Quality Risks in the Data Exchange Process for Collaborative CPPS Engineering

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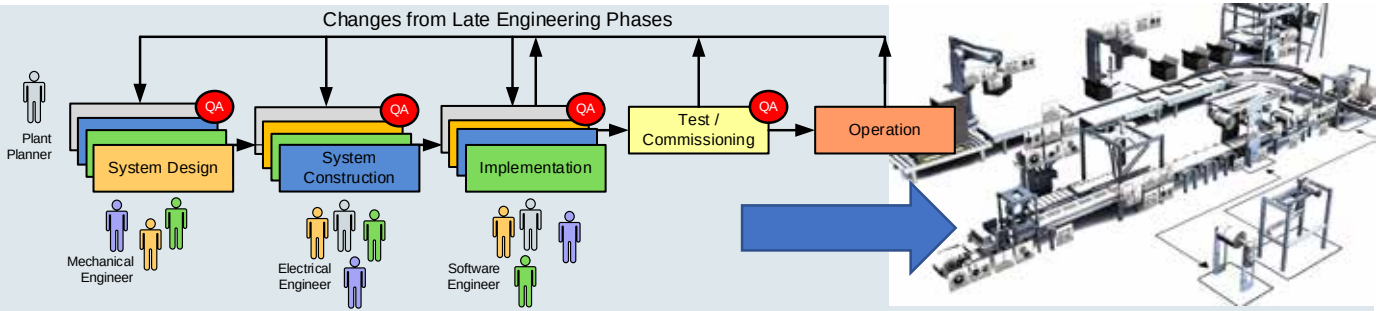
Context & Goal



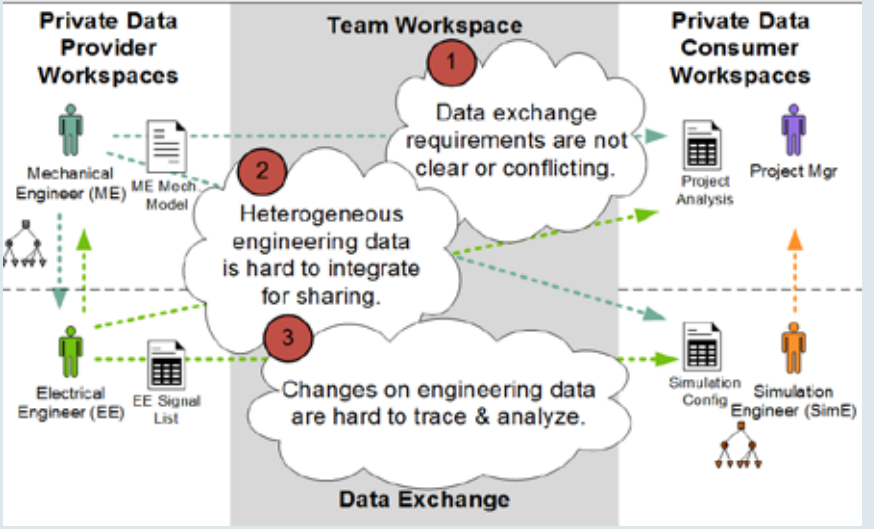
Context:

- Cyber-physical production systems.
- Multi-disciplinary and heterogeneous engineering environment with parallel and collaborating working groups.
- *Description Languages (DLs)* of discipline-specific (isolated) engineering views hinder efficient data exchange and lead to *quality risks* (associated with *Technical Debt*).

Goal:

- Investigate *Quality Risks (Technical Debt)* of description languages (DLs) for engineering data exchange between workgroups.

Challenges in CPPS



1. Data Exchange Requirements are not clear or conflicting.
2. Heterogeneous data is hard to integrate for sharing.
3. Changes on engineering data are hard to analyze and trace.

Related Work: CPPS & Description Languages

Data exchange in CPPS environment:

- Increasing parallelism.
- Standardized data exchange formats such as AutomationML, STEP or XMI.

Engineering data logistics to facilitate efficient engineering data exchange between data producers and data consumers.

