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Manufacturing Blueprints: Model-Driven Manufacturing Knowledge (Technical Report)

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1. MULTI-LEVEL KNOWLEDGE MODELLING ARCHITECTURE

To enable the reuse of the building blocks of the manufacturing knowledge across different manufacturing domains, and to ease the consistent specialization of those building blocks by the collaborators in manufacturing networks, our blueprint approach uses a model-driven architecture[1], as shown in Figure 1.

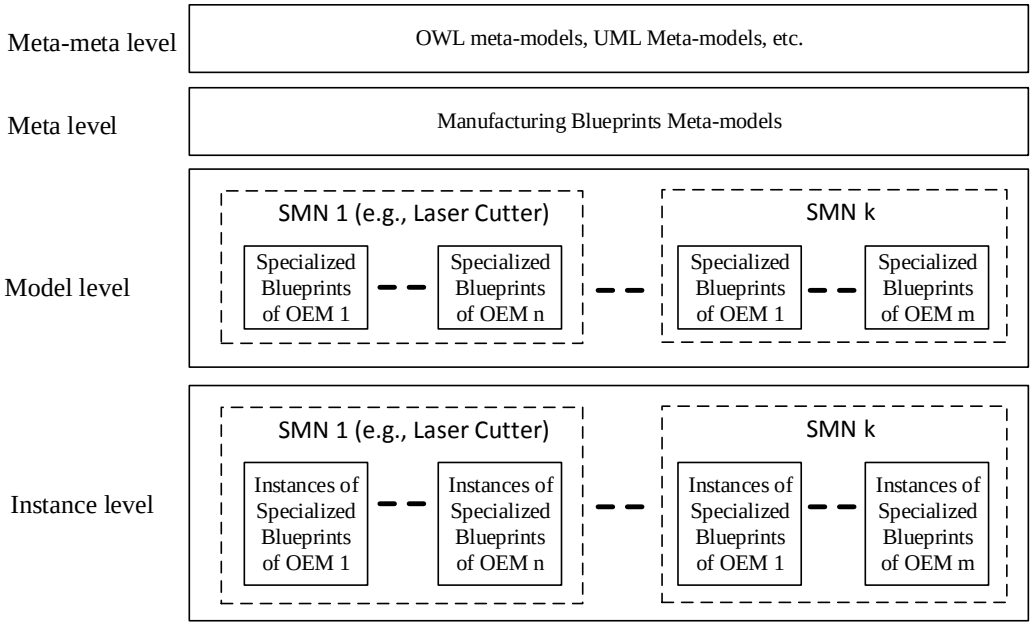


Figure 1. The blueprint modeling architecture

2. BLUEPRINT MODELS

2.1 Partner Blueprint Model

Figure 2 shows the partner blueprint model.

