The LinkedDesign approach to semantic modelling for design and manufacturing

Dimitris Kiritsis

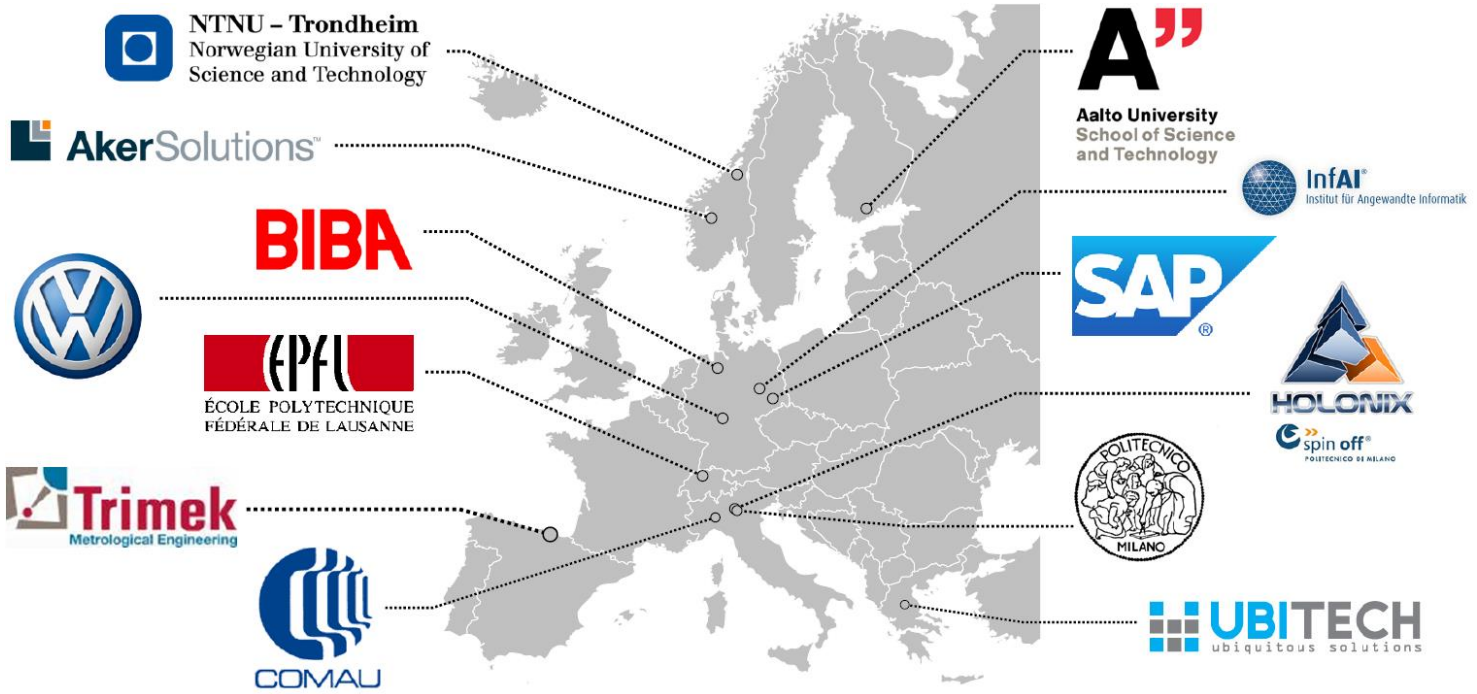
EPFL, ICT for Sustainable Manufacturing

dimitris.kiritsis@epfl.ch

Outline

- Introduction
- The LinkedDesign project
- USM method
- Reusable resource
- From backlog to ontology
- Meta-model of USM process
- ADOxx :
    - USM
    - Reusable resources
    - Concept definition
    - Object properties
- Final met-model
- Conclusion

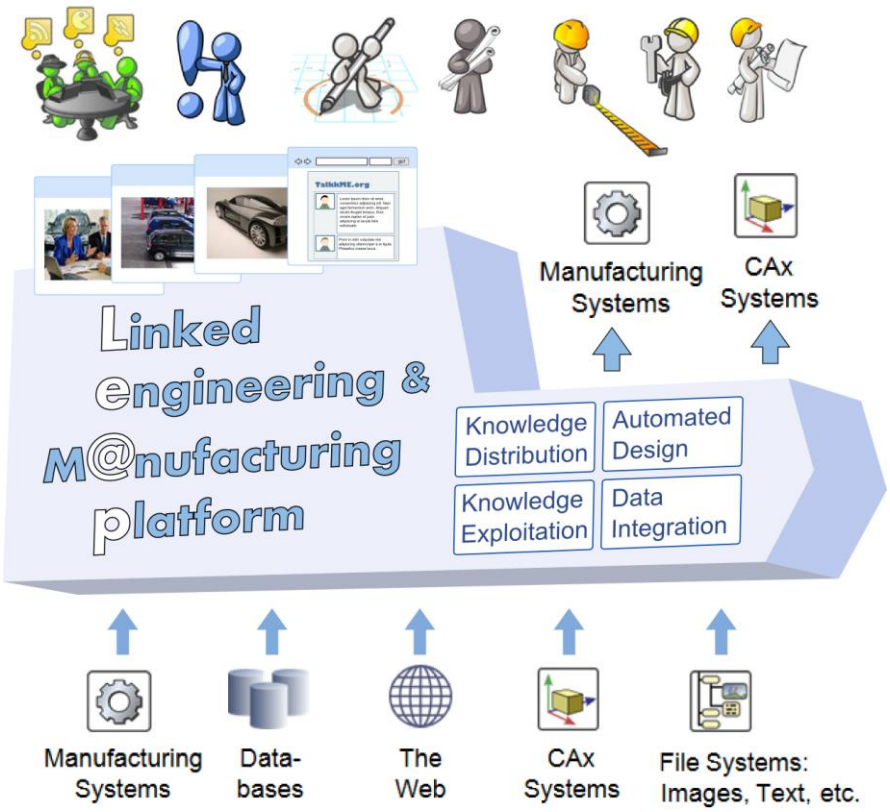
Linked Knowledge in Manufacturing, Engineering and Design for Next-Generation Production



Project Vision

Provision of

- a holistic view on data, persons and processes across the full product lifecycle.
- by integrating all relevant product lifecycle information incl. novel information sources in LEAP
- to improve the design, efficiency and sustainability of products and processes in manufacturing



LinkedDesign enables

Data federation

- across trusted sources in the product lifecycle
- independent of its format, location and origination time

Context-driven access and analysis of federated information

- integrated role-driven information access
- manufacturing-specific data analytics such as simulations and sentiment analysis

User collaboration

- collaboration workbench to foster cross-discipline user collaboration and information exchange