Description Languages (DL) :

- Represent engineering information, with symbols, syntax and semantics, e.g., *.csv, *.xml, SysML, Petrinets.
- Selected best practices for an engineering organization according to VDI 3695 [31]:
    - Description languages are structured.
    - The DLs describe identical facts always equally.
    - The DLs are coupled with each other.
    - The DLs can be converted into each other.

[31] Verein Deutscher Ingenieure. Richtlinie 3695: Engineering von Anlagen - Evaluieren und Optimieren des Engineerings. VDI-Verlag, Düsseldorf, 2009.

Related Work: Technical Debt (TD)

Technical Debt:

- Concept from software engineering to communicate disadvantages with respect to deviations from best practices.

Definition: “TD are **violations** in engineering artifacts **compared to best practices** of engineering process **documentation** and **configuration** for collaborative workgroups in the PSE domain.” (adapted from [15])

- TD Item: “A TD item is a unit of TD in a software system”
- TD Cause: “The reason for the existence of TD”
- TD Effect: “A sign manifesting the existence of TD”

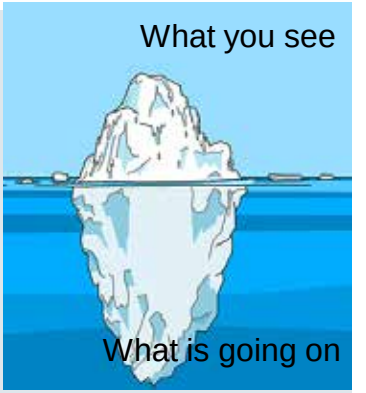
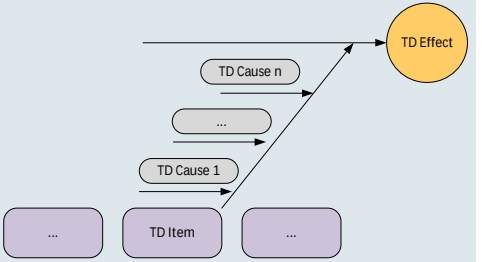


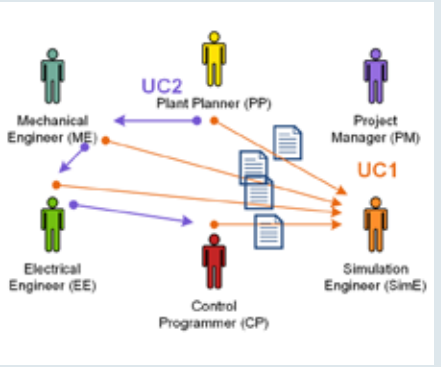
Image by MotoOo from Pixabay.

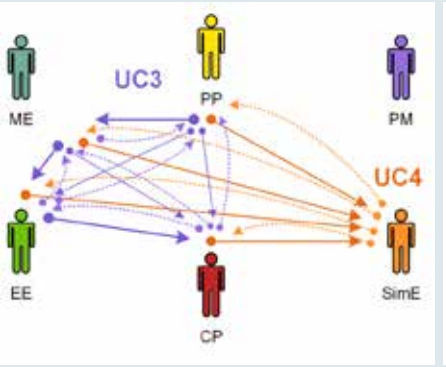


Schematic Overview on TD aspects.

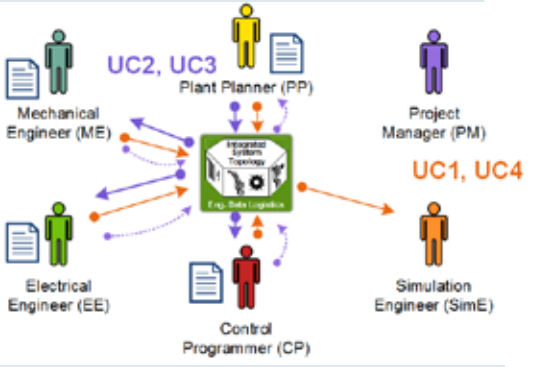
[15] Z. Li, P. Avgeriou, and P. Liang, “A systematic mapping study on technical debt and its management,” Journal of Systems and Software, vol. 101, pp. 193–220, 2015.

