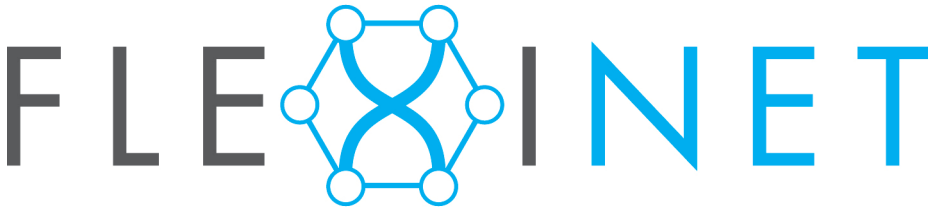
FLEXINET

FP7-2013-NMP-ICT-FOF (RTD) Project 608627



Deliverable D3.2

Initial formal ontologies

Workpackage: WP3 – Product-Service-Production Reference Ontologies

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FLEXINET Partners

Loughborough University	Loughborough University, UK
Coventry University	Coventry University, UK
ITI INSTITUTO TECNOLÓGICO DE INFORMÁTICA	Instituto Tecnologico de Informatica, Spain
Fraunhofer IPK INSTITUTE PRODUCTION SYSTEMS AND DESIGN TECHNOLOGY	Fraunhofer-Gesellschaft zur Foerderung der Angewandten Forschung E.V., Germany
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INDESIT company	Indesit Company S.P.A., Italy
KSB	KSB AG, Germany
custom drinks container + beverage solutions	Customdrinks SL, Spain
HIGHFLEET	Highfleet INC, United States
HOLONIX LIFECYCLE KNOWLEDGE SOLUTIONS	Holonix S.r.l., Italy
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Executive Summary

This deliverable reports on the work that has been developed to date within Task 3.2 to provide the formal ontologies for the project. It formalises the lightweight ontologies produced in Task 3.1 and delivered in D3.1 and incorporates additional concepts following further inputs from WP1, WP2 and WP4. Task 3.2 will provide a further deliverable, D3.3, at M24, which will further extend these ontologies and provide the formal ontologies for integration into the compliance services. This current deliverable, D3.2, provides a step towards the full Product-Service production reference ontology definition as well as progressing the enterprise level ontologies for our three end user partners.

The formalisation of these ontologies has been undertaken using the Knowledge Frame Language (KFL). This is based on the Common Logic standard and therefore provides a good basis for a standard reference ontology as well as providing an expressive logic based representation of the concepts, relations, constraints and rules that are important to the project.

In documenting the ontologies this deliverable follows the five levels of concept specialisation defined in D3.1. The full set of the KFL definitions of the ontologies are provided here in annexes related to these levels, while the main body of the D3.2 illustrates the key elements of the ontologies. These are explained against the five levels of the ontology and also against specialisations of the key concepts defined at level one. The level five end user enterprise specific KFL code has been placed within a separate annex, provided on the FLEXINET portal, to ensure that any potentially sensitive information is not openly available. In addition to the ontologies an updated set of competency questions for each end user is provided, which will continue to be updated in D3.3 as the project develops.

Aspects of the ontologies are already being exploited by WP5 in their preparation of the initial software releases. The ontology will continue to be developed, especially in terms of the new understanding coming from WP2; the developments to come from WP4; and the understanding in terms of constraints, rules, relations, queries and facts as WP6 progresses the initial customisation of the FLEXINET services.

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1 Introduction

1.1 Purpose and Scope

This technical document details the initial formal representation of the reference and specialised ontologies produced in T3.2, to be used for initial testing in WP6. These have been produced in the Knowledge Frame Language (KFL) as used in the HIGHFLEET software, which is based on Common Logic.

The overall objective of T3.2 is to structure and formally model these concepts, relationships, constraints and related facts to provide an underpinning environment against which specific network configuration designs can be evaluated. This deliverable (D3.2) provides the first step towards this objective by providing the initial formal ontologies that will be further extended in D3.3 in the form of ontologies and facts that will be implemented in HIGHFLEET's ontology and KB development environment.

This deliverable D3.2 provides the first iteration of these formal ontologies. The objectives for this deliverable are therefore:

- To take the lightweight representations provided in D3.1 and develop these concepts and relationships into heavyweight, or formal, ontologies. Also to further develop these ontologies as the project's understanding, especially from WP2 and WP4, has developed and add constraints and rules to provide the underpinning ontological environment into which specific facts can be populated and evaluated. The modelling consists of:
    - Formal definition of reference ontologies for cross-sector applicability.
    - Formal definition of specialised ontologies for CustomDrinks.
    - Formal definition of specialised ontologies for INDESIT.
    - Formal definition of specialised ontologies for KSB.

These formal definitions will be iteratively developed as new understanding develops in conjunction with WP2 and WP4. Further refinement will also take place through early testing of the ontologies to be performed in WP6.

1.2 Approach for Work Package and Relationship to other Work Packages and Deliverables

This deliverable D3.2 provides the initial set of developed formal ontologies for the FLEXINET project. The work in D3.2 has utilsed the outputs of D3.1 and work of WP2 and WP4, to enhance the reference ontologies so that they represent an up-to-date model to support the requirements that exist within the project from the various partners. The outputs of the End User use cases from WP1 (D1.3) have also been used to further refine the level 5 end user ontologies.

D3.2 represents the initial version of the formal ontologies, the intention for this is so that they can feed into WP5 and WP6 to provide a basis for the FLEXINET services and applications to be developed. The feedback received from these workpackages will be used to further update the ontologies and the refined ontologies will be documented in the M24 deliverable D3.3.

1.3 Structure of the Document

The D3.2 document describing the initial reference ontology along with three initial end user ontologies has been structured to maximise the understanding of the ontology development while minimising the repetitive nature of reading the KFL code which is used to represent the ontologies. To this end the main sections of D3.2 provide a guide to the individual levels of the reference ontology and the specific end users ontologies, along with an explanation the Knowledge Framework Language (KFL) code used to represent the levels of the ontology. In addition illustrations of the concepts and relationship are provided by way of UML class models to allow readers to gain some visual perspective upon the ontologies, rather than merely relating to multiple lines of KFL code. The full KFL for each level of the reference ontology is provided in the annexes to the document.

A further important consideration in the way the document has been structured has been to provide a publicly accessible deliverable that still ensures that any potentially sensitive end user information has been protected. This has been achieved by providing a limited overview of the end user ontologies in section 7 of this document, while providing a separate annex to capture the full end user KFL information. This end user annex, entitled "FXNT_D3.2_Level5_Annex" can be found on the FLEXINET portal at:

- http://www.flexinet-fof.eu/Intranet/Shared Documents/Forms/AllItems.aspx?RootFolder=%2fIntranet%2fShared Documents%2fDELIVERABLES%2fD3.2&FolderCTID=&View=%7B03D38F61-9F28-44EE-A00C-885A9EB1C83D%7D

Chapter 2 presents the methodology used for the formal definition of the ontologies within Task T3.2. Chapters 3, 4, 5 and 6 respectively describe each of the reference ontology levels 1 to 4, illustrating the Knowledge Framework Language (KFL) code that has been created to represent the ontology. Chapter 7 sets out the end user specific (level 5) ontologies, showing the updates and developments that have taken place. In Chapter 8 the revised end user competency questions are presented, to show developments. The main body of deliverable is drawn to a close with the conclusions presented in Chapter 9. The full KFL code is presented in annexes A – E related to each of the levels of the ontology and a further Annex F provides a basic description of the use of the key KFL terminology.