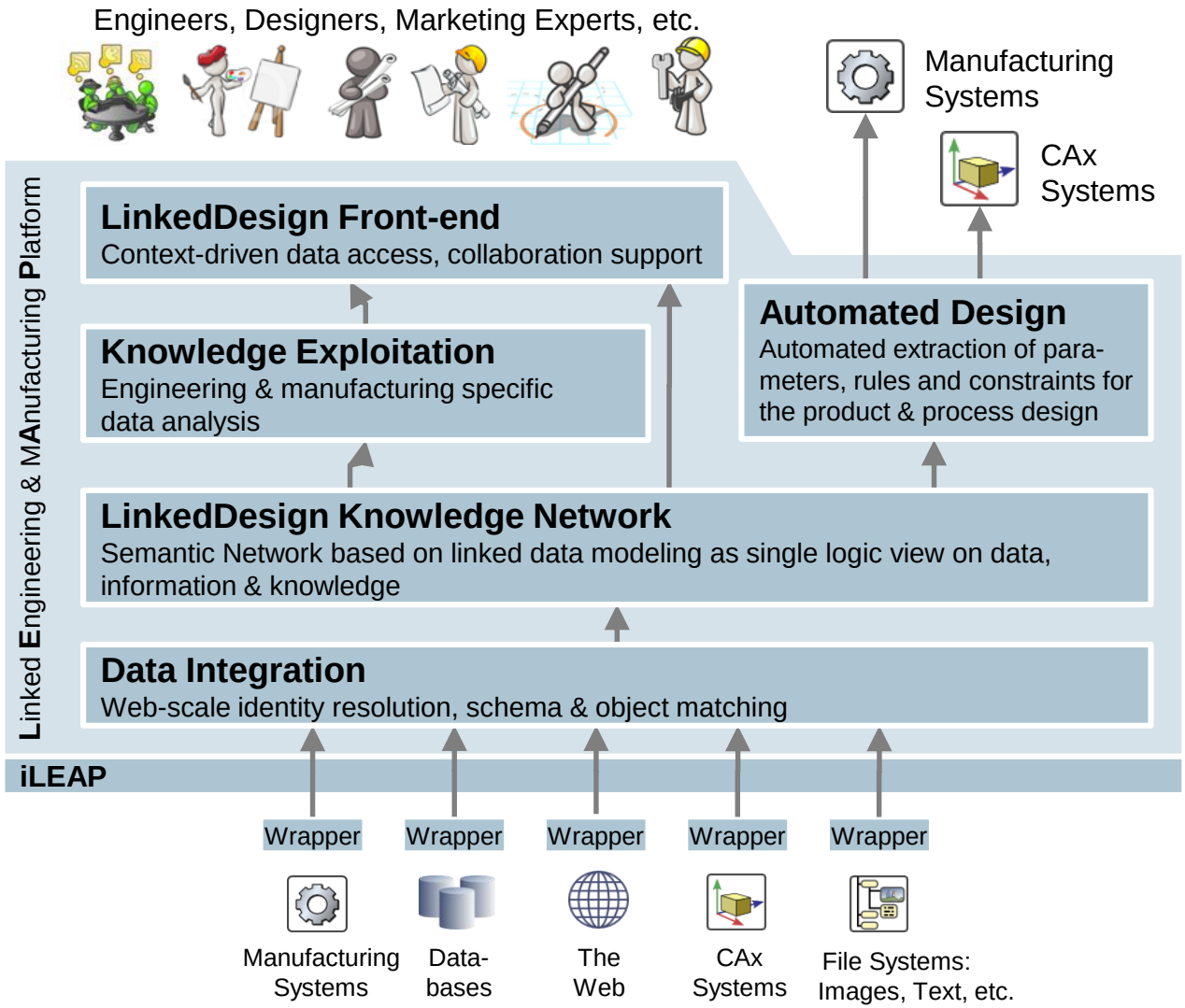
Feedback into existing systems

- backwards integration of enriched information
- connections to engineering systems (e.g. CAx)

Application Scenarios & Demonstrators

Academia	NTNU – Trondheim Norwegian University of Science and Technology; BIBA; InfAI Institut für Angewandte Informatik; Aalto University School of Science and Technology; Politecnico di Milano; EPFL École Polytechnique Fédérale de Lausanne		
SMEs	Holonix; UBITECH ubiquitous solutions; Trimek Metrological Engineering		
Industry	AkerSolutions; COMAU; SAP; Volkswagen		
Application Prototypes	Knowledge Re-use and Collaboration in Automated Design for Offshore Engineering	Manufacturing Design based on Plant Lifecycle Costs	Metrology-driven Manufacturing in the Automobile Industry
Demon-strators	Virtual Obeya Automated Design	Lifecycle Design Optimisation	Manufacturing Quality Control