Use Cases: Data Exchange via Engineering Data Logistics





Basic Use Cases (Data Flows)



Basic Use Cases with Data Logistics

Selected Use Cases from industry partners by example

- UC 1: Data for production system simulation (data consumer).
- UC 2: Provide artifacts, such as plant topology (data provider).
- UC 3: Sequential / parallel enrichment of artifacts (data producer / consumer).
- UC 4: Information Backflows (data producer / data consumer).

Research Questions & Approach

Research Questions:

- RQ.1: What are technical debt (TD) *effects* in the data exchange process of collaborative CPPS engineering?

?

- RQ.2: How do *TD effects* relate to *TD items* and *TD causes*
  a) in the data exchange process of collaborative CPPS engineering and
  b) the Engineering Organization (EO)?

?

Research Approach:

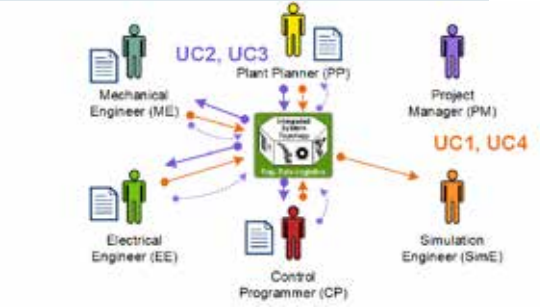
- Case Study at a large scale engineering company (steel mill engineering).
  - Results derived from two workshops and semi-structured interviews with company partners (involving 28 domain experts from 12 workgroups).
  - Informal validation with domain experts and practitioners.
- TD Effects à TD Items à TD Causes à Alignment of Effects, Items, and Causes.

RQ.1 – Results –Observed TD Effects

TD effect I: High Effort and Duration of Data Integration

- Heterogeneous data sources.
- Effort for Data Extraction.
- Effort for Data Transformation.
- Effort for finding data.

à unplanned effort for conflict detection & rework.



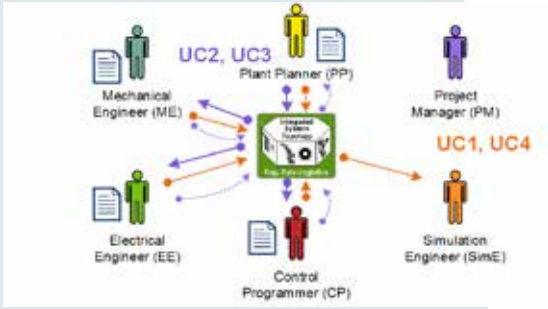
TD effect II: Data Quality of Exchanged Data at Risk

- Both influenced by syntax and semantics.
- Different levels of data maturity throughout project phases.
- Meta information rarely documented.

à Wrong or divergent interpretation of exchanged data may lead to wrong or low-quality design decisions.

RQ.2a – Results – TD Items and Causes

Focus on relationships between TD effects, TD items, and potential causes in the data exchange process.



Identified TD Items

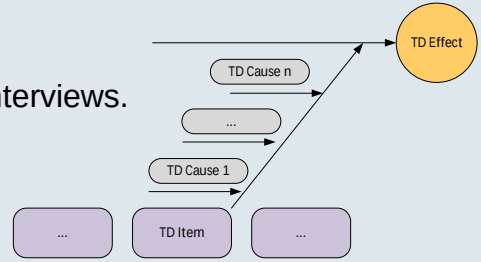
- TD Item 1: Description Languages Incompatible for Data Exchange.
- TD Item 2: Description Languages are Hard to Map for Data Exchange.
- TD Item 3: Semantic Descriptions Inadequate for Data Exchange.

Identify TD Causes

- Based on literature and industry partner workshops / interviews.