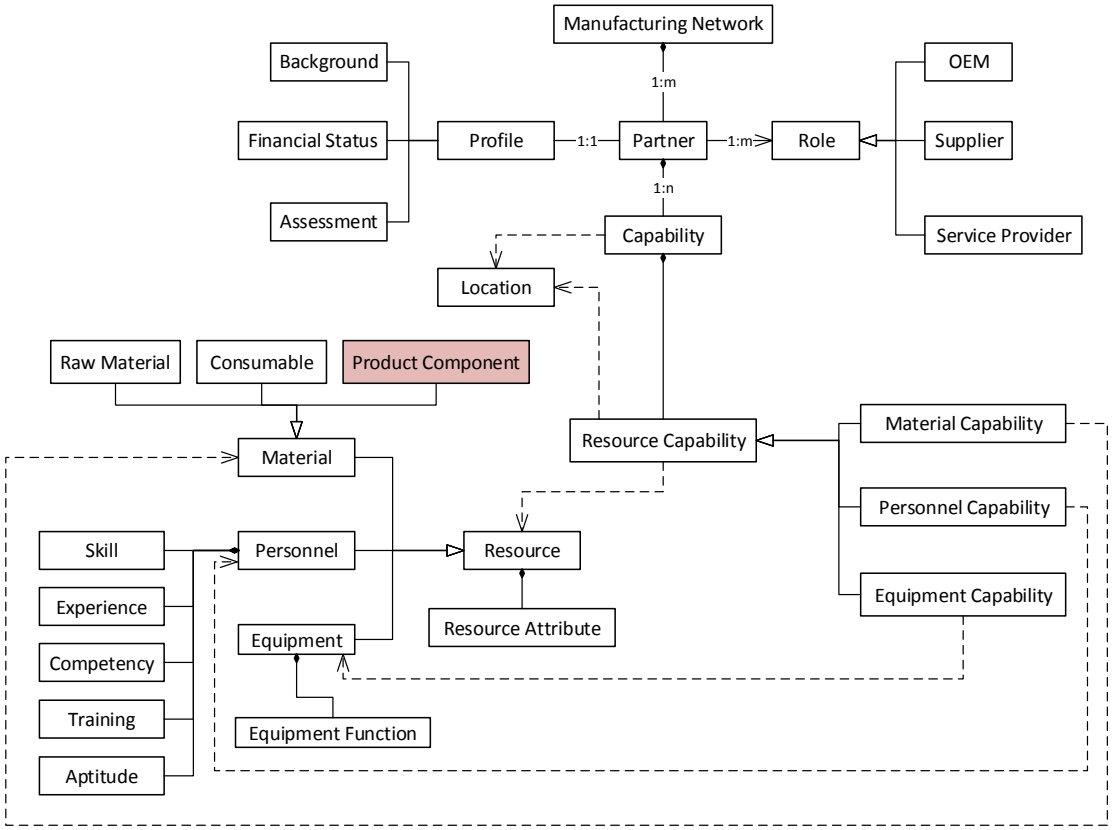


Figure 2. The partner blueprint model

Table 1. Data Properties of the Partner Blueprint Classes

Name		Explanation	Example
Location	Name	Name to identify a location - ISA 95	Tilburg Production Site
	Type	One of { enterprise, site, area, process cell, production line, or production unit } - ISA 95	Site
Resource Capability	ID	Unique identifier for a resource capability	EN10002
	Status	Available, Unattainable, or Committed • ISA 95	Available
	Duration	Duration of (un)availability - ISA 95	From 1999-12-31 11:59 to 2000-01-01 12:00
	Reason	Reason for (unavailability) -ISA 95	Maintenance

	Quantity	Quantity of the capability in specific units -ISA 95	2000 40
	Unit	Unit of Measure - ISA 95	Sheets hours
Material Capability	Material Use	Defines the material use: Material Consumed, Material Produced, Material Consumed or Consumable • ISA 95	Consumable - Electricity Material Consumed - Glass Raw Materials Material Produced - Glass Tubes
Resource	ID	Unique identifier for a resource	
Personnel	Name	Name of Person	
Material	Quantity (may not require as material capabilities define quantities)		
Personnel Role	As of now, we can have domain specific specializations and their instances such as “Glass Sheet Maker”, “Glass Tube Cutter”, “Glass Tube Cutter A”		
Equipment Role	As as above		
Skill	As as above - “Glass cutting”, “Communication”, “CNN Programming” (From SCOR)		
	Competency (From SCOR)	Scale/Level of Skill	Excellent
Experience	Duration	Duration	1 year
	Workplace	The place where the experience was gained.	Company X

Training (From SCOR)	Provider	Training Provider organization	Company Y
	Name	Name of the Training / Course	Glass Tube Making Level 1
	Duration	Duration of the training	1 month

2.2 Product Blueprint Model

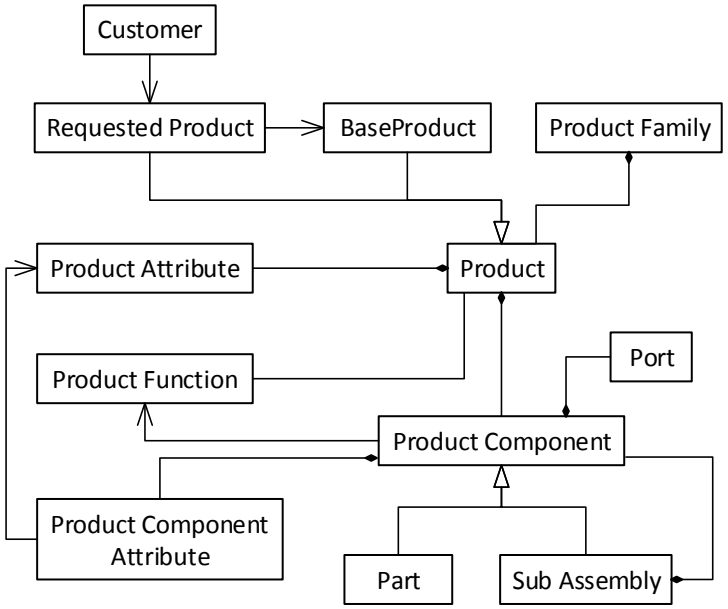


Figure 3. The product blueprint model

able 2. Data Properties of the Product Blueprint Classes

Name		Explanation	Example
Port	Connected	Identify to whether the port is connected [1]	True or False
	There will be domain specific port types such as HDMI, PCI, Intake Port, etc		
Product	ID		