2 Formal Ontology Developmental Approach

2.1 FLEXINET Ontology Levels

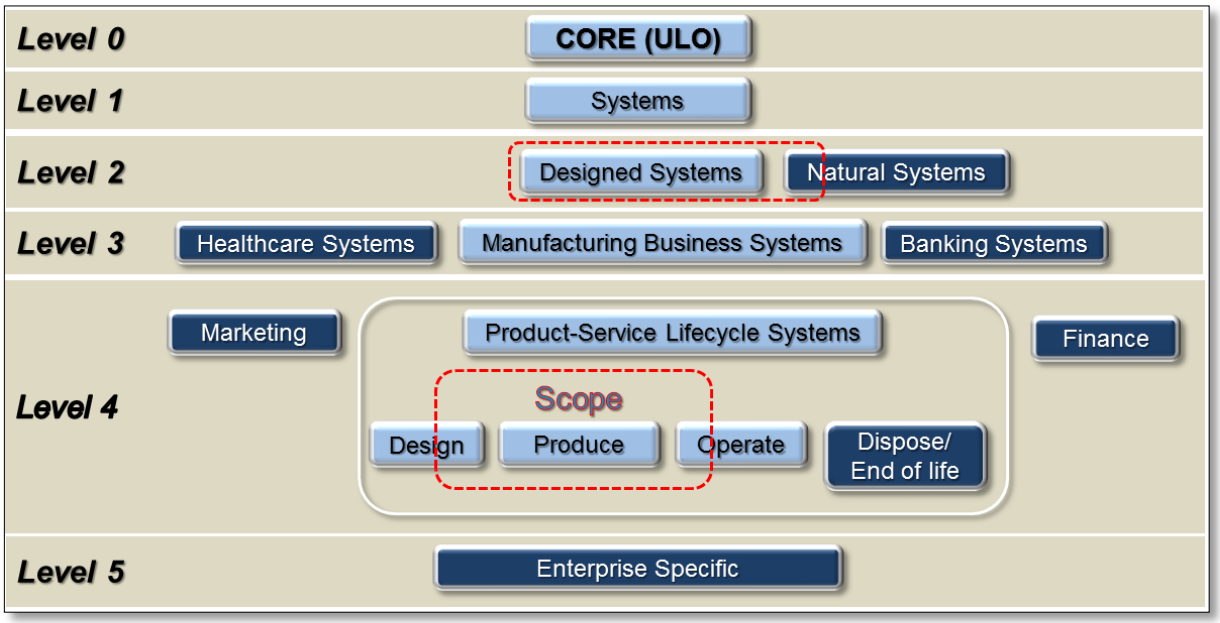


Figure 2-1: FLEXINET reference ontology levels

Figure 2-1 sets out the five levels of the FLEXINET ontology as initially described in D3.1. Level 0 Core consists of foundation concepts applicable to all domains. These foundation concepts include time, events, aggregation and lists and are derived from the Highfleet Upper Level Ontology (ULO) (Highfleet, 2014). Level 1 contains the few key concepts necessary to model any system and therefore concepts that are fundamental to Global Product Network systems. A system transforms inputs into outputs and is defined as "*a combination of interacting elements organized to achieve one or more stated purposes"* (ISO/IEC 15288:2008). Level 2 uses Banathy's classification (Banathy, 1992) to specialise systems into "Natural Systems" and "Designed Systems". Natural systems are living systems of all kinds, the solar system and the Universe. Designed systems are man-made creations, including fabricated physical systems, conceptual knowledge and purposeful creations. FLEXINET will provide decision support for global production network configuration within the context of product-service lifecycle systems and, as this requires human input (i.e. input from a living system), the scope of FLEXINET covers purposeful creations and overlaps into natural systems.

Level 3 further differentiates designed systems, FLEXINET being concerned with Manufacturing Business Systems which are specialised within Level 4. At this level FLEXINET considers Product-Service Lifecycle Systems. The lifecycle phases are denoted as design, produce, operate and end of life (including disposal, recycling and remanufacturing). The focus of FLEXINET is how to design a GPN to produce and operate a product-service. The main area FLEXINET considers within the Product-Service Lifecycle is "Produce" (producing the product) but the scope also overlaps into "Design" (of the network) and "Operate" as the operation of the product and the service needs to be considered. These levels comprise the reference ontology levels while Level 5 applies this to the enterprise specific domains of each of the FLEXINET end users.

The importance of this approach is to provide a method of concept specialisation such that the level of commonality between concepts can identified readily from the ontology, as was described in D3.1. Hence the level 1 ontology is fundamental to all FLEXINET concept developments and these then become specialised through the inheritance defined for each level in the ontology. Level 2 concepts are all defined in relation to level 1. Many concepts are defined at this level. It is interesting to note however, that at this stage in the ontology development only a few specific concepts have been identified at level 3 and at level 4. This is because specific specialisations of level 2 concepts have not been identified and so level 5 concepts can inherit directly from level 2. This is anticipated to change as new understanding of constraints, rules and relationships become evident from WP2, WP4 and the end user test cases.

2.2 Project Technical Assistant Comment

The following comment (11/09/2014) was made by the Project Technical Assistant (PTA) to improve the end user ontologies:

- *"In the initial lightweight ontologies include (and/or clarify the inclusion of) in all use cases, as much as this is possible, the main Project concepts, relationships and constraints of: external and risk factors."*

This comment has been addressed in this deliverable. All the end user models have been linked to environ factors (new naming for external factors) and risk factors. This has been represented in two ways, (i) firstly, the end user UML models in chapter 7 have been updated to show the links between each of their unique perspectives and the environ and risk factors, and (ii) secondly, the KFL code has been developed to represent the changes in the end user models and the newly developed, concepts, relationships and constraints.

2.3 KFL Development Method

The challenge for Task 3.2, has been to convert the UML ontology models developed for levels one to five in D3.1 into formal ontology code at the same time as evolving the ontology structure as the understanding of the ontology requirements have evolved. A benefit of the formal representation is that it is semantically more rich, descriptive and unambiguous. Hence the process of translation from a lightweight representation into heavyweight can be a difficult task, due to the extra information that must be generated to precisely and succinctly represent classes, relationships, rules and constraints so that they are unequivocal and cannot be misinterpreted. The following section sets out the method used to accomplish this.

A number of inputs were used to create the heavyweight KFL code, these were:

- End User requirements (D1.1).
- End User lightweight UML models (D3.1).
- End User competency questions (D3.1).
- End User informal constraint descriptions (D3.1).
- Cross sector generalisation lightweight UML model (D3.1)
- FLEXINET Reference Ontology lightweight UML model (D3.1)

- End User Use Cases (D1.3)

The method for creating the heavyweight KFL code is listed below, this has been applied to each of the five ontology levels, when being generated:

1) Create a KFL context for the ontology level being addressed.
2) For each UML class, create a KFL property.
3) For each UML relationship between UML classes, create a KFL relationship.
4) Using the end user informal constraint descriptions and UML models, create KFL axioms (constraints).
5) Using the end user informal constraint descriptions, create KFL rules.
6) Using the end user competency questions, create KFL queries.

It is important to note that, as each KFL code entry is created, a supporting REM statement is created. These REM statements provide textual descriptions of the meaning of the each KFL code segment for feedback to system users.

It is also important to note that this method is cyclic and the ontology, especially the constraints and rules, will continue to develop as the project undertstanding develops.

3 Reference Ontology Level 1

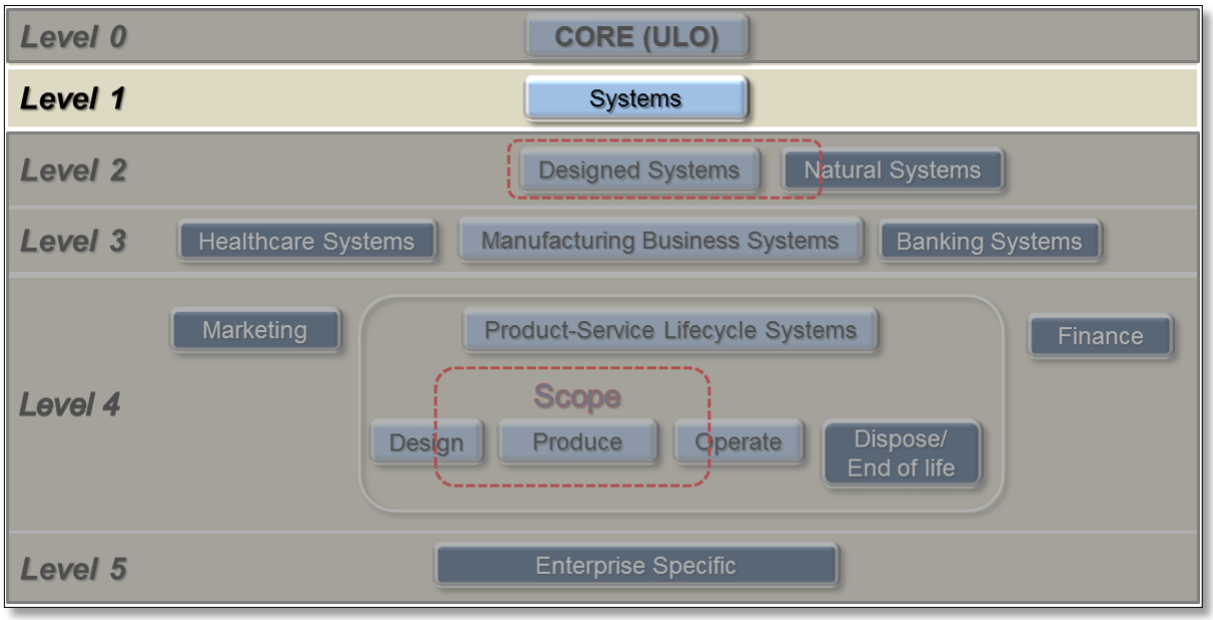


Figure 3-1: FLEXINET Reference ontology level 1

The area of focus in chapter 3 is the Level 1 FLEXINET ontology (see Figure 3-1). The following sections each detail and explain representative sections of the Level 1 FLEXINET Reference Ontology Knowledge Framework Language (KFL) code that has been generated. This KFL code represents the formal ontology code that will be used to support FLEXINET services and applications. The intention in these KFL code chapters is to show sections of KFL code, explain their purpose, the KFL code syntax and the context with which they have been created, i.e. the FLEXINET ontology. The full KFL code is provided in Annex A.