Alignment of TD Effects, TD Items, TD Causes

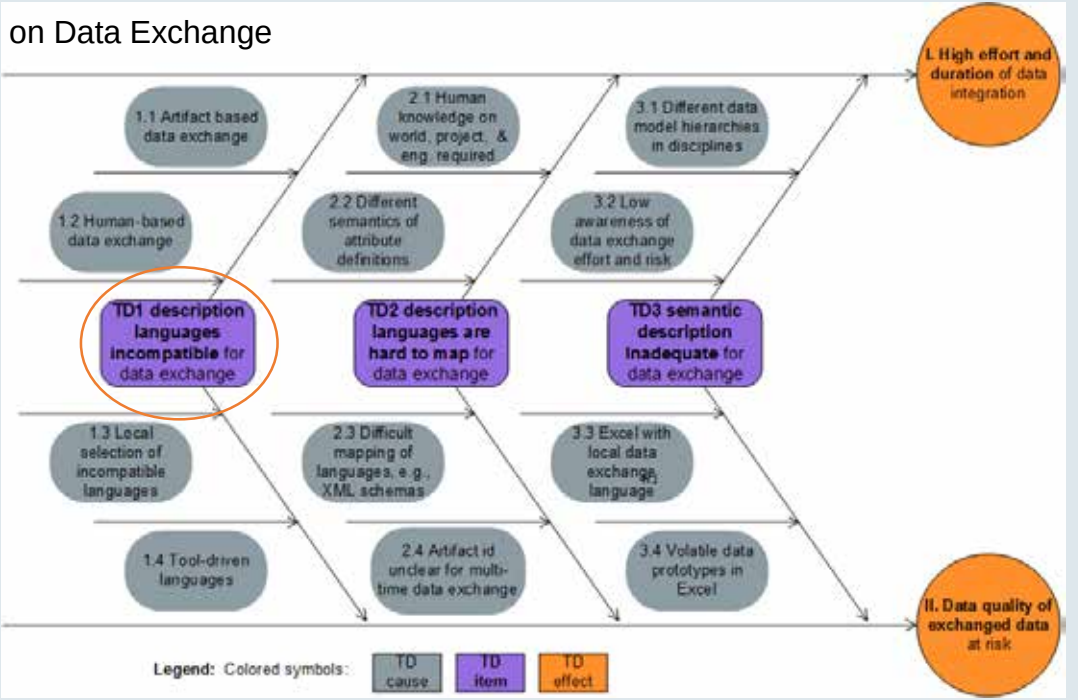
- Map TD Items and Causes to TD Effects.



Schematic Overview on TD aspects.

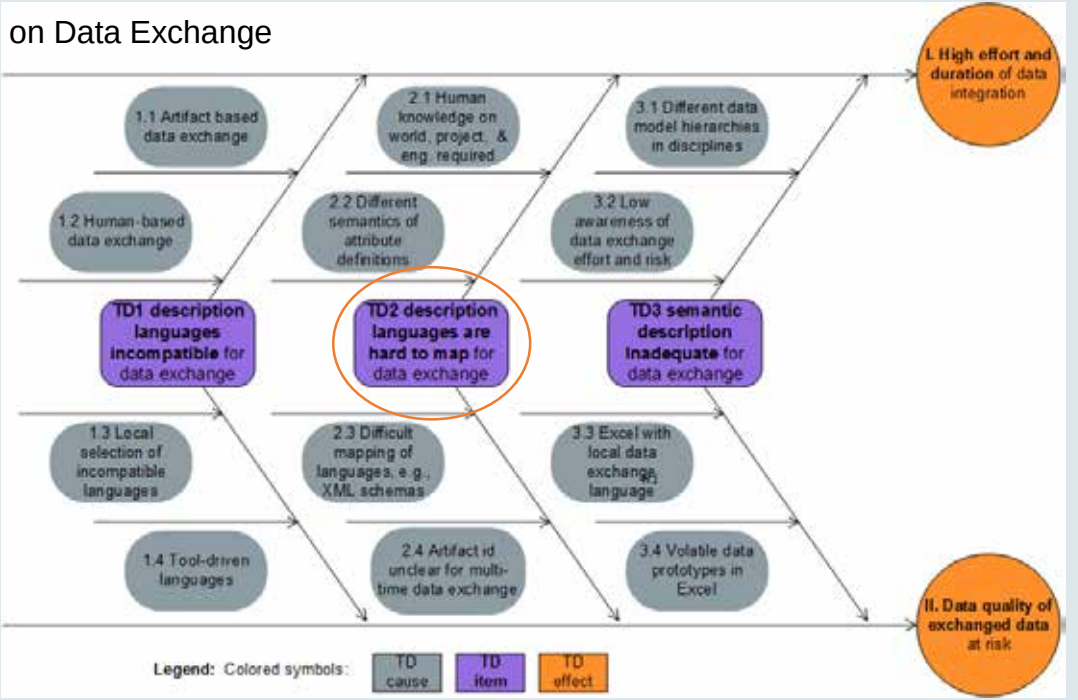
TD Item 1: Description Languages Incompatible