Component	Image	For visualization	
	Engineering Drawing	For more detail info	
Product	ID		
	image	For visualization	
	Engineering Drawing	For more detail info	
	Customer		
Product Consumable	These are resources such as Internet, CPU, Energy (Oil, Electricity), etc, which required for functioning production components. These resources will have their own attributes.		

2.3 Product Service Blueprint Model

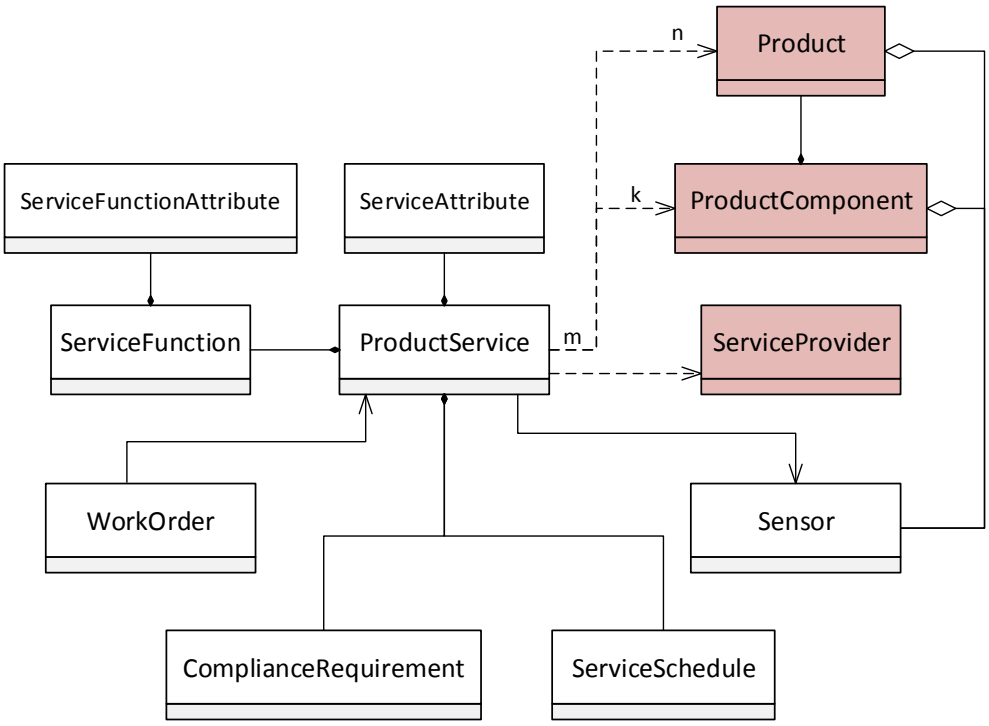


Figure 4. The product service blueprint model

Table 4. Data Properties of the Production Service Blueprint Classes

Name		Explanation	Example
Product Service	ID	Unique identifier for an service instance	MaintenanceByX
	There are will be domain specific service types and thier instances such as “LaserCutterRepair” and “LaserCutterRepairByY”.		
Service Function	There are will be domain specific service functions and their instances such as “InspectLaserCutter” and “ReplaceLaserCutterParts”		
Service Provider (These attributes from IBM Supplier Profiles)	ID	Unique identifier for an service instance	Service Provide Z
	Performance score (average/latest)		4.5
	Risk score (average/latest)		6
	Website		
	Status	Active / Inactive	
Service Provision Capabilities	These are the availability of different types of resources at the service provider to provide specific services (similar to Production Capabilities of partner)		