The FLEXINET level 1 reference ontology seeks to represent a system or a number of systems as a generic representation. For D3.2, the Level 1 reference ontology has been further developed from the initial output in D3.1 with the addition of the concept "scenario", as illustrated in Figure 3-2. Scenario concepts are defined within the FLEXINET reference ontology in order to provide a method to describe multiple alternative instantiations of global production networks (this is further described in Section 3.6). For clarity, we repeat here, from D3.1, the key elements of explanation of the level 1 concepts, with the addition of the scenario concept. Level 1 consists of two parent classes, those of Basic and Role. Basic has four main subtypes, those being Material, Energy, Information and System; Role has four main subtypes, those being Input, Output, Resource and Control. As per the UML model, a Basic can consist of a Basic or any number of Basics, this applies equally to Role, in that it can be composed of Roles. But, a Basic can affect the state of a Role, and in turn a Role can affect the State of a Role. In turn, a Role dependsON a System for the context, and a System is composed of Roles. Roles can exist relative to a TimeSpan (a concept taken from the Level 0 Core ontology) and are played within a scenario. Additionally scenarios can be composed of scenarios. The cardinality for Basic and Role states that a Basic can play more than one Role, and a Role can be played by more than one Basic.

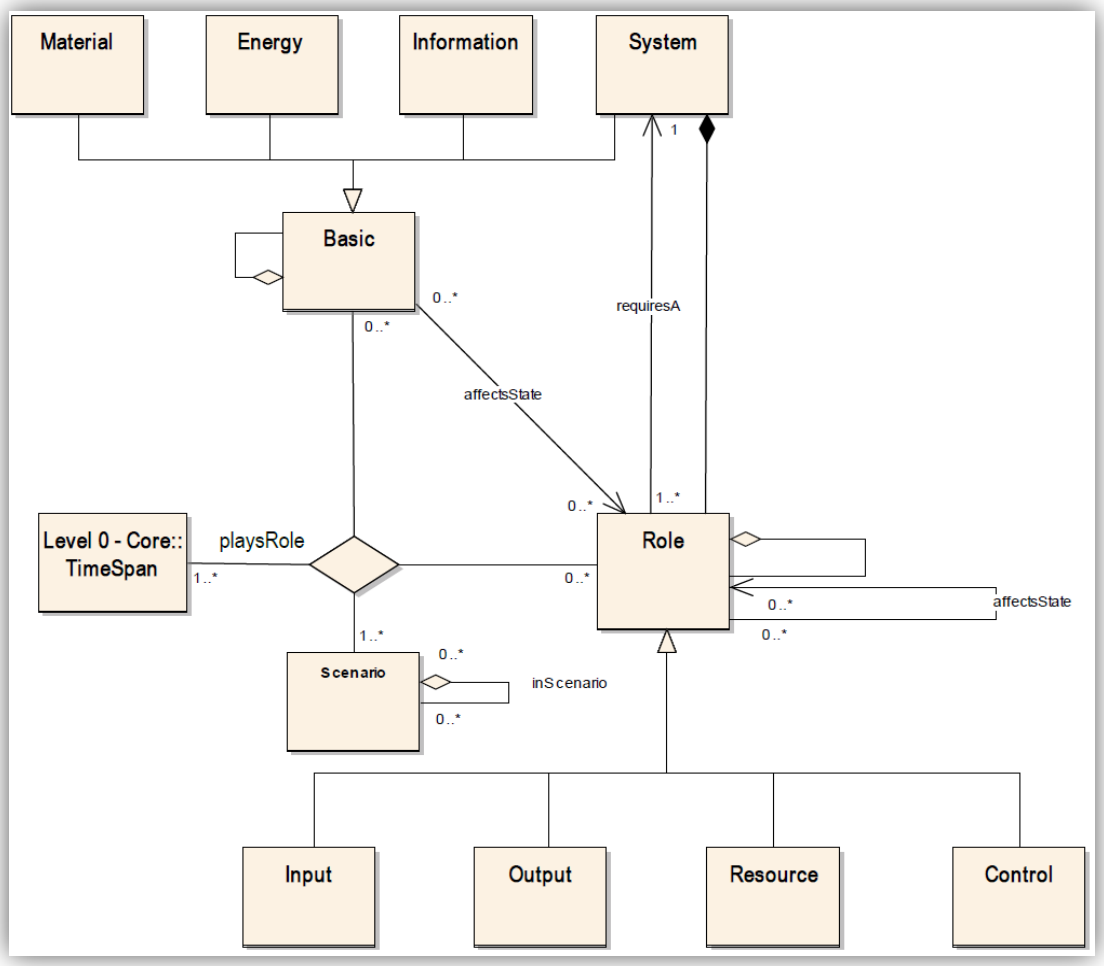


Figure 3-2: Reference ontology level 1 UML model

The following sub-sections provide an explanation of the key concepts of Basic, Role Scenario and PlaysRole from the level 1 ontology in order to illustrate the use of KFL to model the various classes and relationships. Illustrations of a constraint and a rule are also provided. The scenario concept has been defined as it is needed to store answers to "what-if" questions and therefore extends the general level 1 concepts as defined in D3.1.

3.1 Reference Ontology Level 1: Context

```
;; Context file
:Use MLO
:Ctx 1SYSCtx
:Inst UserContext
:supCtx MLO
```

Figure 3-3: Level 1 context in KFL

For each reference ontology level within the KFL code a context must be stated so as to uniquely identify the concepts relative to a given perspective, in this instant the perspective is level 1. Figure

3-3 shows the KFL code for the Level context statement. The first line states 'Use MLO', this is the Highfleet Middle Level Ontology (MLO). The purpose of this is a reference point to a general top level ontological lexical resource to be used by the FLEXINET reference ontology. Such an ontology contains concepts useful to many perspectives. The second line 'Ctx 1SYSCtx' defines the context (Ctx) as the FLEXINET Level 1 Systems (SYS) Context (1SYSCTx). The third line 'Inst UserContext', identifies that 1SYSCTx is an Instance (Inst) of UserContext. UserContext is a MLO concept, not to be mistaken with Level 5 End User contexts. The final line states that it inherits from the MLO, i.e. includes the concepts from the MLO, in addition to the user defined concepts.

3.2 Reference Ontology Level 1: Properties

```
:Prop Basic

:Inst Type

:Inst NonLogicalFunctor

:sup Particular

:partitionedBy (listof System Energy Material Information)

:rem "A Basic concept is independent of the <sym>1SYSCtx.System</sym> or context, its definition
does not depend on another concept.

A Basic can be classified as <sym>1SYSCtx.System</sym>, <sym>1SYSCtx.Information</sym>,
<sym>1SYSCtx.Material</sym> or <sym>1SYSCtx.Energy</sym>."
```

Figure 3-4: Level 1 property KFL for 'basic'

Properties are frames that allow concepts to be defined. Figure 3-4 illustrates the property 'Basic' (Prop Basic) from the level 1 UML diagram in Figure 3-2. It is an instance of a type (Inst Type), as such a type is something that always exists, additionally it is an instance of a non-logical functor (Inst NonLogicalFunctor) and hence is infinitely valued. It has a super-property (sup) of a Particular (things that are unique) contained within the Highfleet MLO. 'PartitionedBy' states that the only sub-properties of Basic can only be 'System', 'Energy', 'Material' and 'Information' (as per the UML diagram in Figure 3-2), additionally 'Partiti*onedBy' implies that any instances of basic sub-properties are pairwise disjoint, i.e. an instance of a sub-property cannot be an instance of another sub-property, for example Gas_ID_27 cannot be an instance of Energy and Material. The final part of the KFL code is a 'rem' statement. These are textual statements within the code not meant for computation, providing more information for user comprehension of the specific items of KFL code. For property 'Basic' the rem statement defines what a Basic is and its sub-properties. '/sym' is a hyperlink to other items or relations within the ontology.

```
:Prop Role

:Inst Type

:sup MLO.AbstractEntity

:disjointWith Basic

:rem "The Role type includes all of the types of <sym>MLO.AbstractEntity</sym> terms that participate in systems.

A Role cannot exist without a context. A <sym>1SYSCtx.System</sym> provides a context for the Roles it contains.

To aid efficiency all Roles are declared as pairwise disjoint. A Basic can play more than one role."

(disjointSubProps Role)
```

Figure 3-5: Level 1 property KFL for 'role'

Figure 3-5 sets out the Role property. It is an instance of a Type and has a super-property (sup) of MLO.AbstractEntity (i.e. does not have the relationships MLO.LocatedIn). It is 'disjointWith' a Basic, i.e. an instance of role cannot also be an instance of a basic. The rem statement explains meaning of the property Role, in this instance, all roles include AbstractEntities that participates in systems, that a role cannot exist without a context, that all Roles are pairwise disjoint and as per the UML representation a Basic can play more than one Role.

```
:Prop Scenario
:Inst Type
:sup AbstractEntity
:rem "A scenario provides a view upon a <sym>1SYSCtx.System</sym>
by providing an identifier for each <sym>1SYSCtx.Role</sym> played
within the System."
:disjointWith Role
:disjointWith Basic
```

Figure 3-6: Level 1 rule KFL code for a scenario

A new concept addition at level 1 in this deliverable D3.2 is the concept, or "property" in KFL terminology, of Scenario (see Figure 3-6). Scenario concepts are defined within the FLEXINET reference ontology in order to provide a method to describe multiple alternative instantiations of global production networks. It is defined at level 1 in order to catch its relationships with Basics and Roles. However, it is developed in detail at level 4 in section 7.5.