Focus on Data Exchange



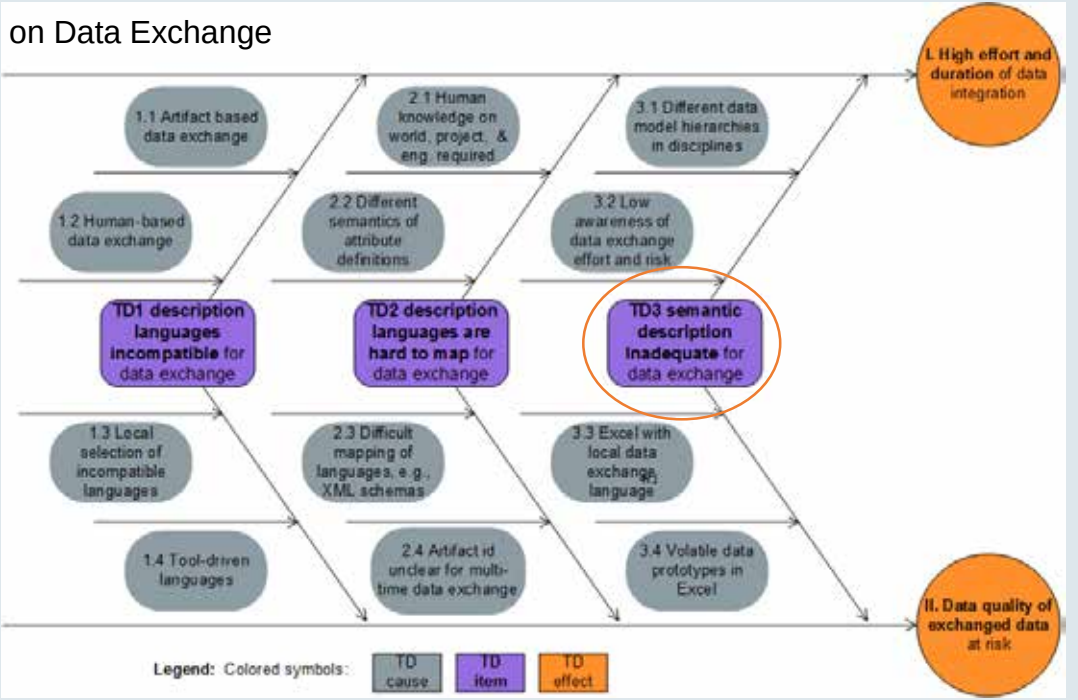
TD Item 2: Description Languages are Hard to Map