2.4 Production Process Blueprint Model

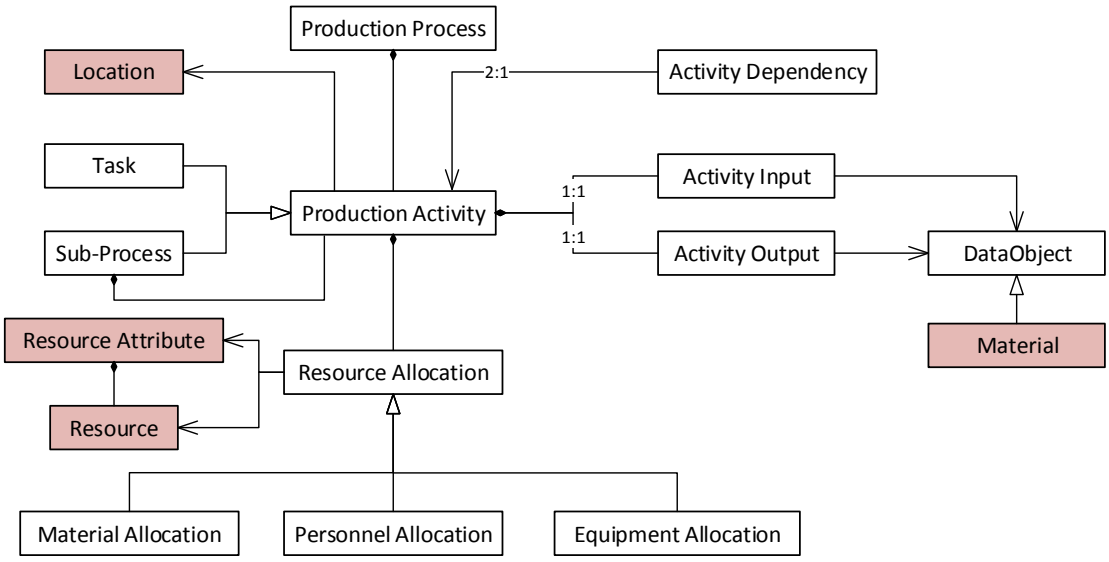


Figure 5. The production process blueprint model

Table 3. Data Properties of the Production Plan Blueprint Classes

Name		Explanation	Example
Process Segment	ID	Unique identifier for an process instance	Progress Segment B
	Status	State of the execution / schedule	Running
Segment Dependency (For ISA)	To		Progress Segment B
	From		Progress Segment A
	Time factor (from ISA)	Timing factor used by dependency	30 min
	Dependency Type (from ISA)	Like Allen's temporal interval interval algebra (see below)	Start B no later than 30 min after A start (from ISA)
Resource Allocation	Quantity		100
	Unit		Hours , Kg
Material Allocation	Material Use (from ISA)	Defines the material use: Material Consumed, Material Produced, Material Consumed or Consumable - ISA	Material Consumed
Production Process	StartTime (from ISA)	If known	
	EndTime (from ISA)	If known	
	Status (from ISA)	State of the execution / schedule	Paused
	Priority(from ISA)	Priority	1 (High)

