP

As artificial intelligence (AI) rapidly transforms the manufacturing sector, companies are under increasing pressure to integrate these technologies in a manner that is not only innovative but also responsible and human-centred. This thesis addresses this challenge by developing a visual, design-based roadmap tailored to guide NTS, a Dutch high-tech manufacturer, and similar organisations towards responsible, context-sensitive AI adoption. The project's central aim is to provide a clear, actionable framework that balances technological advancement with organisational values and human expertise, by supporting sustainable innovation in complex industrial environments.

Background and Motivation

The motivation for this research comes from the increasing recognition that implementing AI in manufacturing is not just a technical challenge. Rather, it is a multifaceted process involving ethical considerations, organisational readiness, and the development of effective human-AI collaboration. NTS, as a leading player in ultra-precision manufacturing and mechatronic assemblies, exemplifies the type of organisation that must navigate these complexities. The absence of a one-size-fits-all solution and the risk of rushed and misaligned adoption highlight the need for a structured, adaptable approach that can evolve alongside technological and organisational change.

Research Objectives and Methodology

The main objective of the thesis is to develop a roadmap that systematically incorporates both the opportunities and challenges of AI implementation, with the purpose of guiding NTS towards responsible and context-sensitive adoption. The research is guided by the following question:

How can a visual roadmap be developed to systematically incorporate both the challenges and opportunities of AI implementation, in order to guide companies such as NTS towards a more responsible and context-sensitive adoption process?

To address this, the study employs an iterative, design-based methodology inspired by Integrated Product Development (IPD) and sociotechnical systems thinking. The process unfolds in several stages:

- **Literature Review:** Establishes a theoretical foundation by synthesising academic and industry perspectives on responsible AI adoption, with a focus on ethical governance, organisational infrastructure, technical implementation, and human-AI collaboration.
- **Stakeholder Engagement:** Gathers insights and priorities from NTS personnel to ensure relevance and contextual accuracy.

- **Information Mapping:** Organises findings into structured matrices, mapping dependencies and interconnections across three foundational pillars: People, Technology, and Organisation.
- **Iterative Development:** Translates mapped insights into a visual framework, refined through stakeholder feedback and practical evaluation.

The research identifies three interdependent pillars as critical to responsible AI adoption:

1. **People:** Emphasises skills development, ethical awareness, and the design of human-AI cooperation protocols.
2. **Technology:** Focuses on data quality, explainability, integration with legacy systems, and technical robustness.
3. **Organisation:** Addresses leadership alignment, governance structures, cultural readiness, and strategic planning.

These pillars are operationalised through a construction site metaphor, which structures the roadmap into three sequential layers:

- **Foundation Layer:** Establishes prerequisites such as stakeholder alignment, ethical guidelines, and data readiness.
- **Core Layer:** Builds robust processes, technical systems, and collaborative practices between humans and AI.
- **Feature Layer:** Represents advanced, value-adding AI applications and innovative practices tailored to organisational goals.

Mapping Opportunities and Challenges

A key aspect of the project is the dual-matrix approach, which maps both opportunities (e.g., process optimisation, knowledge management, hybrid human-AI roles) and challenges (e.g., data quality, skills gaps, trust, integration with legacy systems) across the three pillars. Stakeholder surveys evaluate the relevance and urgency of each item, using standard deviation and median scores to prioritise actions and identify areas of consensus or divergence.

The roadmap visually distinguishes between challenges (depicted as structures under construction or requiring repair) and opportunities (fully defined blocks), using colour coding to represent the three pillars. Assessment checkpoints are integrated to encourage regular evaluation and adaptation.

Results and Evaluation

The final roadmap was evaluated against a set of requirements derived from both literature and stakeholder input, focusing on visual clarity, relevance, usability, adaptability, and alignment with organisational values. Stakeholder interviews confirmed that the roadmap:

- Provides a clear, intuitive overview of the AI adoption landscape.
- Facilitates structured, human-centred discussions about technology, people, and organisational change.
- Supports prioritisation and strategic planning by making complex interdependencies accessible to diverse audiences.

However, feedback also highlighted areas for further refinement, such as the need for a clearer entry path, step-by-step guidance, and the potential for digital or interactive formats to enhance long-term utility.

Conclusions and Future Directions

This thesis demonstrates that a visual, design-driven approach can effectively support responsible AI adoption in manufacturing by bridging the gap between abstract frameworks and practical, context-specific action. The roadmap offers a flexible and scalable tool that not only clarifies the interplay between people, technology, and organisation but also fosters alignment and ongoing dialogue among stakeholders.

While the current version serves as a robust foundation, future iterations should incorporate more detailed action paths, interactive features, and impact-effort analyses to further enhance its applicability and value. Ultimately, the approach developed for NTS is designed to be adaptable, offering a model for other organisations seeking to balance innovation with ethical and human-centred principles in the era of AI-driven transformation.