Focus on Data Exchange



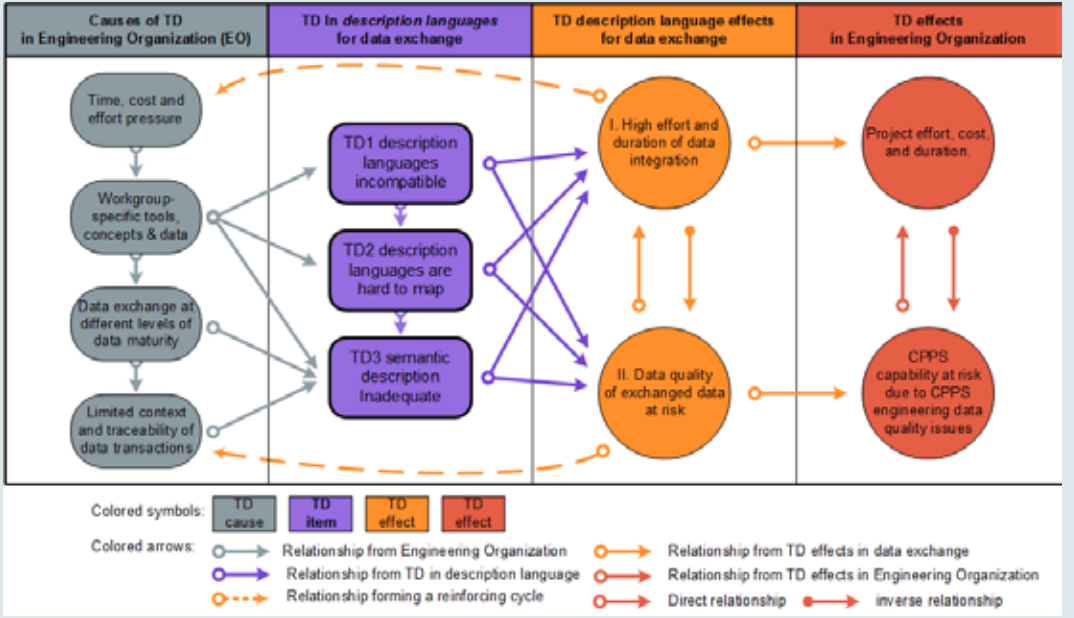
TD Item 3: Semantic Descriptions Inadequate

Focus on Data Exchange



RQ.2b –Feedback Loops between Effects and Causes

Focus on Feedback cycles on organizational level for prioritization of efforts and repayment options.



Summarized Results

RQ.1: Technical Debt (TD) effects in the data exchange process of collaborative CPPS engineering.

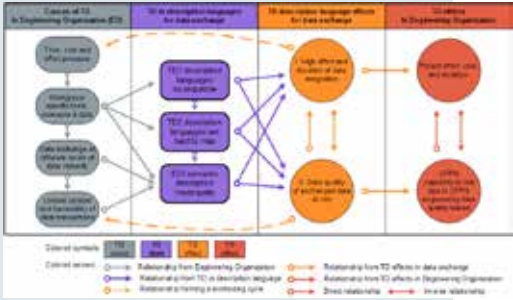
- Based on an exploratory study at our industry partner.
- Two critical TD **effects** have been identified.

RQ 2: Relationship of TD effects, items, and causes

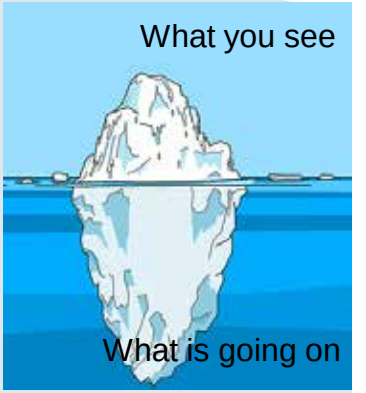
- Three **TD items** and a set of **candidate causes** were identified.

- RQ.2a Practitioners found this approach useful for analyzing Technical Debt (and quality risks).

- RQ.2b. Manager found the feedback cycle useful to identify effects of TD items regarding description languages in CPPS and to prioritize repayment options to reduce TD effects.



Limitations, Conclusions, and Future Work



Limitations

- Domain experts from one company.
- Result is an initial cause-effect diagram.
- Focus on description languages for data exchange.

Conclusions

- The selection of *description language* is important for engineering results.
- *Tool selection* has a large impact on the efficiency of data exchange.
- Feedback cycles support identifying TD for data exchange on project level and for feedback on organizational level.

Future Work

- More detailed evaluations within the case study organization.
- Broaden the scope by involving additional company partners in different domains.
- Consideration of security measures.

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