2.5 Quality Assurance Blueprint Model

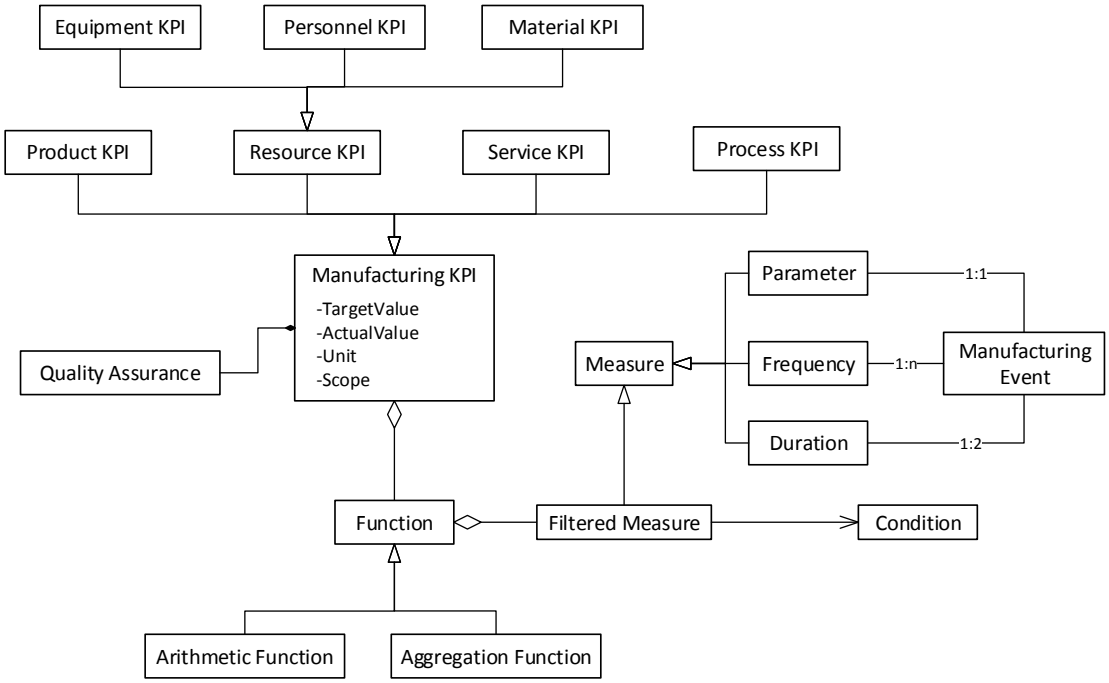


Figure 6. The quality assurance blueprint model

Table 6. Data Properties of the Production QA Classes

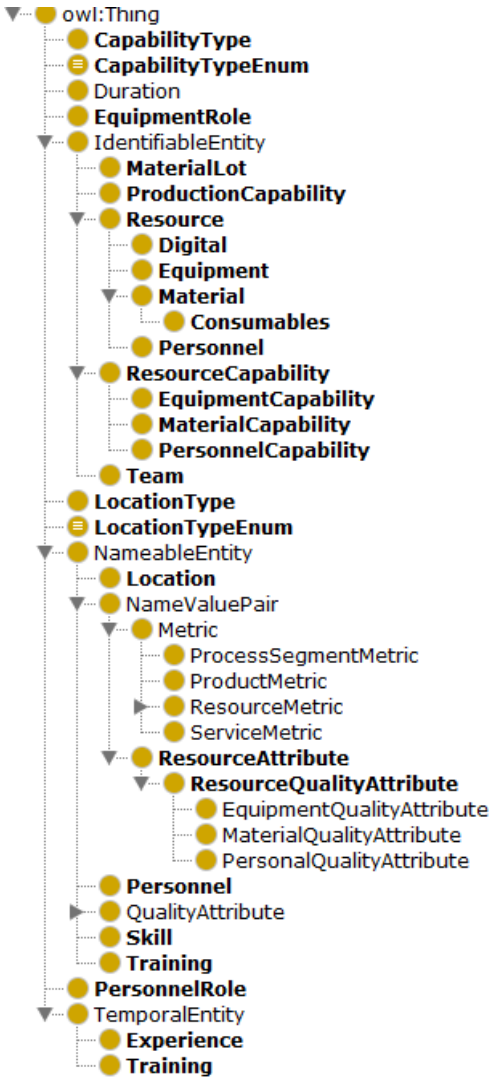
Name		Explanation	Example
ProcessEvent	ID	Unique identifier for an event instance	TubeCuttingEnd_E1
	EventTime	Timestamp of occurrence of the event	Tue 01-01-2009 6:00
	Process Segment ID	The owner of the event	PS AA12
	Process Segment Status	Started, Paused, Terminated, ...	
	There are will be domain specific event types and their instances. Also, there will be event specific attribute that contains specific data (measurements) for example, device id , signal, ..		
Resource Consumption	Quantity		100
	Unit		Kg
Production	ID		

Process Response	Published Date (from ISA)		
Process Segment Response	Actual Start Time (from ISA)		2005-10-30 T 10:45 UTC
	Actual End Time (from ISA)		2005-11-00 T 10:45 UTC

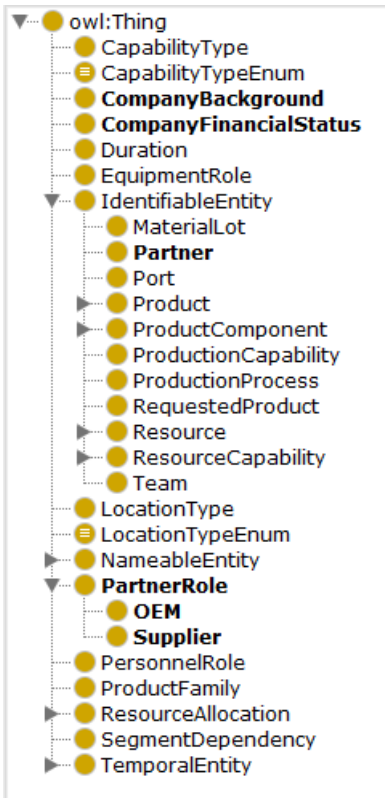
3. IMPLEMENTATION

We have implemented the blueprint models using OWL (Web Ontology Language)[2].