Research Topics



LinkedDesign Ontology

- ✓ Generic and lightweight
- ✓ Reusable in different industrial applications

LinkedDesign

isSpecialization

isSpecialization

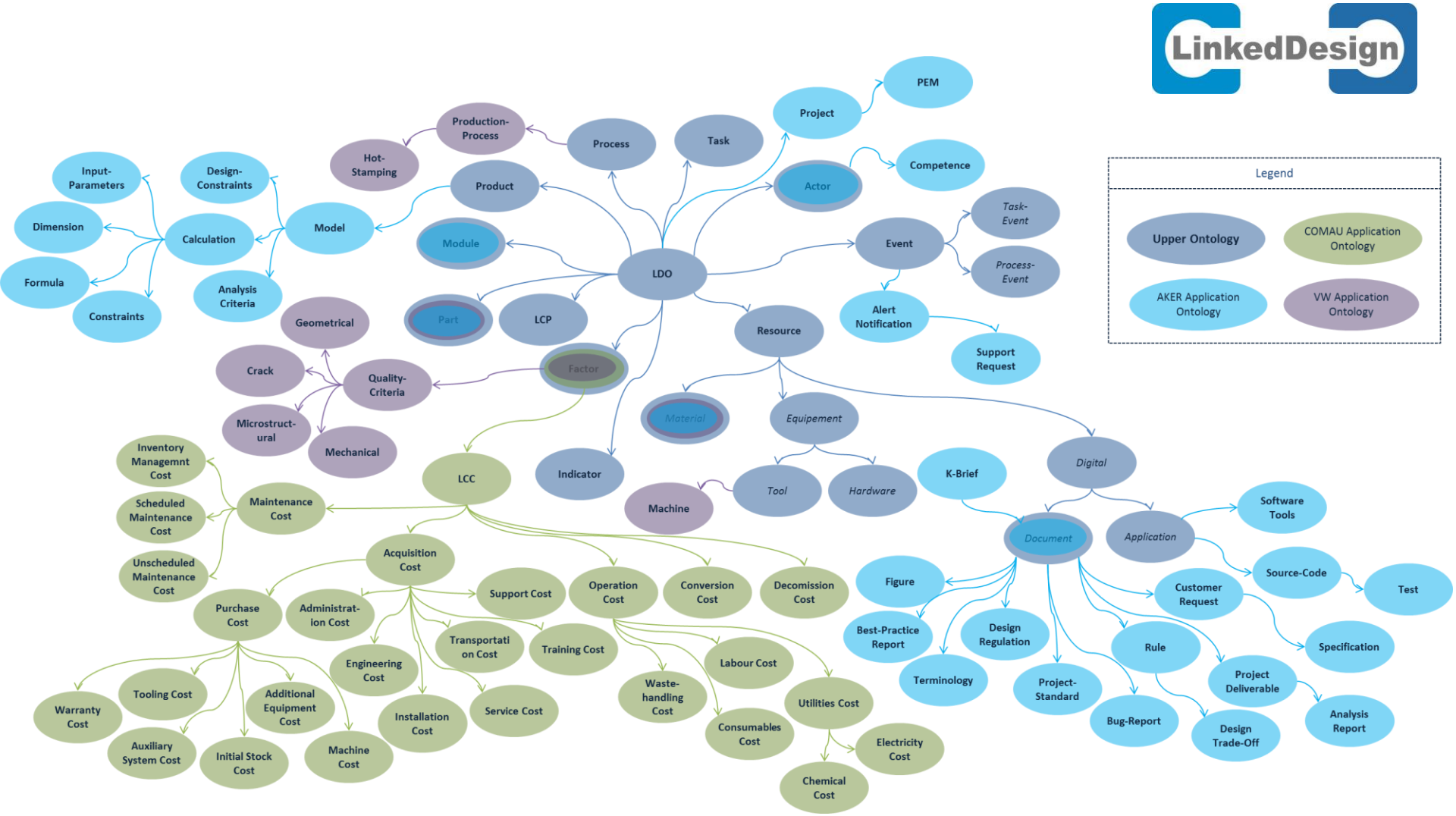
isSpecialization

Product Definition
Lifecycle Cost Assessment Ontology

Product Design
Design Knowledge Ontology

Product manufacturing
Quality Control Ontology

LinkedDesign Network Ontology

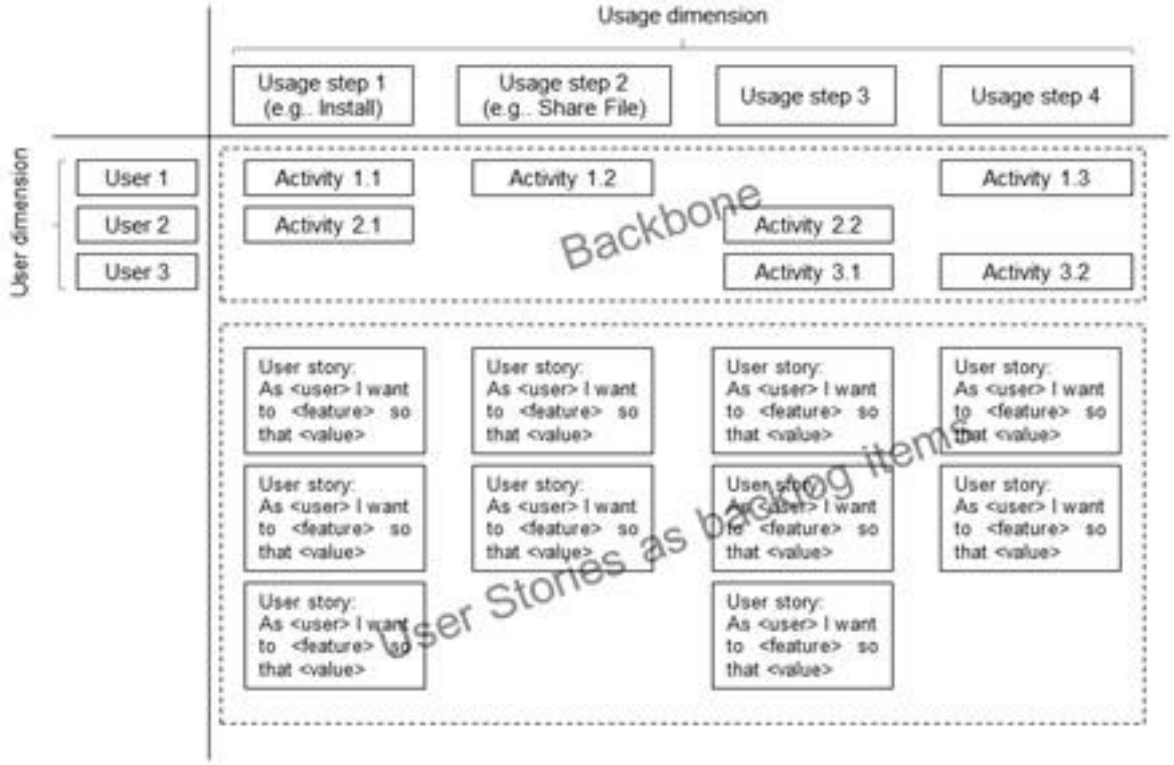


Inference Analysis

	Use case requirements	Knowledge Capture	Knowledge Conceptualization	Implementation	Interaction with LEAP
VW-TRIMEK	- Identification of risky parts - Crack detection in hot stamping process	Optimal values for each parameter: Oven temp., Dwell time, Insertion and extraction temp., Pressing force, etc.	Base set of 20 rules defining tolerable deviation of real measured values compared to optimal	Implemented using SWRL	Production Line Real Time Monitor Data: Sensor values
COMAU	- Support LCA of production line - Monitor the performance of the line in operational phase	- Calculation of MTTR, MTBF, availability, down time... - Optimal values for parameters: MTTR, MTBF…	Base set of 20 rules defining calculation of parameters and relevant set of design constraints	Implemented using SWRL	Product Lifecycle Optimization Tool Data source: Customer Specs. Sensor values
AKER	- Semantic enrichment of engineering standards - Recommendation based on the business context	- Industrial standards handling and application - K-brief maintenance	Base set of 10 rules for K-briefs and set of 27 rules as an example for standards usage	Implemented using SWRL	Concept level - Virtual K-Briefs Data: Design parameters, K-Brief properties/

- User story mapping (USM) for domain modelling is a method derived from software functionality definition
- The domain of interest is defined though collection of user activities, which indirectly gathers all actors, resources, processes and overall dynamics of the domain.
- It gathers all relevant concepts of the domain that are to become a part of ontology
- Using ADOxx modelling tool, it was possible to create a USM digital tool which provides enhanced performance and visual environment.

A user story map is a user centric approach and organizes the backlog along scenarios and users. It answers the question how a user uses the product that is software platform relaying on ontology



1. Usage dimension – It describes how a user would use the product. It shows the sequence of steps that a user would perform when using the product.