3.3 Reference Ontology Level 1: Relationships

```
:Rel playsRole

:Inst TernaryRel

:Inst NonRigidRel

:Sig Basic Role Scenario

:Args "Basic" "Role" "Scenario"

:lex "Basic entity ?1 plays Role ?2 in Scenario ?3"

:rem "To provide a <sym>RootCtx.TimeSpan</sym> use the ECLIF operator
<sym>holdsIn</sym>."
```

Figure 3-7: Level 1 relationship KFL for 'playsRole'

Figure 3-7 depicts the KFL code for, the PlaysRole relationship. It is an instance of a ternary relationship ('Inst TernaryRel') between three properties and a NonRigid relationship ('RigidRel'), i.e. these relationships will only hold over a particular timespan. 'Sig Basic Role Scenario' states the properties of the arguments of the relationship i.e in this case the relation must be between a basic a role and a scenario.. 'Args' are strings that provide more detailed descriptions of argument properties. 'lex is a string template intended to provide a human-readable expression of its semantics.

Note: While the UML model shows a quaternary relation, ECLIF provides an operator "HoldsIn" which provides the equivalent of the "timespan" shown in Figure 3-2.

Utilising this relationship and the 3 concepts of Basic, Role and Scenario we can start to model useful GPN relationships. Consider two possible apple suppliers to CustomDrinks; BrownFarms and JonesFarms. These are 2 instances of basic that play the role of suppliers. The use of scenario allows us to consider, in this case, 2 possible options: scenario 1 where BrownFarms is the supplier; scenario 2 where Jones Farms is the supplier. The latter would be represented as JonesFarms playsRole AppleSupplier.

3.4 Reference Ontology Level 1: Constraints

```
(=> (Role ?r)
    (exists (?s)
                (and (System ?s)
                        (requiresA ?r ?s))))
:IC hard "The Role ?r requiresA System to provide a context."
```

Figure 3-8: Level 1 axiom KFL for role requiring a system for a context

Constraints prevent inconsistent statements. KFL can model hard (IC hard) or soft constraints (IC soft). Integrity constraints are used to check data when it is loaded into the ontology. A hard IC must be obeyed and therefore can stop data being loaded that does not conform to the constraint. A soft IC produces a warning when data is loaded but data can still be loaded if this is ignored. Figure 3-8 illustrates an IC, it states that for all roles (Role ?r), a system (System ?s) must exists (exists (?s)), the role is related to the system (requiresA ?r ?s.).

3.5 Reference Ontology Level 1: Rules

```
(=> (requiresA ?x ?y)
    (systemContainsRole ?y ?x))
;;;A Role requiring a System as a context implies that the System contains the Role
```

Figure 3-9: Level 1 rule KFL for a role requiring a system

Ontology rules are used to derive new information from the existing knowledge within the knowledgebase. Figure 3-9 shows an example of a rule, it states in KFL that if an instance of a role 'requiresA' specific system (requiresA ?x ?y), then that system also contains that role (systemContainsRole ?y ?x).

4 Reference Ontology Level 2

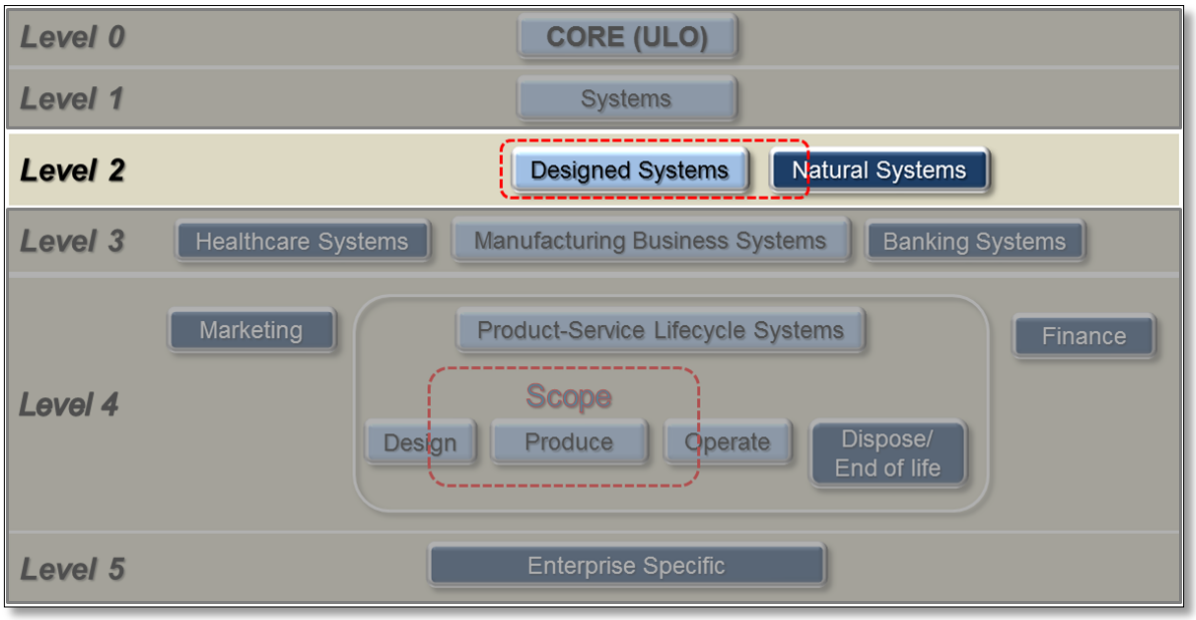


Figure 4-1: FLEXINET Reference ontology level 2

The area of focus in chapter 4 is the Level 2 FLEXINET reference ontology as highlighted in Figure 4-1. The following sections each explain the sections of the Level 2 FLEXINET Reference Ontology along with representative Knowledge Framework Language (KFL) code that has been generated.

To enable a fuller perspective for the reader of the Level 2 FLEXINET reference ontology, Figure 4-2 provides a high level overview of the layout and structure of the concepts (properties in KFL) that exist within it. These Level 2 concepts have been specialised from Level 1, hence there are a set of Basics, a set of Systems (a specialised sub set of Basics), a set of Roles and a set of Environ Factors. (a specialised sub set of Roles). The level 2 Basics include concepts such as Customer Demand, Visualisation and Report, additionally Systems includes concepts like Organisation, Facility and Logistics. The Level 2 Roles are broken down into three specialisations, firstly there are the Disparate Roles (example concepts being Asset, Product and Requirements), then the Qualifier Roles (example concepts being Performance, Quality and Robustness) and finally the Actor Roles (example concepts being Customer, Supplier and Service). Contained within the Actor Roles is Risk, which is detailed in section 4.7. The Environ Factors include and account for the Social, Technological, Economic, Environmental and Political (STEEP) factors within the FLEXINET reference ontology. These are set out in section 4.6.

It is important to note that there are many concepts that have been identified in level 2. These, at this stage of development have a indication of their applicability in their "rem" statements but these applicability constraints have yet to be formalised. This will be carried out in D3.3 for those concepts that are identified to be of particular significance to the end user test cases. Some of this activity is already underway in relation to environ factors, risk and GPN actors.

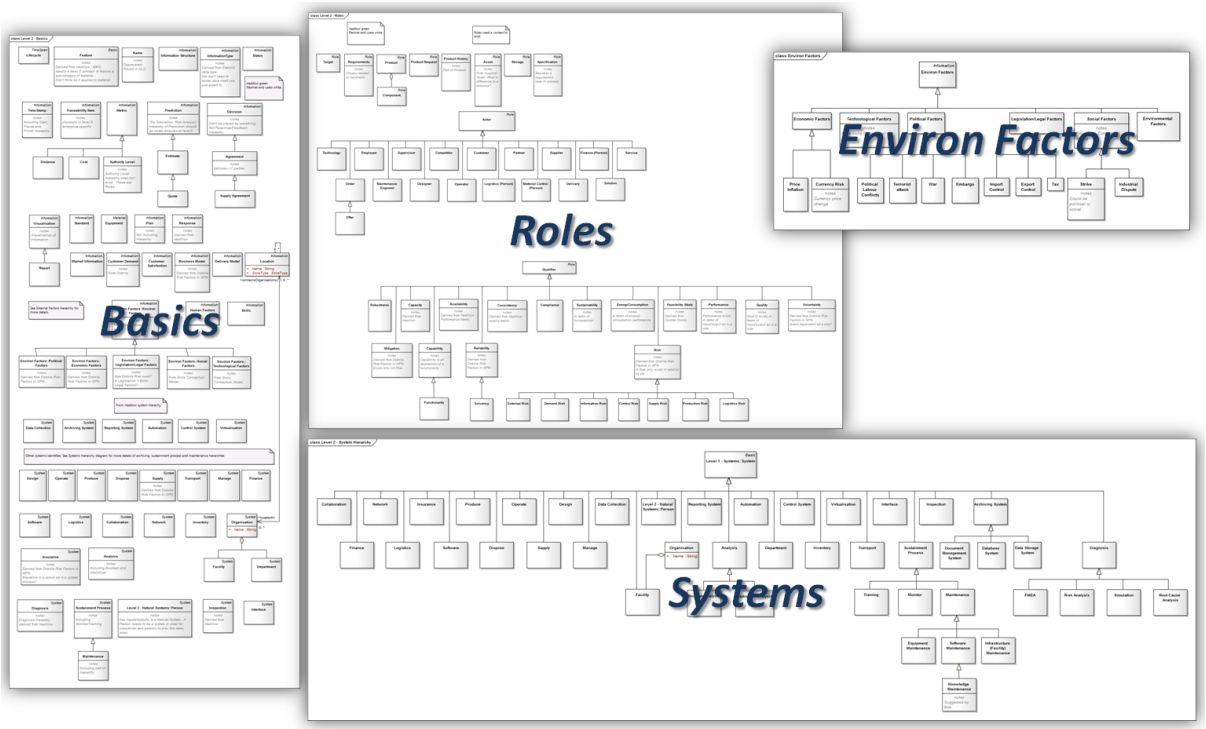


Figure 4-2: An overview of the Level 2 reference ontology properties

4.1 Reference Ontology Level 2: Context

The context (Ctx) defined for level 2 is 2DSCtx (see Figure 4-3). This is an instance of a UserContext and inherits from the level 1 context (1SYSTCtx). Properties, Rules, Axioms and Constraints will be defined within this context.

```
:Use ../1SYSCtx

:Ctx 2DSCtx
:Inst UserContext
:supCtx ../1SYSCtx
```

