Towards a Hybrid Process Model Approach in Production Systems Engineering

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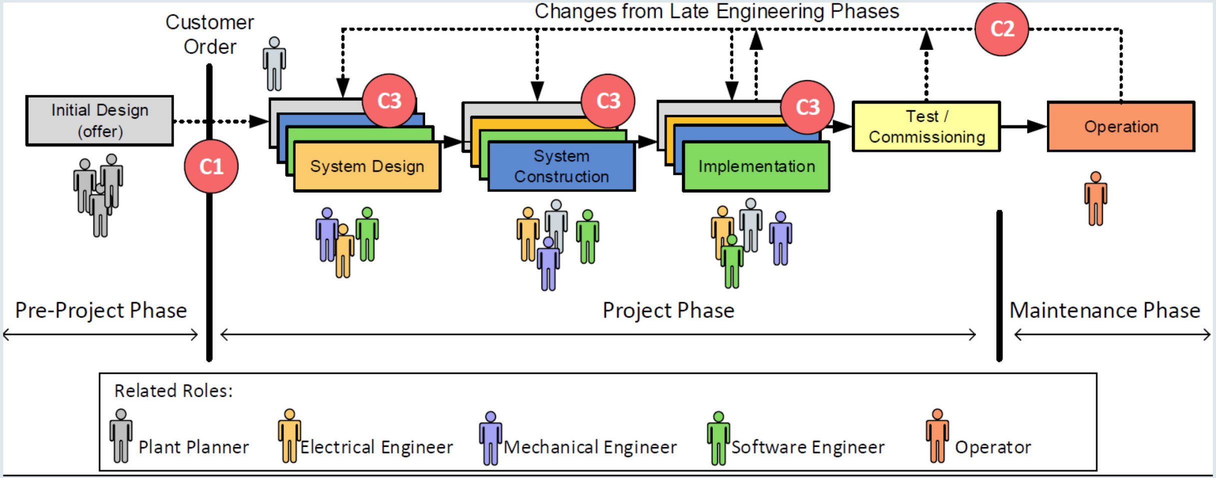
Context

- 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.

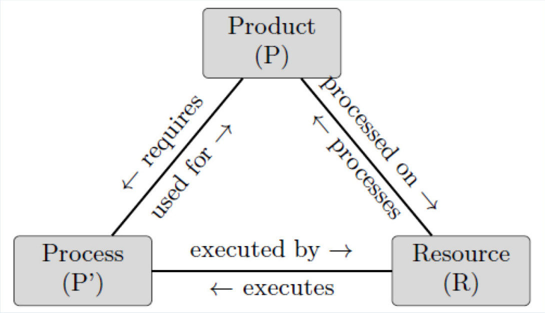
Challenges of Selected Life Cycle Phases in PSE



- C1: Limited **Data Exchange** Capabilities: Pre-Project Phase vs. Engineering Phases.
- C2: Limited **Information Backflow** and **Reuse of Engineering Knowledge**.
- C3: Limited **Traceability** of Design Decisions between Engineering Phases.

Concept: Product – Process – Ressource (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.

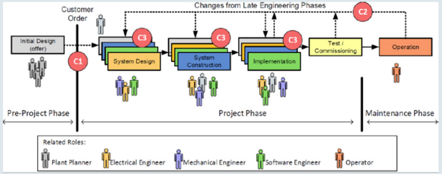


- **Product** to be constructed by the production facility (Bill of Material).
- Production **Process** defines how the product is constructed (Bill of Operation).
- Production **Resources** facilitate process execution and product construction.

*M. Schleipen, A. Lüder, O. Sauer, H. Flatt, and J. Jasperneite. Requirements and concept for plug-and-work. at-Automatisierungstechnik, 63(10):801-820, 2015.

Research Issues

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



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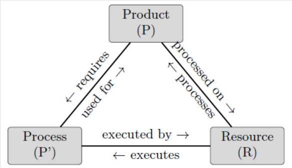

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RI.1: What are the **basic requirements** for a hybrid process approach that supports early life cycle phases in PSE?

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*:

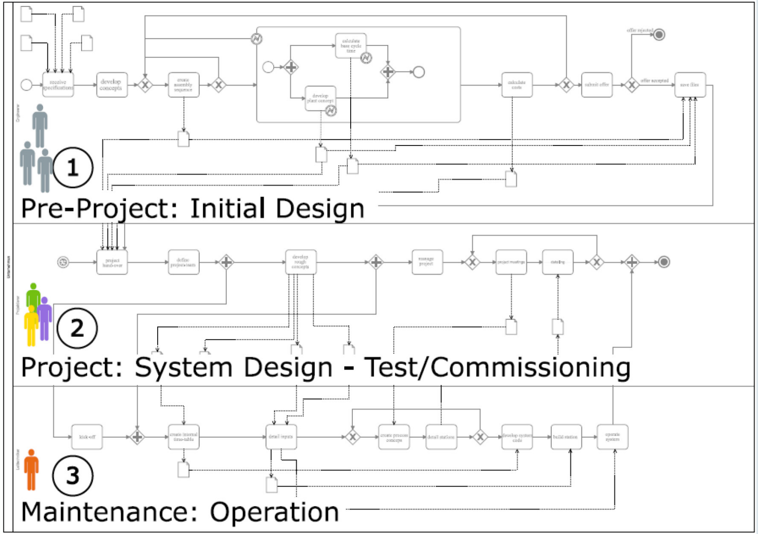
1. **Problem Investigation and Process Modeling**.
   - As-it-is Analysis based on selected stakeholder groups.
   - Identification of project workflows based on BPMN.
2. **Design (of a hybrid engineering process)**
   - Elicitation of process requirements (based structured interviews) – RI.1
   - Integrating 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.