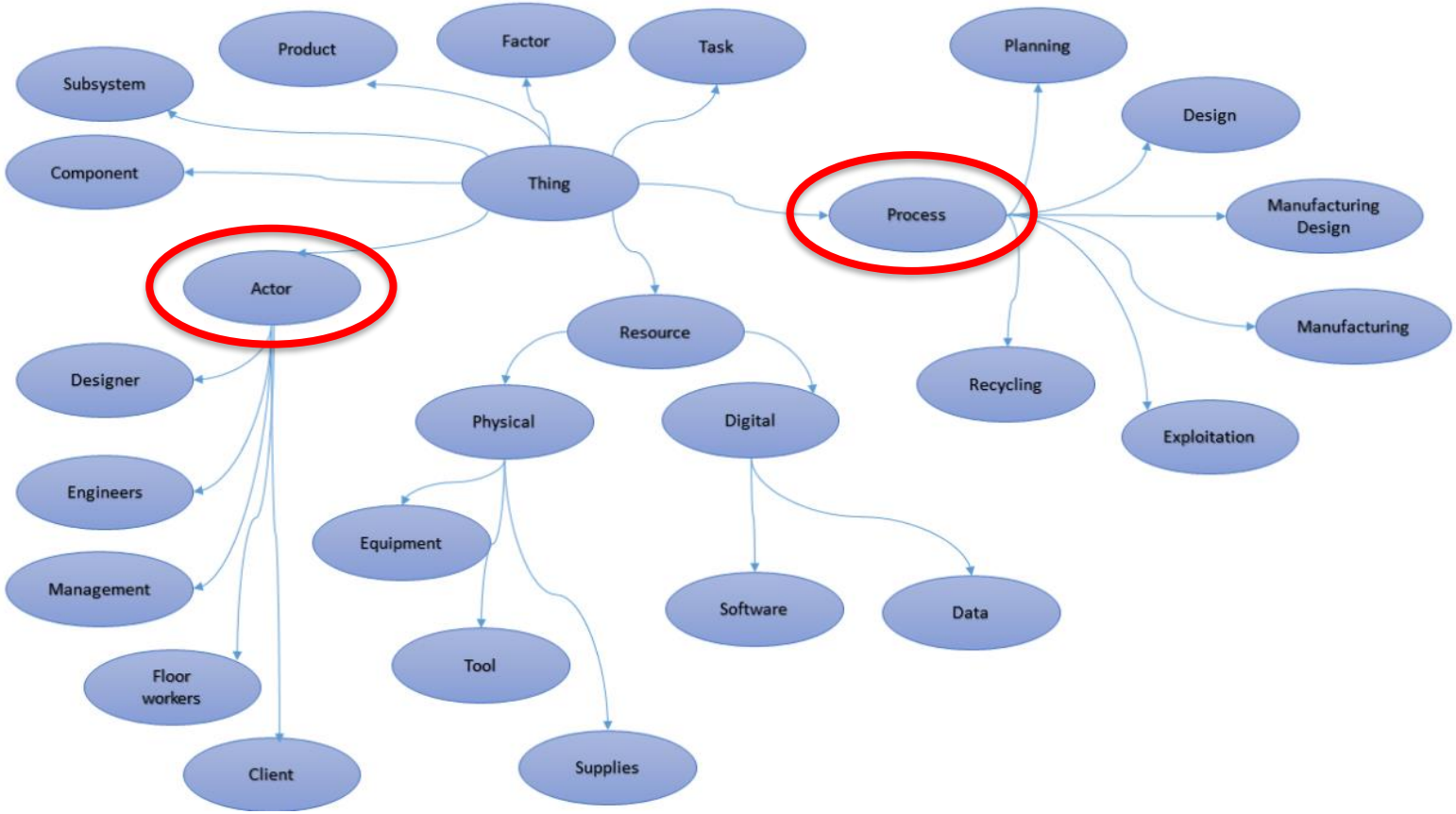
2. User dimension – This dimension defines the types of users that will use the developed product.

3. Backbone – This section describes the activities that a user performs within a usage step. The backbone describes the activities that a user performs using the developed product.

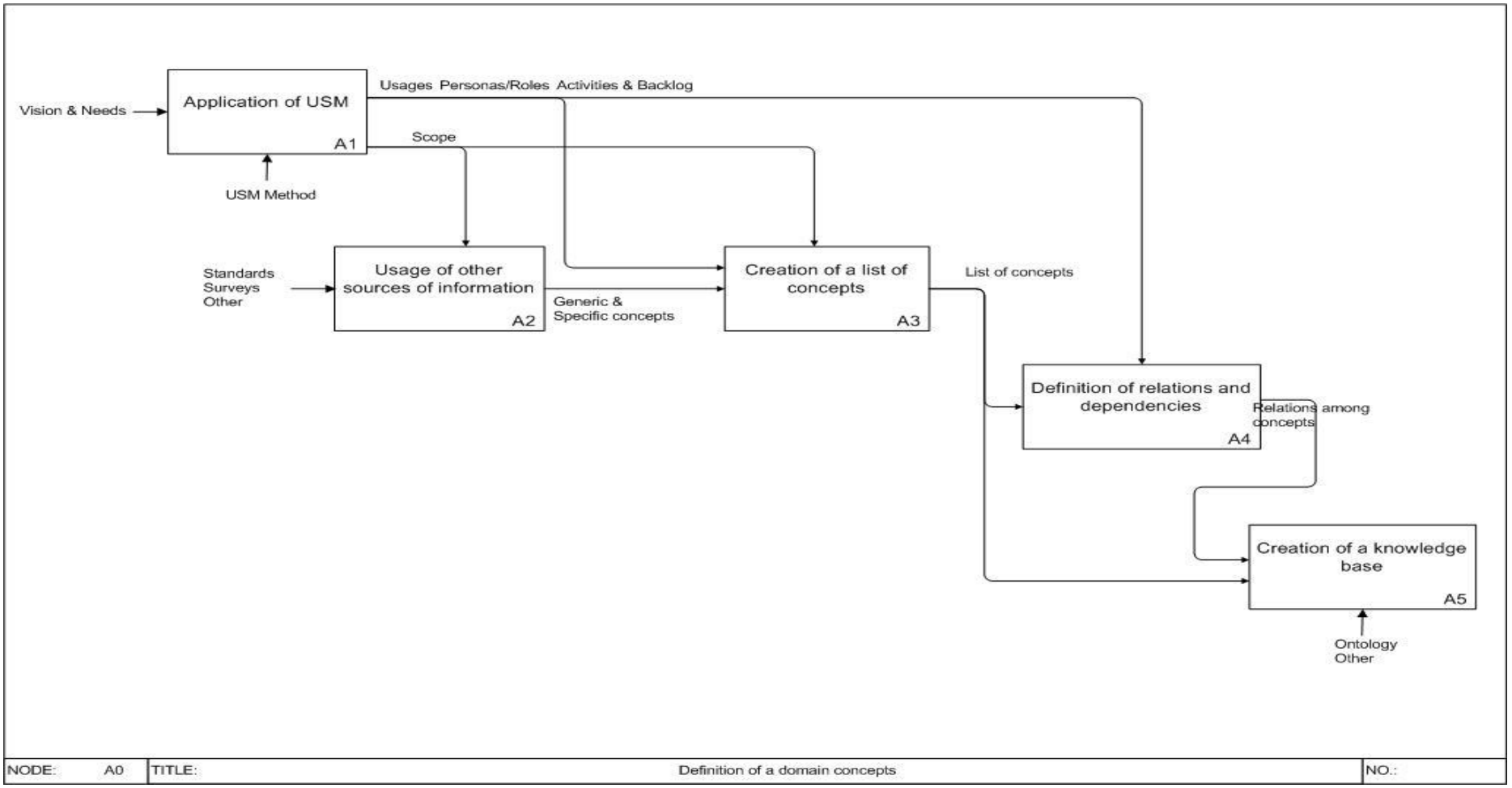
4. User stories as backlog items – This is the actual placeholder for the user stories. It is recommended that user stories follow the pattern “As <user> I want to <feature> so that <value>”.