Figure 4-3: Context Level 2

4.2 Reference Ontology Level 2: Systems

Systems elements within level 2 of the FLEXINET reference ontology represent (as described in D3.1) the set of the "Designed Systems" that are man-made creations, including fabricated physical systems, conceptual knowledge and purposeful creations. Systems in level 2 are the set of elements that will inherit properties, relationships, constraints and axioms from the term "System" defined in the above section.

Figure 4-4 shows the UML representation of the list of systems (subtypes of System) within the FLEXINET reference ontology level 2. As an example, we highlight concepts like Facility and Organisation, both are subtypes of System but, in FLEXINET they are defined as 'a composition of Facilities'.

General subtypes of Systems such as Logistics, Network, Supply, Department, Analysis and Transport are defined in this level. The following terms, Analysis, Sustainment Process, Maintenance, Archiving Systems and Diagnosis are Systems which encompass more subtypes. Analysis System has two subtypes, Boolean and Statistical Analysis. Archiving System has three, Document Management System, Database and Data Storage System. Similarly, Diagnosis term has for subtypes, Sustainment Process and Maintenance classes have also three subtypes. Finally, we consider Knowledge Maintenance as a subtype of Software Maintenance.

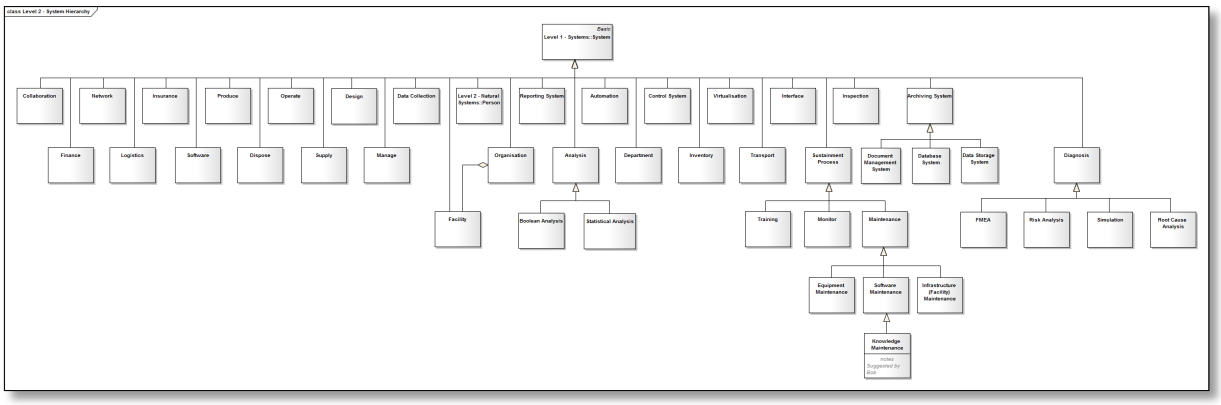


Figure 4-4: Level 2 reference ontology subtypes of System

The following is a description of how the terms and concepts described in Figure 4-4 have been implemented in KFL.

4.2.1 Properties

Properties defined in KFL are those represented in Figure 4-4 as UML classes. Annex B provides the complete list of properties referring to Systems in Level 2. As representative examples of systems at this level the following terms Facility, Organisation and Logistics, are presented. These representations all show the inheritance from level 1 "system". All level 2 concepts will inherit from a level 1 concept.

4.2.1.1 Organisation

Figure 4-5 shows the definition of the level 2 systems term Organisation in KFL. It is an instance of a type, inherits from System and is disjointWith Facility. As such it is defined as 'a social unit of people that is structured and managed to meet a need or purpose or to pursue collective goals'.

```
:Prop Organisation
:Inst Type
:sup System
:disjointWith Facility
:rem "A social unit of people that is structured and managed to meet
a need or to pursue collective goals."
:referenceRem "http://www.businessdictionary.com/"
```

Figure 4-5: Level 2 Property Organisation KFL

4.2.1.2 Facility:

Figure 4-6 represents the property Facility in KFL. It is an instance of a type and inherits from System. Facilities (along location and regions) will represent the building blocks in the representation of a GPN.

It is important to note that as we are principally concerned with systems and their inputs and outputs. We therefore represent facilities that provide outputs as being systems. It is also possible to represent the buildings that comprise the facility as being a "material" basic.

```
:Prop Facility
:Inst Type
:sup System
:rem "Permanent, semi-permanent, or temporary commercial or industrial property such as
a building, plant, or structure, built, established, or installed for the performance of
one or more specific activities or functions."
:referenceRem "http://www.businessdictionary.com/"
(disjointSubProps Facility)
```

Figure 4-6: Level 2 Property Facility in KFL

4.2.1.3 Logistics:

Figure 4-7 represents Logistic property definition in KFL. It is an instance of a type and inherits from System. Its definition is the management of materials flow between facilities, from raw materials through to finished goods.

```
:Prop Logistics
:Inst Type
:sup System
:rem "The management of materials flow through an organization,
from raw materials through to finished goods."
:referenceRem "http://www.collinsdictionary.com/"
```

Figure 4-7: Level 2 property Logistics in KFL

4.2.2 Relationships

Figure 4-8 illustrates the relationship between Organisation and Facilities. In FLEXINET an Organisation is composed of Facilities.

```
:Rel OrganisationComposedOfFacility
:Inst BinaryRel
:Inst RigidRel
:Sig Organisation Facility
:Args "organisation" "facility"
:lex "?1 is composedOf ?2"
:rem "An organisation is composed of facilities."
```

Figure 4-8: Level 2 OrganisationComposedOfFacility relationship in KFL

4.3 Reference Ontology Level 2: Actor Roles

This section is focused on Actor Roles (formerly named as Participator Roles). Actor roles are Roles 'capable of fulfilling functional requirements'. They are processes that perform functions and are played by Systems (also Basics)" (D3.2). Figure 4-9 presents the list of Actor roles considered at level 2. Almost all the terms are subtypes of *Actor Role*. An exception is "Offer" which is subtype of "Order".

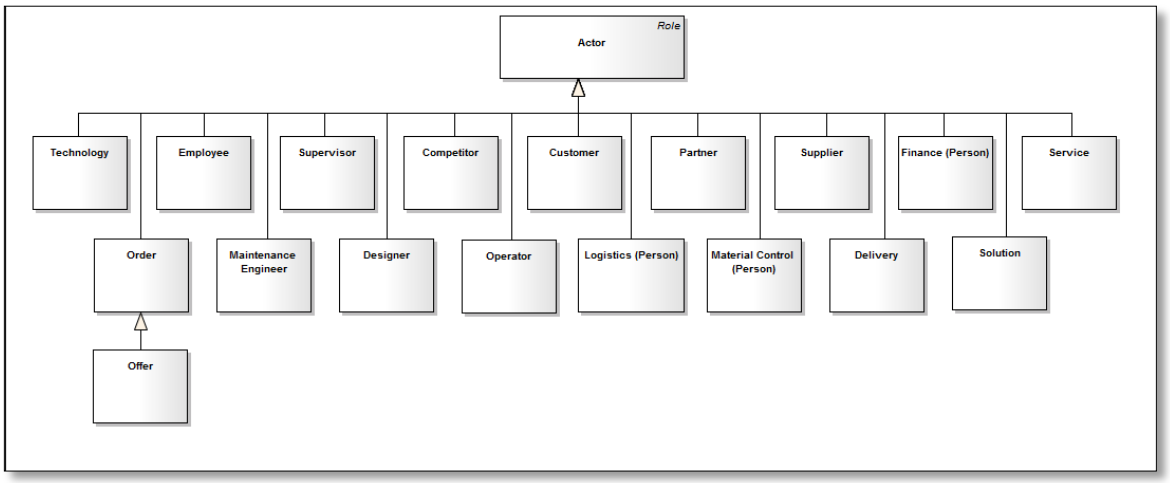


Figure 4-9: Level 2 reference ontology Actor Roles

To date the main actor roles of importance to the project have been identified as Supplier, Intermediary (logistics), Producer, Service Provider, Customer, and Consumer. The Consumer. Intermediary and Service Provider concepts have yet to be represented in KFL and will be included in the next deliverable D3.3.