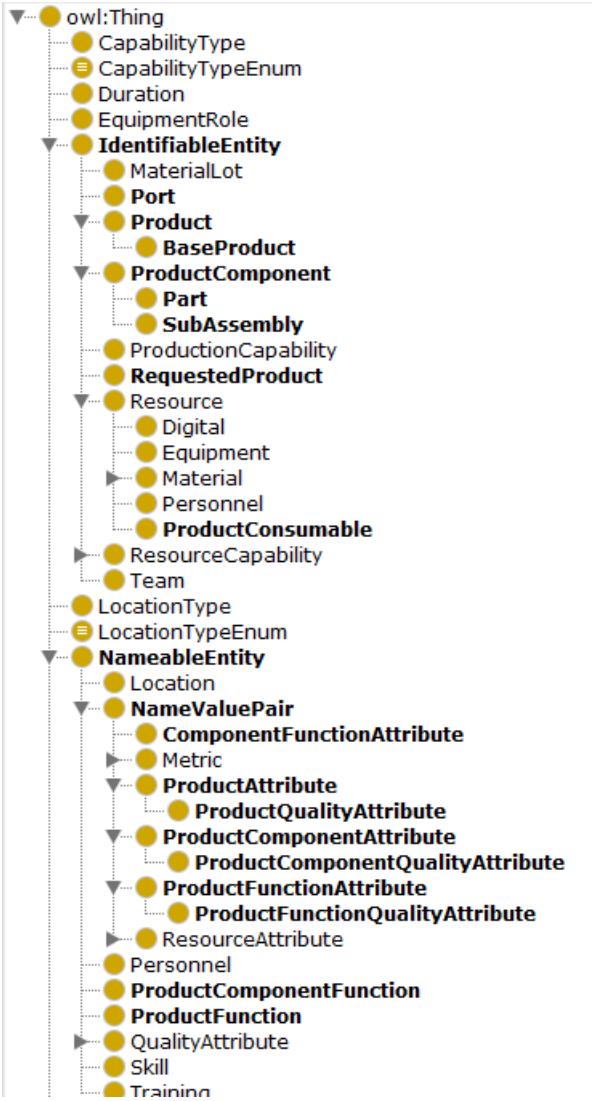
3.1 Production Capability Blueprint Model