Upper ontology- reusable resource

Upper ontology was created as guideline to help recognize all relevant objects in USM backlog and transform them into ontology concepts



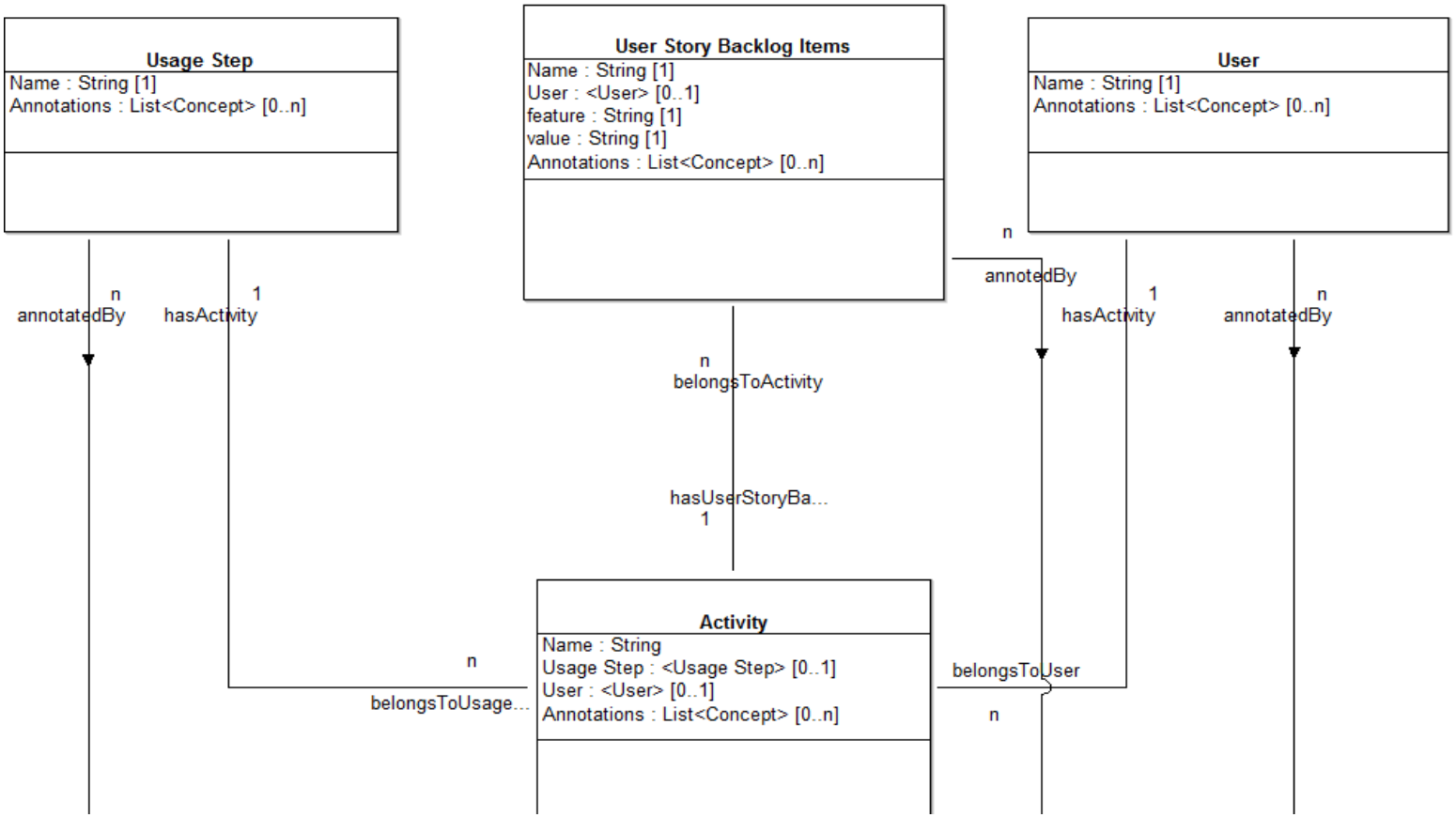
Based on this, we can create a simple algorithm for building a complete and structured knowledge base that is ontology



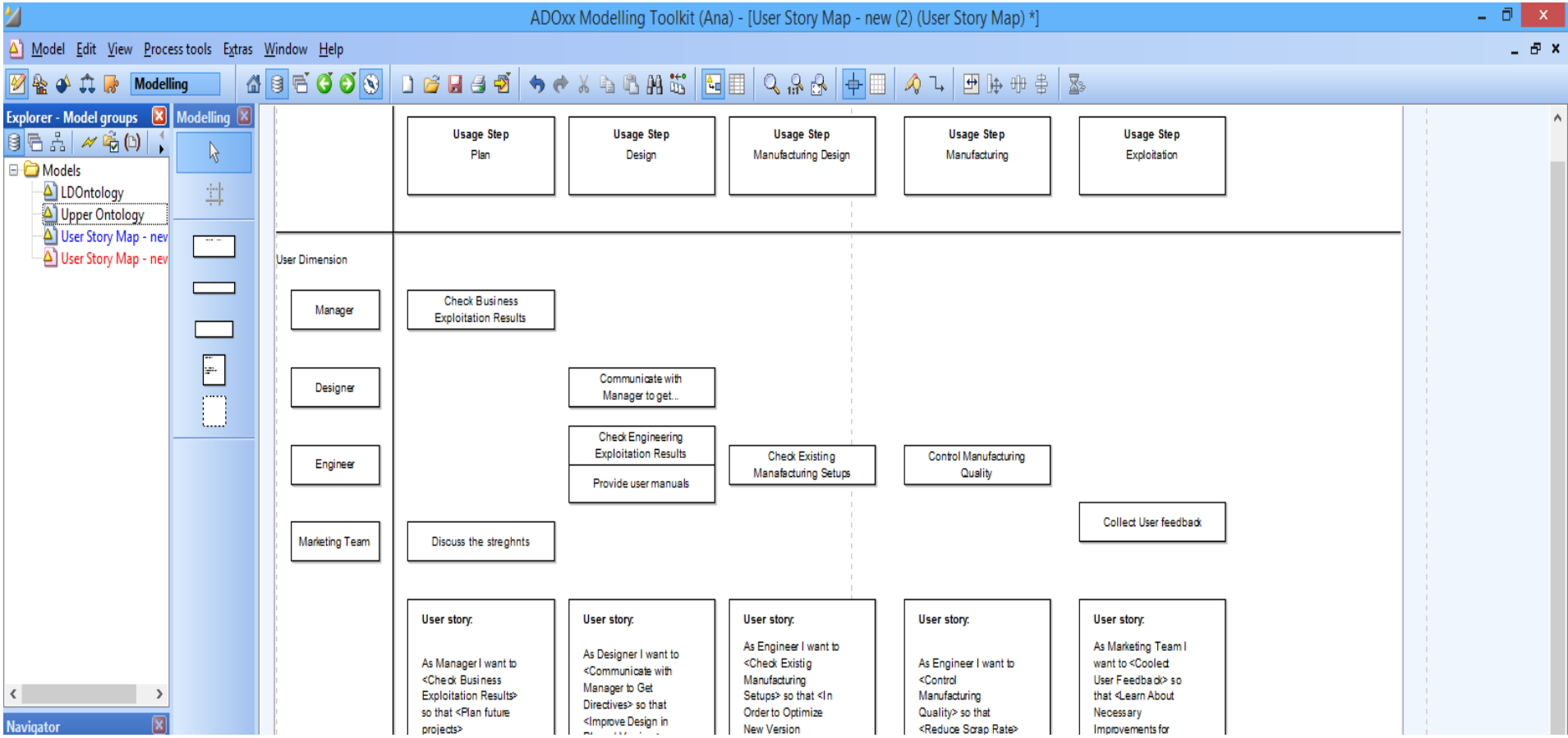
The Algorithm :