4.4 Reference Ontology Level 2: Basics

This section is focused on properties that are sub-properties of the Basic properties 'Material' and 'Information' (see Figure 4-10) that are defined in Level 1. The representation of these Basics is provided in Annex B. These will be further developed in D3.3 as required for the end user test cases.

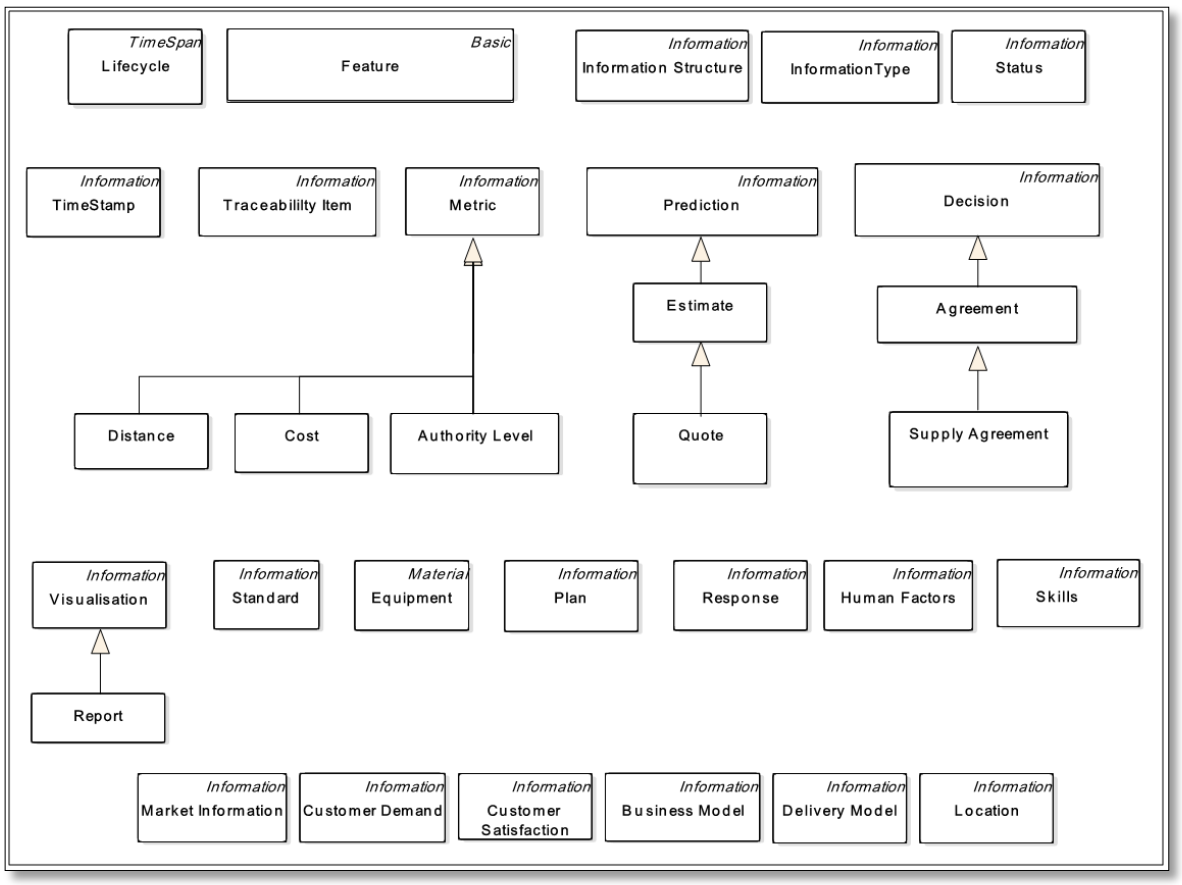


Figure 4-10: Level 2 reference ontology basic Roles

4.5 Reference Ontology Level 2: Disparate Roles

This section is focused in disparate Roles for level 2 as illustrated in Figure 4-11. These roles are a collection of unclassified roles which do not fit into to the Actor of Qualifier role categories.

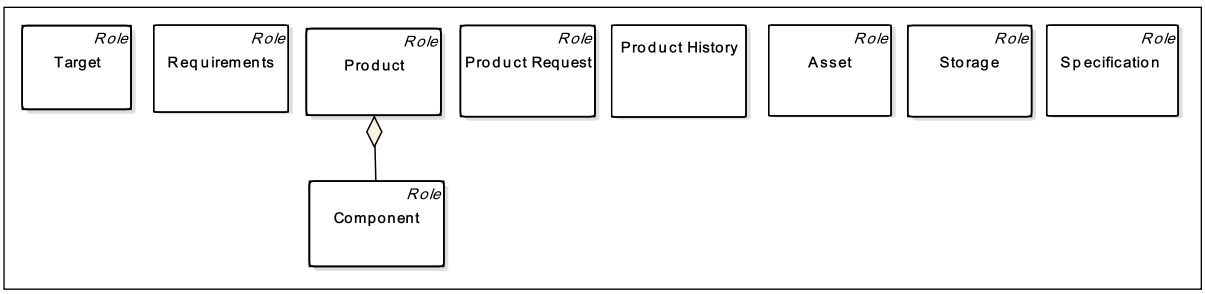


Figure 4-11: Level 2 reference ontology disparate Roles

These concepts are represented in annex B as simple concept representations with no rules, axioms or constraints. Again these will be added and extended as requirements develop from WP and WP4.

4.6 Reference Ontology Level 2: Environ Factors

The following section describes examples of the initial environ factors ontology. The original level 2 ontology name for this section was 'External Factors', but this was renamed due to the connotations and perceptions that this phraseology can produce. Therefore by renaming them to Environ factors they represent "*areas surrounding a place or one's surroundings*" (Oxford English Dictionary, 2014).

It is anticipated that this aspect of the ontology will be developed significantly in D3.3. The new understanding that is coming from WP2 on the relationships between these factors and performance indicators along with the business rules from D2.2 are likely to require substantial extensions to the constraints, rules and relationships in the ontology.

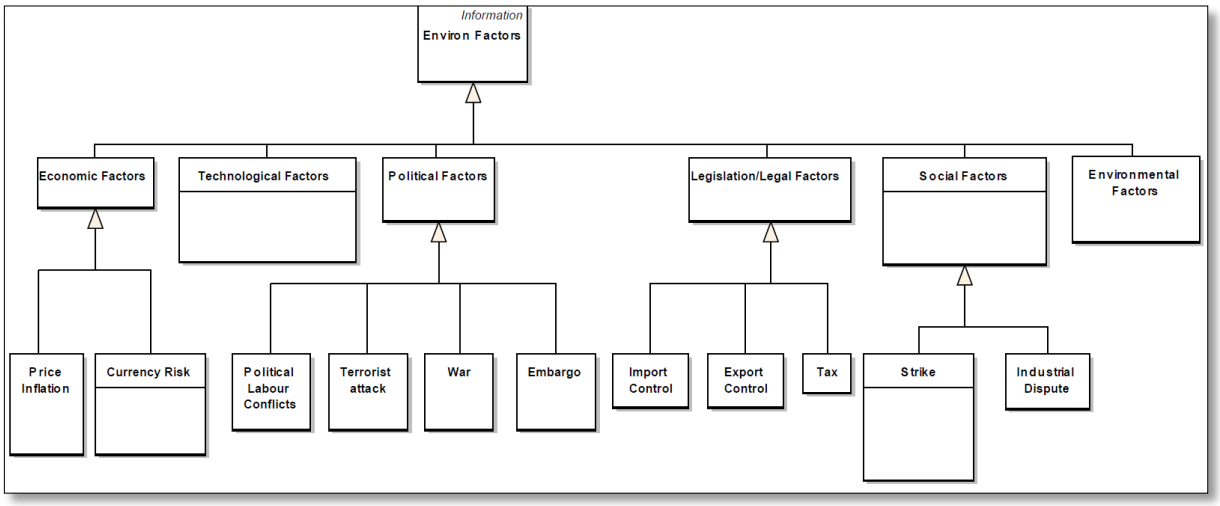


Figure 4-12: Level 2 reference ontology environ factors

4.6.1 Properties

Properties defined in KFL are those represented in Figure 4-12. Annex B provides the complete list of properties referring to Environ Factors in Level 2. Two representative terms are presented as examples.

4.6.1.1 EnvironFactor

```
:Prop EnvironFactor

:Inst Type

:sup Information

:sup MLO.Object

:rem "Environ Factors influence actors in global production networks.

Conceptually, an Environ factor influences certain business model component. (An environ factor has a unique name.

Environ Factor inherits this relation from Object)"

:referenceRem "2014 FLEXINET D2.1"
```

Figure 4-13: Level 2 EnvironFactor in KFL

Figure 4-13 sets out the property for EnvironFactor. It is an instance of a Type, it inherits from the level 1 basic Information and level 0 Middle Level Ontology Object (MLO.Object). As per the explanation in Figure 4-13 and EnvironFactor influences certain business model components.

