Towards a Hybrid Process Model Approach in Production Systems Engineering

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Context

- Production Systems Engineering (PSE).
- Discrete high-speed Manufacturing Systems (countable parts).
- Multi-disciplinary Engineering Teams (i.e., mechanical, software, electrical engineering).
- Sequential and loosely coupled engineering processes and tools (e.g., manual data exchange).

Goals:
- Initiate an Improvement Process at our Industry Partner (Industrial Case Study).
- Establish a hybrid process combined with an improved data model to support (a) efficient data exchange, (b) reuse of engineering knowledge, and (c) traceability of design decisions.
Challenges of Selected Life Cycle Phases in PSE

- C1: Limited Data Exchange Capabilities: Pre-Project Phase vs. Engineering Phases.
- C2: Limited Information Backflow and Reuse of Engineering Knowledge.
Concept: Product – Process – Resource (PPR)*

- Goal: Establish a **hybrid process** combined with an **improved data model** to support (a) efficient data exchange, (b) reuse of engineering knowledge, and (c) traceability of design decisions.

- **Product** to be constructed by the production facility (Bill of Material).
- Production **Process** defines how the product is constructed (Bill of Operation).
- Production **Resources** facilitate process execution and product construction.

Research Issues

From sequential PSE processes to hybrid PSE processes with PPR support:

RI.1: What are the **basic requirements** for a hybrid process approach that supports early life cycle phases in PSE?

RI.2: **How can the PPR concept support the PSE process?** (Extension of a data model required)

RI.3: What is the design of a **candidate hybrid process** with PPR that supports the effective and efficient engineering of PSE projects?
Case Study Design

Following the Design-Science Approach*:

1. **Problem Investigation and Process Modeling.**
   - As-it-is Analysis based on selected stakeholder groups.
   - Identification of project workflows based on BPMN.

2. **Design (of a hybrid engineering process)**
   - Elicitation of process requirements (based structured interviews) – RI.1
   - Integrating the PPR Concept – RI.2
   - Design of a hybrid engineering process – RI.3

3. **Validation with domain experts**
   - Step 1: Basic validation from engineering management perspective.
   - Step 2: Evaluation of domain experts (e.g., basic planners, mechanical, electrical, and software engineers) to cover discipline specific views.

4. **Implementation & 5. Validation** will be supported by the case study team as future work.

As-it-is Analysis based on six domain expert interviews (2 hrs. each)

- Pre-Project Phase (Basic Engineering): 2 domain experts.
- Project Phase (Detail Engineering): 4 domain experts.

→ Output: Offer to the customer.

→ Output: Production System (Variants).

→ Output: Parameter Settings & Knowledge.
Extracted & Identified Requirements (Rx):

- **Collaboration and coordination** between engineering groups (R1).
- **Exchange of engineering artifacts, data, and knowledge** (R2).
- **Backflow integration** from operation & detailed engineering to basic engineering (R3).
- **Tracing design decisions** throughout the engineering process (R4).
- **Risk minimization** through less human reworking effort (R5).

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<th>C2. Information Backflow</th>
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D1. Product (P) and Process (P’) knowledge is available and present.

D2. Resource (R) knowledge available, Product (P) and Process (P’) not available → important but not critical.

D3. Resource (R) knowledge available, Product (P) and Process (P’) not available → critical.
C1. Limited Artifact Exchange
• New: Basic Engineers explain Design Decisions to Detailed Planners.

C2. Information Backflow
• New: Investigation of reuse capabilities based on existing projects.
• New: Coordination task after engineering completion for reuse purposes.

C3. Traceability
• Adaption: record and report design decisions to be more explicit (for tracing purposes).
Results – Comparison of different approaches

Process Model Approaches:
• Manual process
• V-Model approach
• Agile Approach (e.g. Scrum)
• Hybrid PPR process

Conceptual Evaluation of
• Expected Benefits
• Expected Limitations

based on
• Industry Partner Workshops.
• Domain Expert Interviews.

Comparison of selected process model approaches vs. PSE Challenges.

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Comparison of selected process model approaches vs. PSE Requirements.

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Discussion & Limitations

Discussion

• **RI.1.** Five identified **critical PSE requirements**: Need for support for (a) collaboration, (b) artifact exchange, (c) Backflow integration, (d) Decision tracing, and (e) Risk minimization.

• **RI.2.** PPR Concept can help to extend existing engineering processes to close gaps in the engineering process.

• **RI.3.** The proposed **hybrid process approach** promises to overcome limitations of traditional (sequential) process approaches and was confirmed by domain experts.

Limitations

• Study size, focus on a selected project at the industry partner (pilot project), limited number of interview partners, selected set of (important) engineering processes, conceptual evaluation.
Conclusion and Future Work

Conclusion

- The proposed **hybrid process** combined with an **improved data model** can support (a) efficient data exchange, (b) reuse of engineering knowledge, and (c) traceability of design decisions in context of PSE projects.

- Positive feedback from industry stakeholders at our industry partner.

Future Work

- Limitations need to be addressed.

- Implementation of the purposed hybrid process approach and evaluation in industry context.

- Improving the process approach and evaluation in larger industry contexts.