1. Apply the USM method
2. Gather other sources of information (standards, upper ontology templates, etc.)
3. Create a unique list of concepts that covers entire domain
4. Define relations and dependencies among these concepts
5. Create a dynamic knowledge base covering the domain, expressed in some of the standard formats like ontology semantic model

Part of the schema formalizing USM method as implemented meta-model of the process :

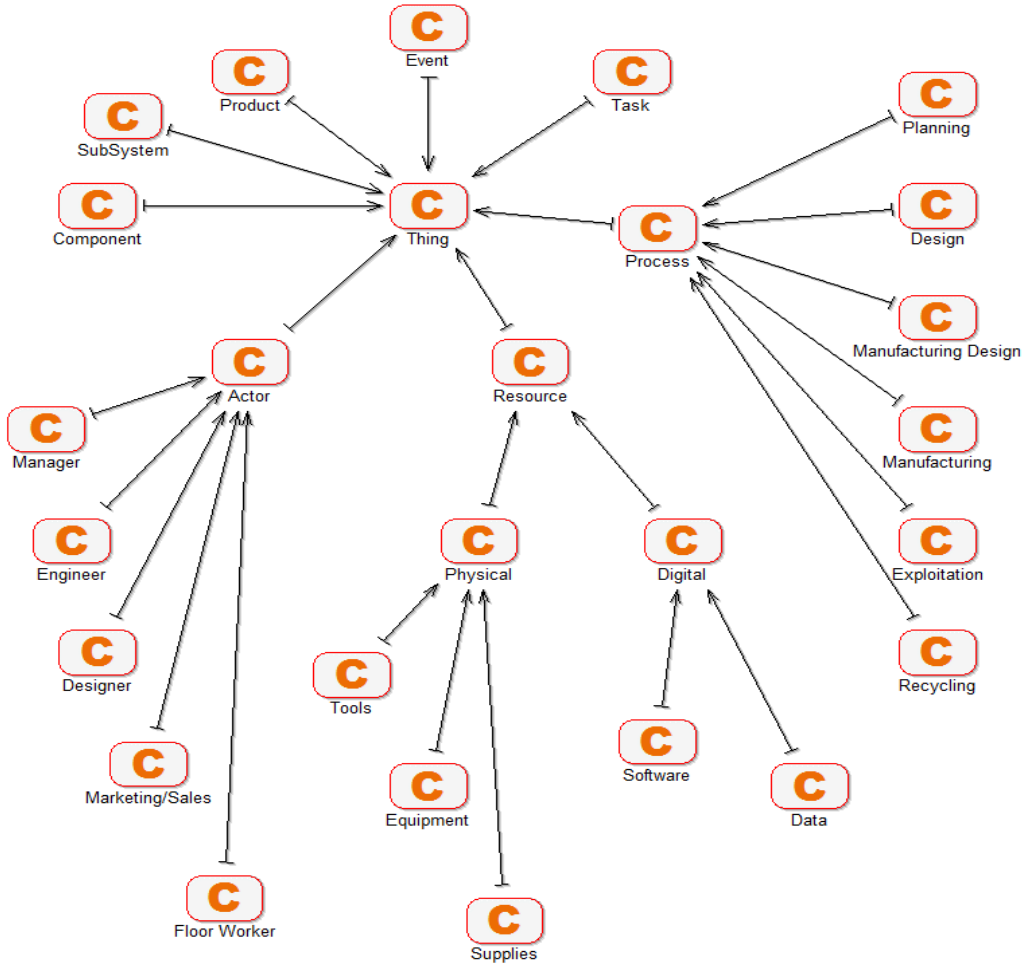


As proof of concept, all steps of knowledge domain definition are implemented using ADOxx modelling environment