4.6.1.2 PoliticalFactor

```
:Prop PoliticalFactor

:Inst Type

:sup EnvironFactor

:rem "Political factors identify to what degree a government intervenes in the economy. Also, political factors determine health, education and infrastructure of a nation to a certain extent."

:referenceRem "2014 FLEXINET D2.1"

(disjointSubProps PoliticalFactor)
```

Figure 4-14: Level 2 PoliticalFactor in KFL

PoliticalFactor is a level 2 specialisation (see Figure 4-14) of EnrionFactor as indicated by the 'sup' EnvironFactor. The rem statement explains what PoliticalFactor pertains to. A 'referenceRem' is a specialisation of a rem statement which provides a reference for the property. The disjoint sub-properties relationship (disjointSubProps) indicates that all sub properties of PoliticalFactor are pairwise disjoint.

4.6.2 Relationships

The relationship hasEnvironFactorDescription is provided as an example of an Environ factor relationship.

4.6.2.1 *hasExternalFactorDescription*

Figure 4-15 illustrates the relationship between EnvironFactor and description. This relation is states that an environ factor may only have one description attributed to it.

```
:Rel hasEnvironFactorDescription

:Inst BinaryRel

:Inst RigidRel

:Sig EnvironFactor String

:Args "Environ Factor" "Description"

:lex "?1 is described by ?2"

:rem "An Environ Factor may only have one description."

(functionalArg hasExternalFactorDescription 2)
```

Figure 4-15: Level 2 hasEnvironFactorDescription in KFL

4.7 Reference Ontology Level 2: Risk

The following section describes examples of the initial risk ontology for level 2, as set out in Figure 4-16, following the input from WP2 and WP4.

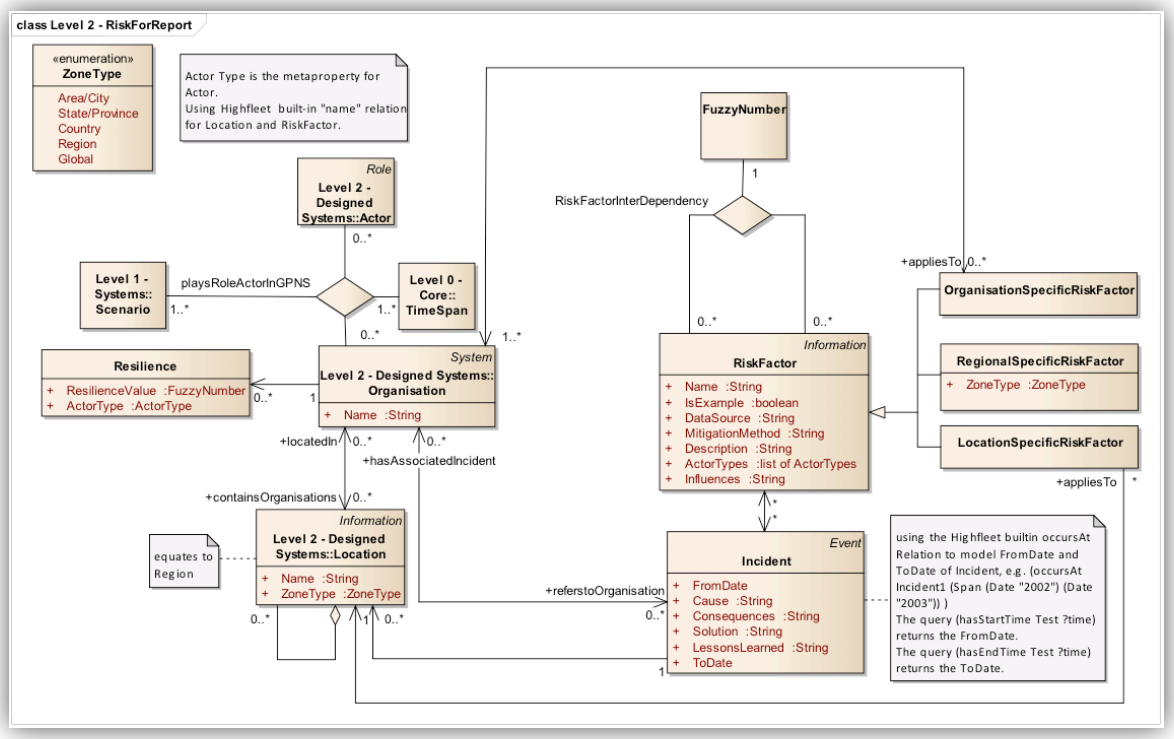


Figure 4-16: Level 2 reference ontology risk factors

Figure 4-16 shows the concepts needed to describe Risk at Level 2. This set of initial risk concepts apply to the Organisation concept which is located at Level 2. The playsRole relation is specialised from Level 1 to playsRoleActor. An Organisation, which inherits from System, has Resiliences and associated Incidents. The Resilience has an actorType and a Resilience Value which depends on the Organisation's Actor role, i.e., an Organisation will have a difference Resilience value depending on whether it plays the Role of a Supplier, Customer, etc. An Incident has related Risk Factors, which are described in detail in D4.1 and followed here in section 4.4. A risk factor has an interdependency value upon other Risk Factors, for example a RiskFactor "Inadequate Product Quantity" might depend on "Unavailability of Ingredients/Materials". The RiskFactor is specialised into OrganisationSpecificRiskFactor, RegionSpecificRiskFactor and LocationSpecificRiskFactor. An OrganisationSpecificRiskFactor applies to a particular Organisation, a RegionSpecificRiskFactor applies to a specific zoneType (e.g. Area/City, Country) and a LocationSpecificRiskFactor applies to particular location (e.g. Loughborough, Spain, etc.). The Risk concepts will be updated to align with the Business Model section of the ontology in D3.3.

4.8 Reference Ontology Level 2: Qualifier Roles

The following section describes examples of the initial qualifier role ontology for level2.

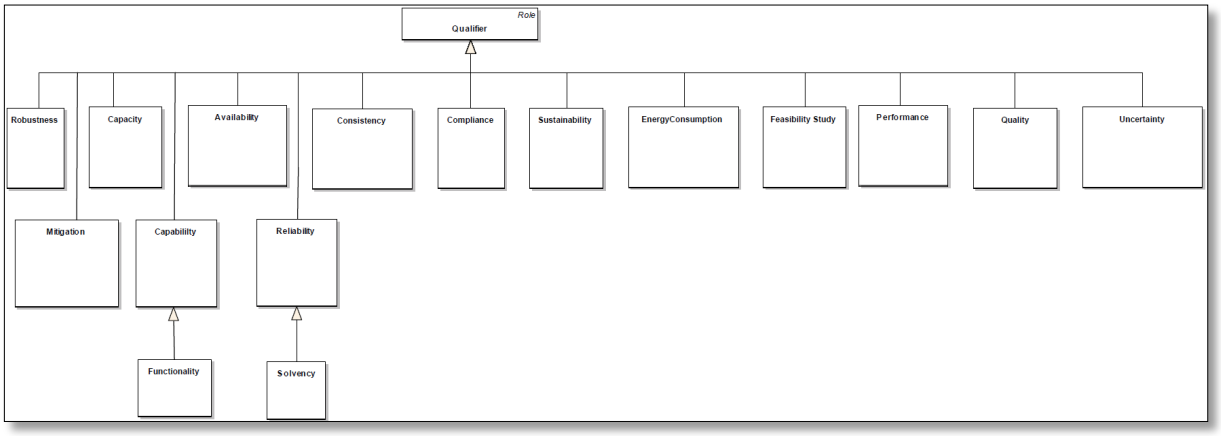


Figure 4-17: Level 2 reference ontology risk factors

4.8.1 Properties

Properties defined in KFL are those represented as the UML classes in Figure 4-17. Annex B provides the complete list of properties referring to Qualifier Roles in Level 2. Two representative terms are presented as examples.