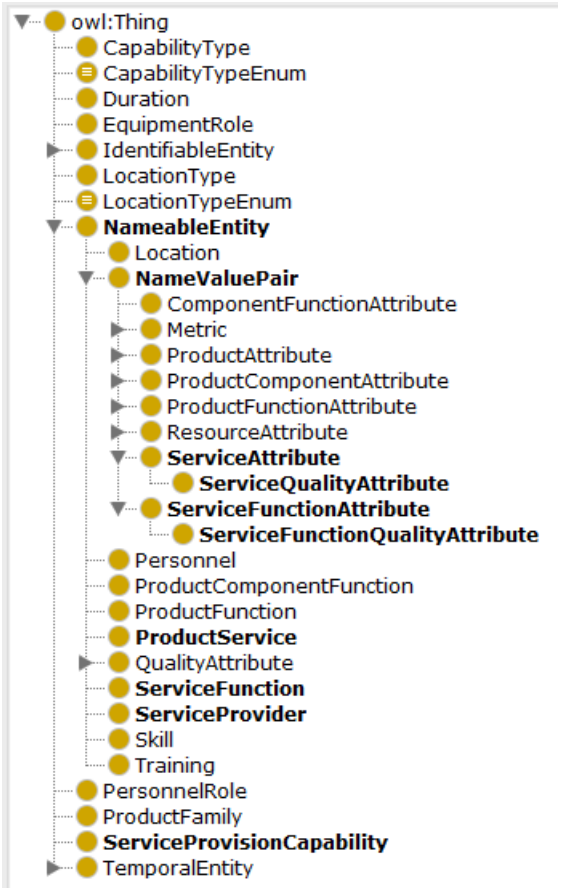
3.2 Partner Blueprint Model



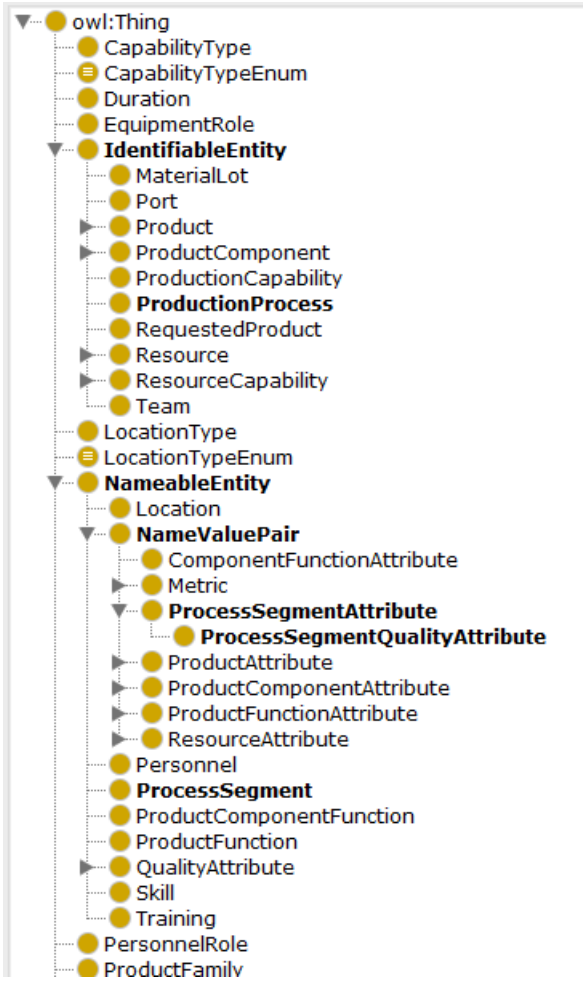
3.3 Product Blueprint Model



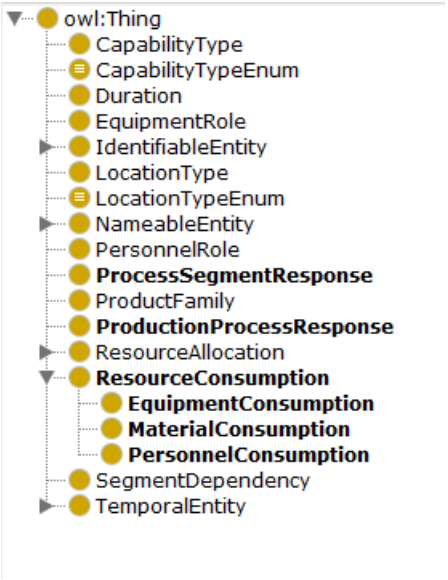
3.4 Product Services Blueprint Model

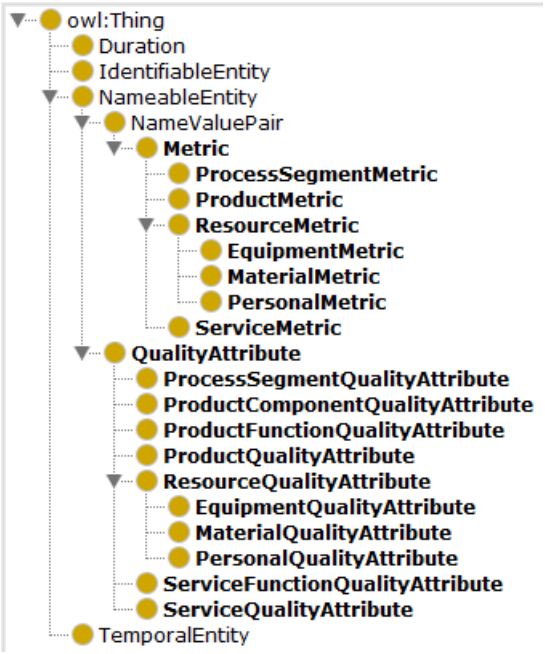


3.5 Production Process Blueprint Model



3.6 Quality Assurance Blueprint Model





4. REFERENCES

[1] J. H. Lee *et al.*, "A Semantic Product Modeling Framework and Its Application to Behavior Evaluation," *IEEE Transactions on Automation Science and Engineering,* vol. 9, no. 1, pp. 110-123, 2012.

[2] D. L. McGuinness and F. Van Harmelen, "OWL web ontology language overview," *W3C recommendation,* vol. 10, no. 10, p. 2004, 2004.