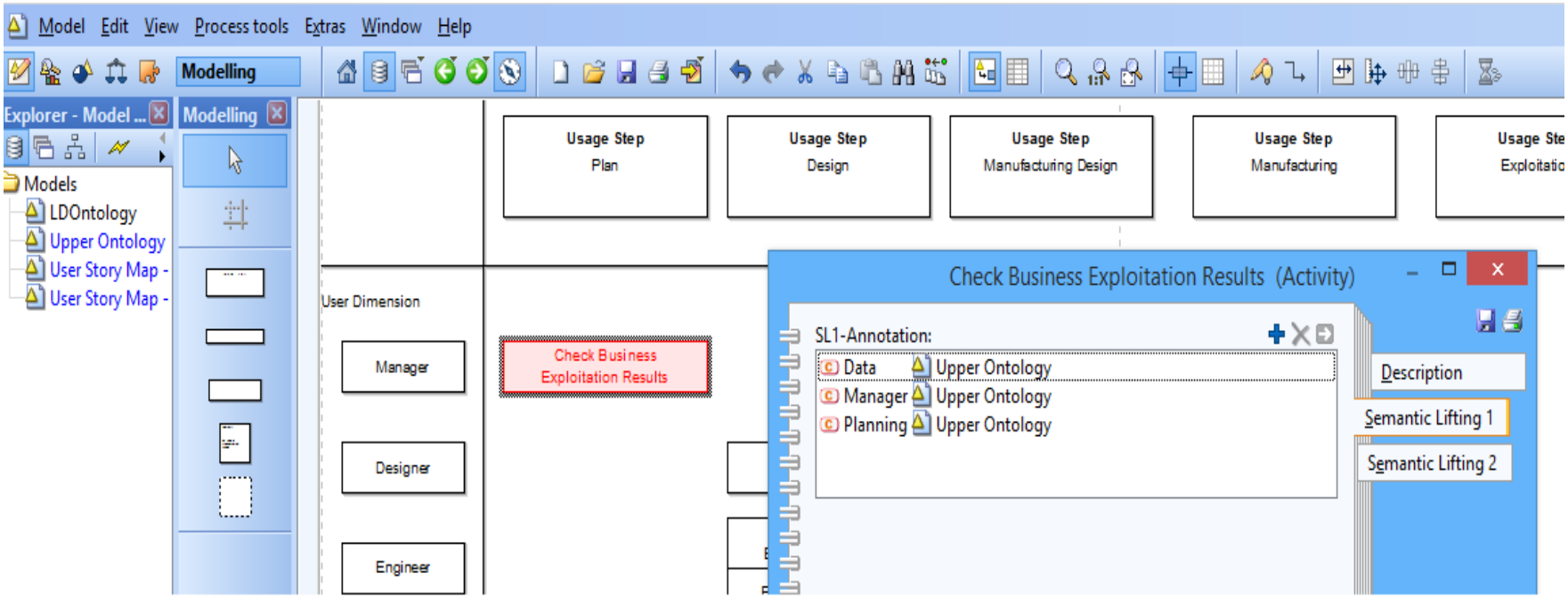


Reusable resources in ADOxx

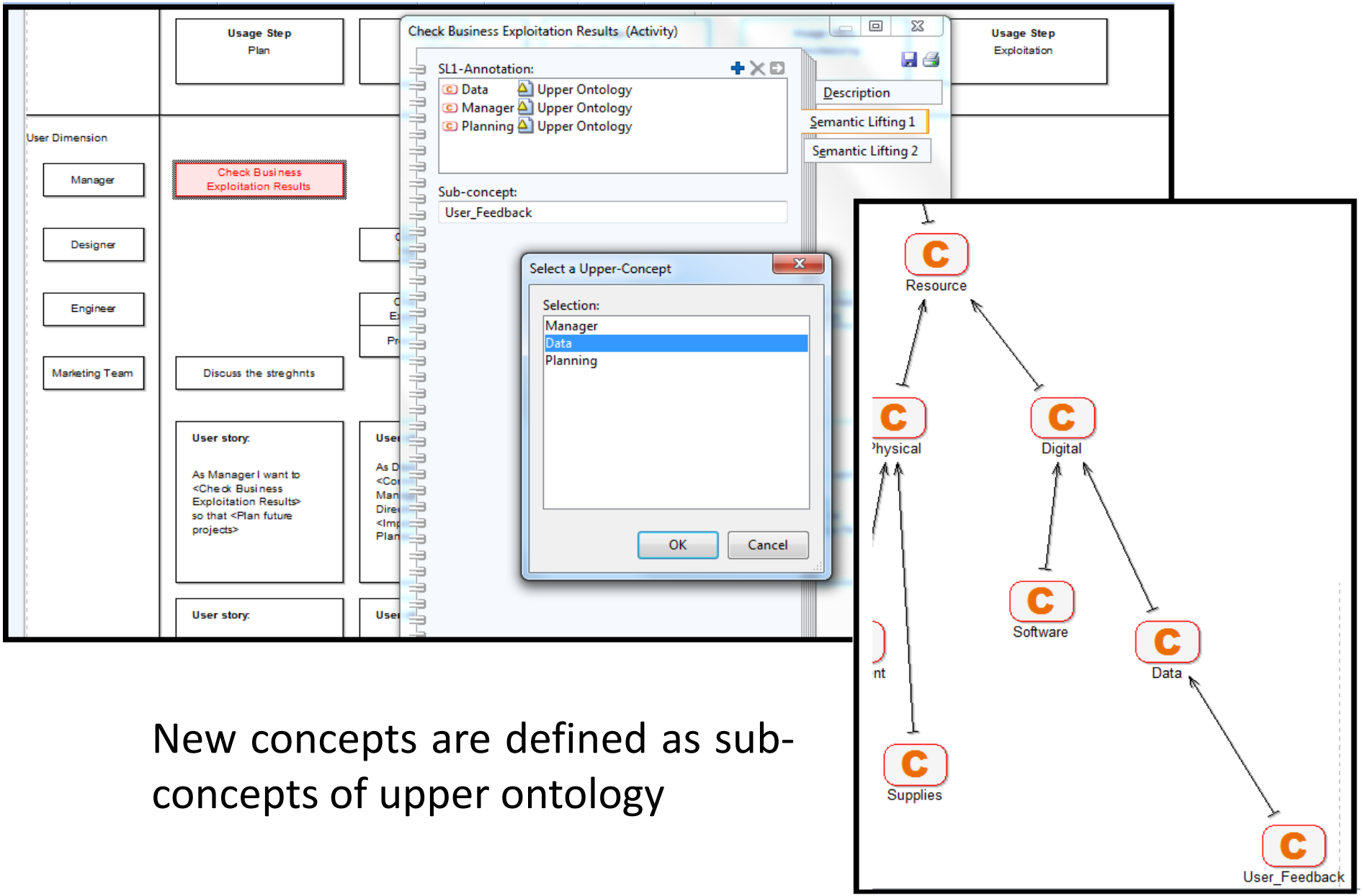
In order to enable exploitation of existing resources Upper ontology was also implemented as ADOxx model



The advantage of having this model is that the process of recognizing concepts required to define specific domain using upper ontology as reference schema, can be implemented as ADOxx tool through semantic lifting mechanism



