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Data-Driven Decision Support in Systems Engineering Using Linked Descriptive and Analytical Models

Master's Thesis Proposal

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Project Portal: https://sadra-hub.github.io/thesis

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1 Master's Thesis Proposal

Supervision and Program Details

- **Proposed Internal Supervisor:** Dr. Pascal Etman (TU/e)
- **External Supervisor:** Pieter Goosen (TNO)
- **Study Load:** 45 ECTS (32 weeks full-time)
- **Program:** MSc Artificial Intelligence & Engineering Systems

1.1 Background

In complex engineering domains, system design decisions are often supported by a combination of descriptive models (architecture, requirements, functions) and analytical models (simulations, performance analysis). Traditionally, these models are disconnected and exist in separate tools or file formats, requiring manual translation by human engineers. This creates information silos, inconsistencies, and inefficiencies in decision making, particularly in large organizations where tools and stakeholders vary widely.

The System Engineering Research Center (SERC), led by Tom McDermot, has proposed connecting descriptive and analytical models through linked data graphs. This enables traceability, dynamic feedback, and scalable integration between systems thinking and data analytics. Key enabling technologies include system modeling languages (e.g., SysML v2), ontologies, and semantic web standards (e.g., RDF/OWL).

This project explores this frontier by building a lightweight implementation of a data integration layer, drawing inspiration from the SERC demonstrator and applying it within a high-tech or healthcare-relevant use case under the guidance of TNO-ESI. The focus is on systems engineering as the core, with AI as a potential enhancement when it clearly adds value.

1.2 Project Goal

Develop and demonstrate a minimal viable environment for model-based decision support by:

- Connecting descriptive models (e.g., SysML representations) to analytical models via a structured data graph.
- Supporting traceability and a simple decision analysis across this connected model set.
- Identifying and characterizing opportunities where AI can improve productivity or decision quality.

Optional (time permitting):

- Implement a basic AI method (e.g., surrogate modeling, ontology assistance, or design space exploration) targeting one productivity bottleneck identified during the first phase.

1.3 Research Method

The research follows a phased, agile-style approach.

Phase 1: Systems Engineering MVP

1. **Literature & Tooling Review:** Explore frameworks for MBSE, semantic integration, and decision analysis.
2. **Model Linking Implementation:**
   - Select or define a minimal descriptive model (e.g., system architecture in SysML or a structured format).
   - Connect to at least one analytical model (e.g., performance simulation).
   - Use a graph-based data structure (e.g., RDF store) to create traceable links.
3. **Demonstration:** Implement a decision analysis scenario using the linked model (e.g., performance trade-off, impact of a design change).
4. **Evaluation:** Measure time, complexity, and tooling effort; identify productivity challenges.

Phase 2: AI Opportunity

1. **Bottleneck Analysis:** Identify a workflow component where AI can add value.
2. **Prototype AI Enhancement:** Apply or experiment with an AI method.

Use Case Domain: ideally aligned with TNO-ESI projects:

- High-tech printing systems
- Electron microscopy systems (e.g., Thermo Fisher Scientific)
- Biomedical applications with healthcare relevance (e.g., MRI workflow)

1.4 Planning (32 Weeks Full-Time)

Weeks	Activities
1–4	Literature review, scope finalization, setup tooling
5–8	MVP architecture and ontology/data graph design
9–16	Implementation: connect descriptive and analytical models
17–20	Run decision analysis scenario; evaluate integration effort
21–24	Identify and prioritize AI opportunities
25–28	Implement small AI proof-of-concept
29–32	Finalize thesis, prepare presentation and defense

1.5 Deliverables

- Working prototype of model linking and decision support demo
- Evaluation report with metrics on effort, integration difficulty, and AI potential for TNO future use cases.
- Master's thesis document suitable for publication (TU/e compliant).

1.6 Integrity and Dissemination

This graduation project adheres to the TU/e Code of Scientific Integrity. Results will be made public via the TU/e library unless an embargo is requested in accordance with TNO or project partner confidentiality policies. Publication of the research is encouraged.

1.7 Notes

- The project will be performed in collaboration with TNO-ESI, including a formal internship arrangement.
- Regular meetings with both TU/e and TNO supervisors will ensure academic rigor and practical relevance.
- This project remains industry-agnostic to maximize learning.