*R. Wieringa. Design science methodology for information systems and software engineering. Springer, Berlin [u.a.], 2014.

Results - Problem Investigation & Process Modeling (1)

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.

Results - Problem Investigation & Requirements (RI.1)

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).

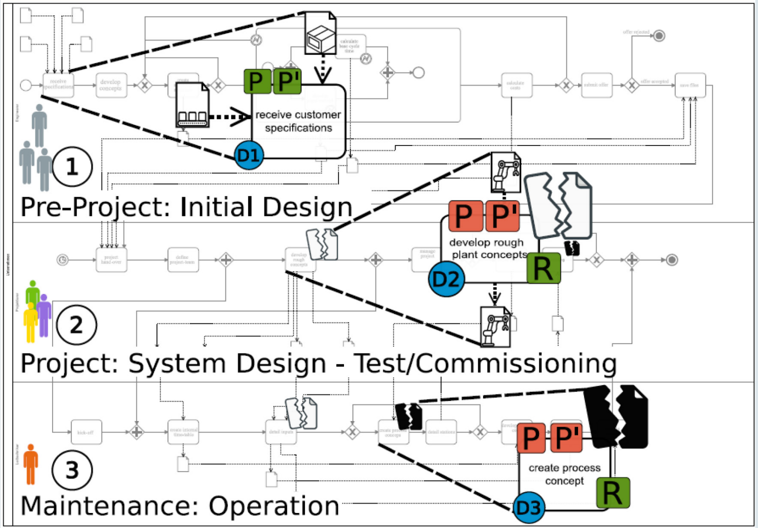
	C1. Data Exchange	C2. Information Backflow	C3. Traceabiliy
R1. Collaboration	X	X	X
R2. Exchange	X		X
R3. Backflow Integration		X	
R4. Decision Tracing	X		X
R5. Risk Minimization	X	X	X

Results – Analysis of PPR Concept Applicability (RI.2)

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.



Results – Hybrid Process Approach (RI.3)

C1. Limited Artifact Exchange

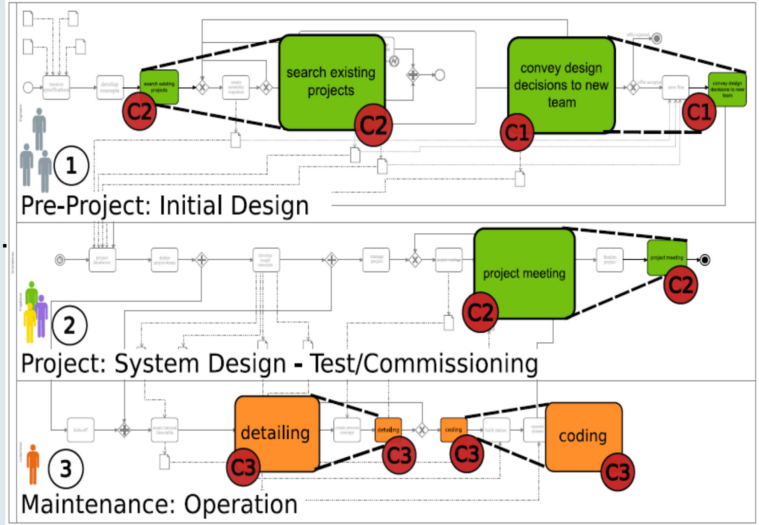
- New: Basic Engineers explain Design Decisions to Detailed Planners.

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 – Comparision of different approaches

Process Model Approaches:

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

Comparison of selected process model approaches vs. PSE Challenges.

	Manual Approach	V-Model Approach	Scrum	Hybrid PPR Process
C1. Data Exchange	-	-	O	+
C2. Information Backflow	-	O	+	+
C3. Traceability	-	O	O	+

Conceptual Evaluation of

- Expected Benefits
- Expected Limitations

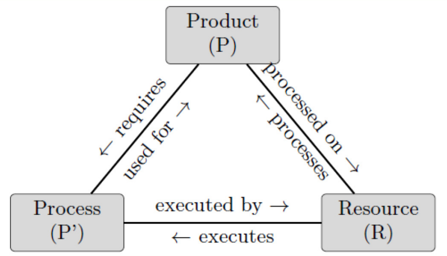
based on

- Industry Partner Workshops.
- Domain Expert Interviews.

Comparison of selected process model approaches vs. PSE Requirements.

	Manual Approach	V-Model Approach	Scrum	Hybrid PPR Process
R1. Collaboration	-	-	+	+
R2. Exchange	-	-	O	+
R3. Backflow Integration	-	O	+	+
R4. Decision Tracing	-	-	O	+
R5. Risk Minimization	-	O	O	+

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

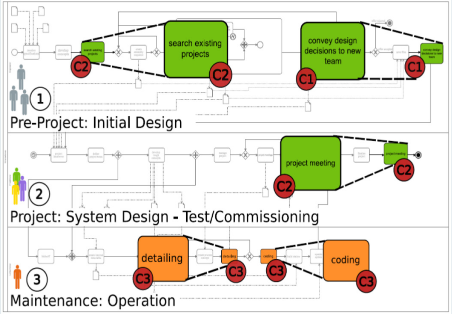
Conclusion

- 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.

Hybrid Process Approach with PPR



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