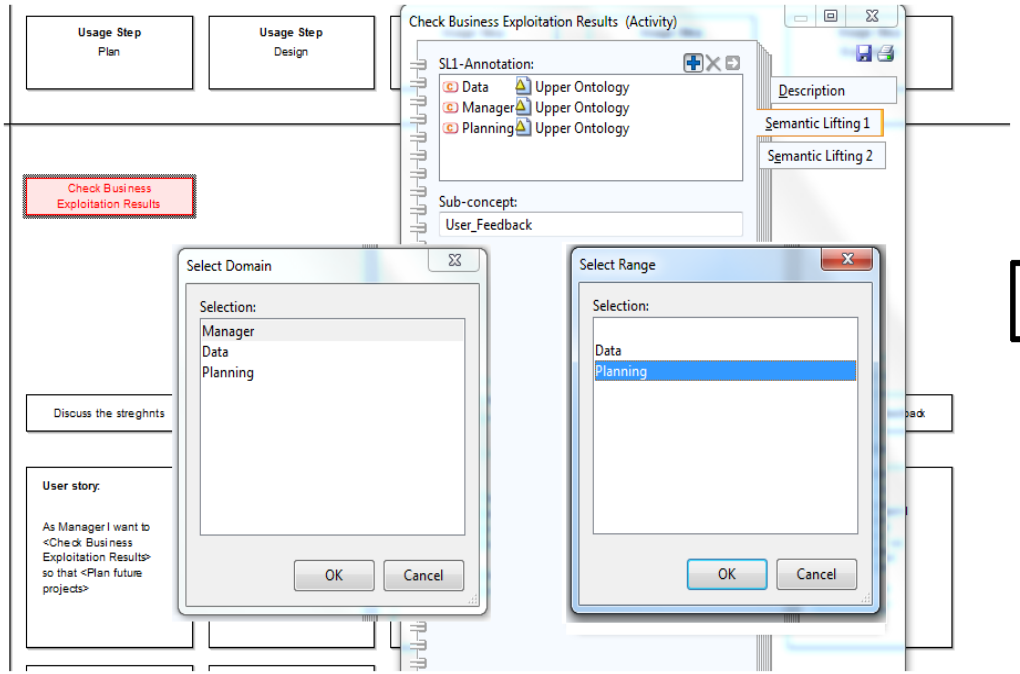
Ontology building in ADOxx

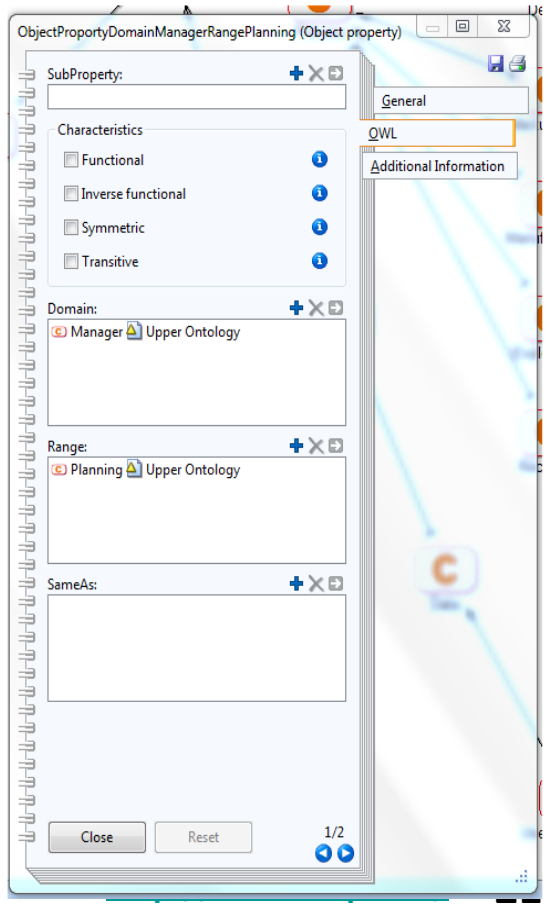


New concepts are defined as sub-concepts of upper ontology

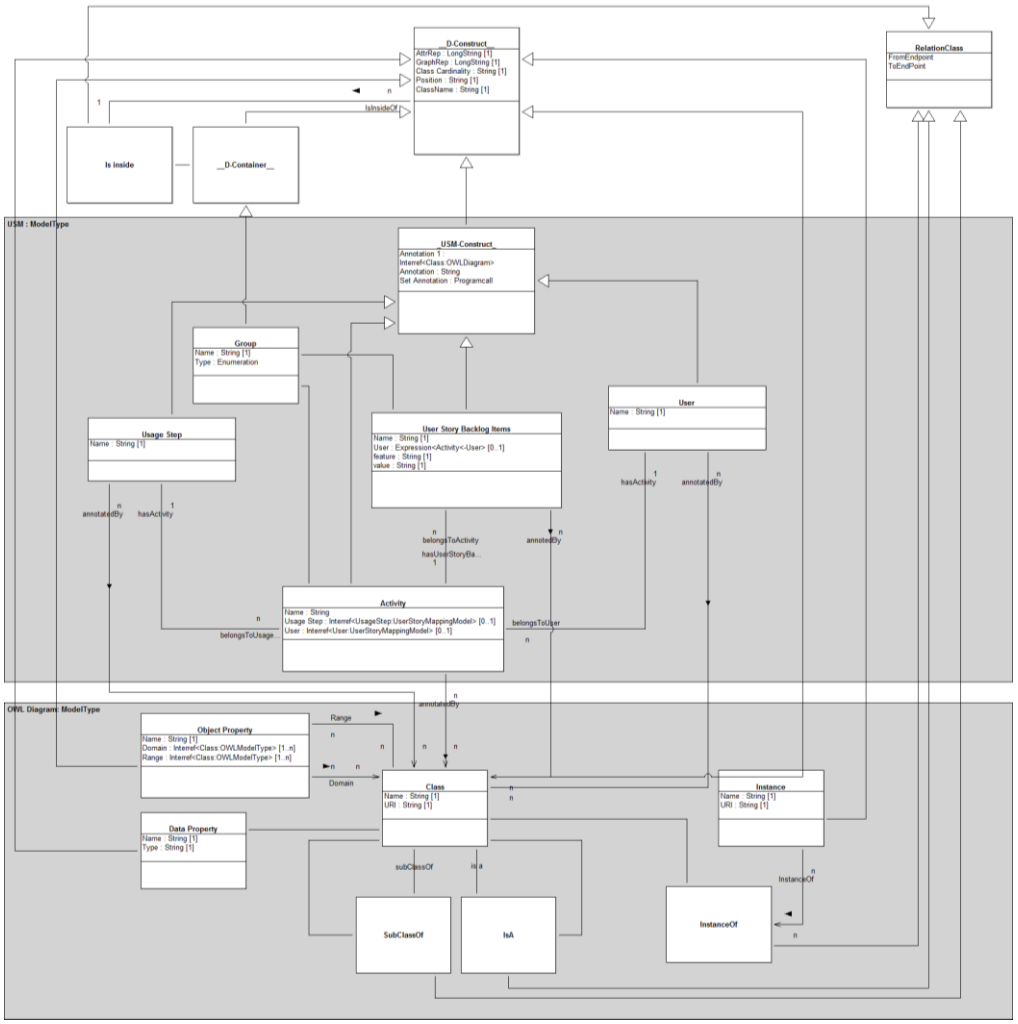
Ontology object properties in ADOxx

Using ADOxx modelling tool, the recommendation system for properties definition was created, relaying again on Activity Backbone. The reasoning is that if one Activity, was annotated with two or more concepts, then it is reasonable to assume that those two concept should have object property connecting them.





Final meta-model



ADOxx modelling tool provides many additional functionalities, such as model querying. The ontology that was created can be used to query each User activity or any other information retrieval. Ontology is reusable and exportable in number of standard formats

Conclusion

- By implementing USM methodology as ADOxx model the entire procedure is enhanced through automatization of deterministic steps.
- Each step can be performed independently and repeated if needed.
- Each step is documented and can be revisited or discussed in the future.
- ADOxx system allows export of models as RDF or XML structures making them available for other software tools.
- Having ADOxx model, opens a field of opportunities for future work that are out of scope of USM as ontology modelling methodology.