4.8.1.1 Qualifier

The property Qualifier is presented in Figure 4-18. It is an instance of a Type (Inst Type) and inherits from role. As such Qualifiers define how systems will operate by controlling them.

```
:Prop Qualifier

:Inst Type

:sup Role

:rem "A Qualifier is a <sym>1SYSCtx.Role</sym> which is able to fulfil a non-functional requirement.

Qualifiers define how a <sym>1SYSCtx.System</sym> will operate by controlling the system processes. A Qualifier is played by a <sym>1SYSCtx.Information</sym> which is a subtype of <sym>1SYSCtx.Basic </sym>."

:referenceRem "2014 FLEXINET D3.1"

(disjointSubProps Qualifier)
```

Figure 4-18: Level 2 qualifier role in KFL

4.8.1.2 Robustness

Figure 4-19 depicts the property for Robustness. It is an instance of a Type, inherits from Qualifier. Robustness qualifiers define the degree to which a system or component can function correctly in the presence of stressful environmental conditions..

```
:Prop Robustness

:Inst Type

:sup Qualifier

:rem "the degree to which a system or component can function correctly in the presence

stressful environmental conditions."

:referenceRem "BS ISO/IEC IEEE 24765:2010"
```

Figure 4-19: Level 2 robustness role in KFL

5 Reference Ontology Level 3

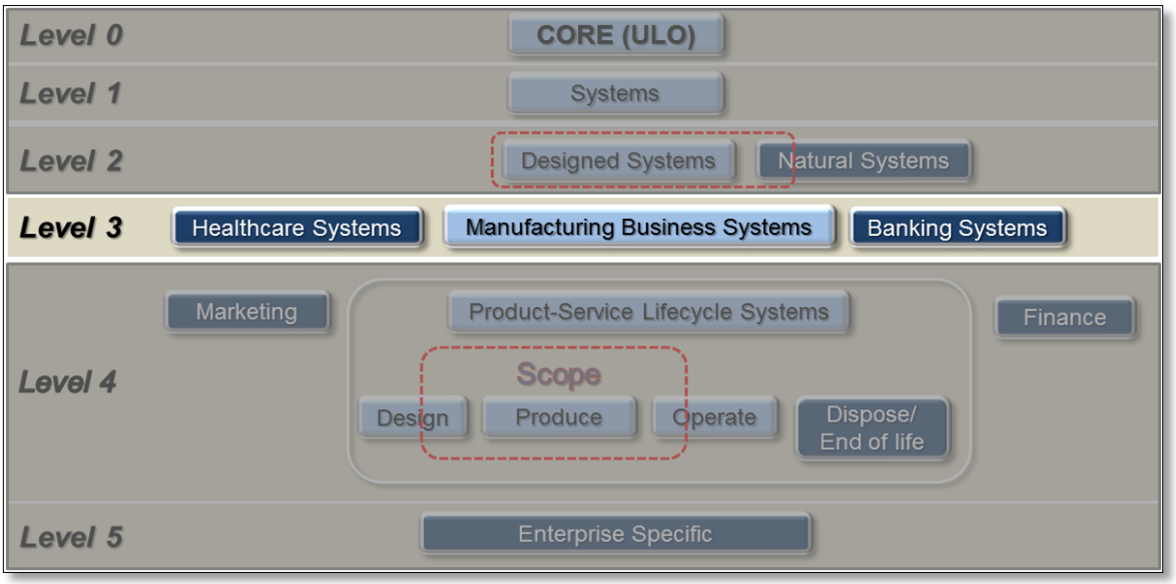


Figure 5-1: FLEXINET Reference ontology level 3

The area of focus in chapter 5 is the Level 3 FLEXINET ontology concerned with Manufacturing Business Systems as highlighted in Figure 5-1. The following sections each explain the representative sections of the Level 3 FLEXINET Reference Ontology.

5.1 Reference Ontology Level 3: Context

The specific context 3MBSCtx for level 3 is included when defining level 3 terms (see Figure 5-2).

```
:Use ../2DSCtx

:Ctx 3MBSCtx
:Inst UserContext
:supCtx ../2DSCtx
```

Figure 5-2: Context Level 3

5.2 Reference Ontology Level 3: Basics

Figure 5-3 illustrates, using a UML class diagram, the Level 3 Basics that are represented in KFL in appendix C. These are specialised from the level 2 concepts illustrated by the name in italics shown in each class in Figure 5-3 e.g. "Manufacturing Business Model" is a specialisation of "Business Model".

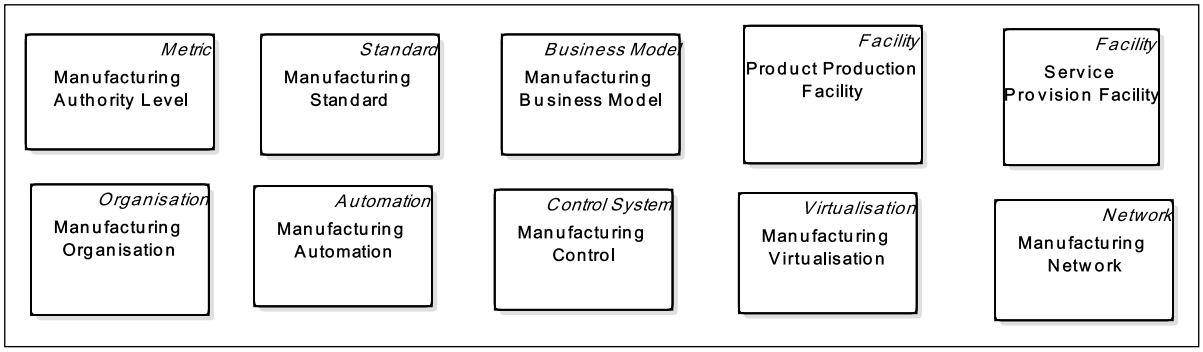


Figure 5-3: Basics in level 3.

5.3 Reference Ontology Level 3: Roles

Level 3 roles are represented, at this stage in the ontology development, by only two terms: Manufacturer and Manufactured Product (Figure 5-4). Other, seemingly related roles such as "supplier" and "customer" are defined at level 2. The KFL code for level 3 roles is provided in Annex C.

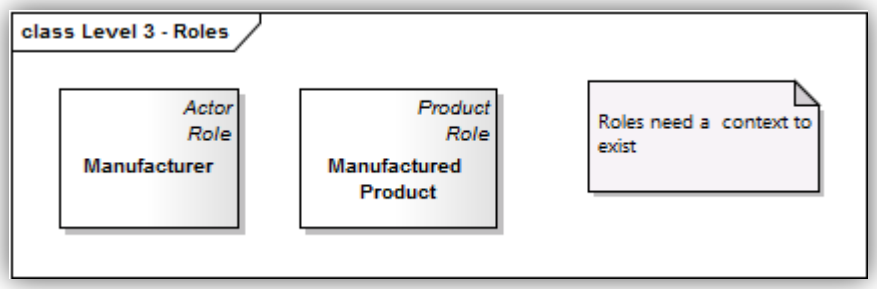


Figure 5-4: Level 3 Roles

6 Reference Ontology Level 4

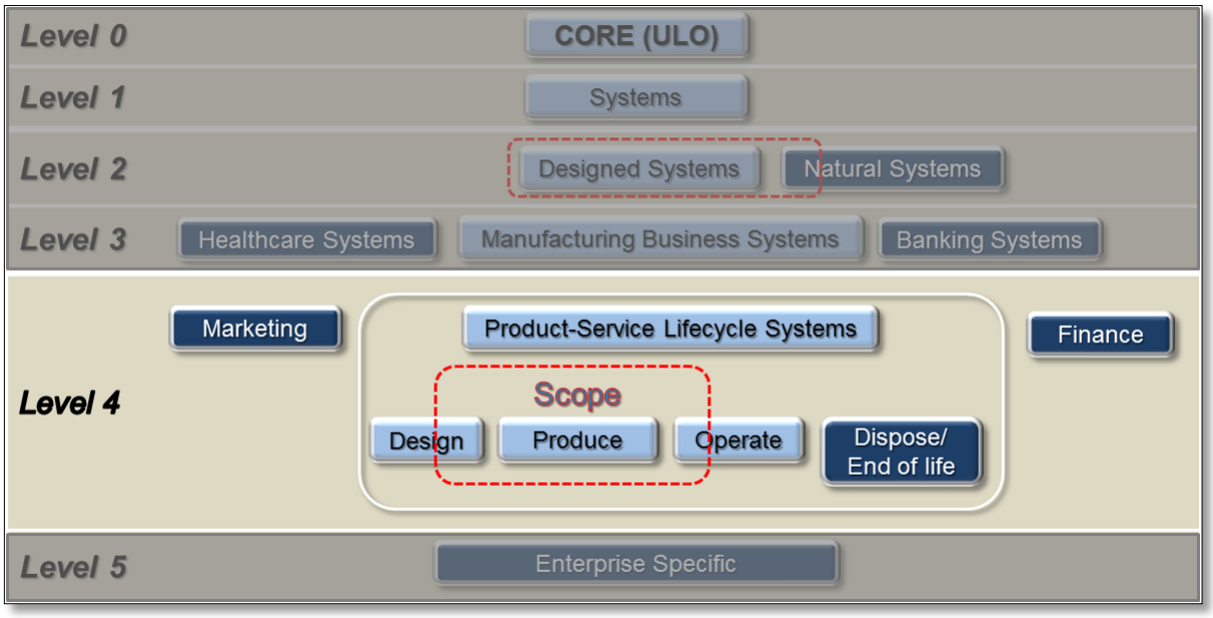


Figure 6-1: FLEXINET Reference ontology level 4

The area of focus in this chapter is the Level 4 FLEXINET ontology for Product Service Production, as highlighted in Figure 6-1. The following sections each explain the representative sections of the Level 4 FLEXINET Reference Ontology. The Knowledge Framework Language (KFL) code that has been generated can be found in annex D.

6.1 Reference Ontology Level 4: Context

The roles at this level make use of the context defined at level 4 as 4PSPCtrx. (see Figure 6-2).

```
:Ctx 4PSPCtx
:Inst UserContext
:supCtx ../4PSLSCtx
```

Figure 6-2: Context Level 4

6.2 Reference Ontology Level 4: Basics

The level 4 Basics are illustrated using a UML Class diagram as shown in Figure 6-3 and the KFL code can be found in annex D. Some of these concepts are specialised directly from level 1 as no more generalised concept has been defined at levels 2 or 3. Again these concepts will be further developed and refined in D3.3.

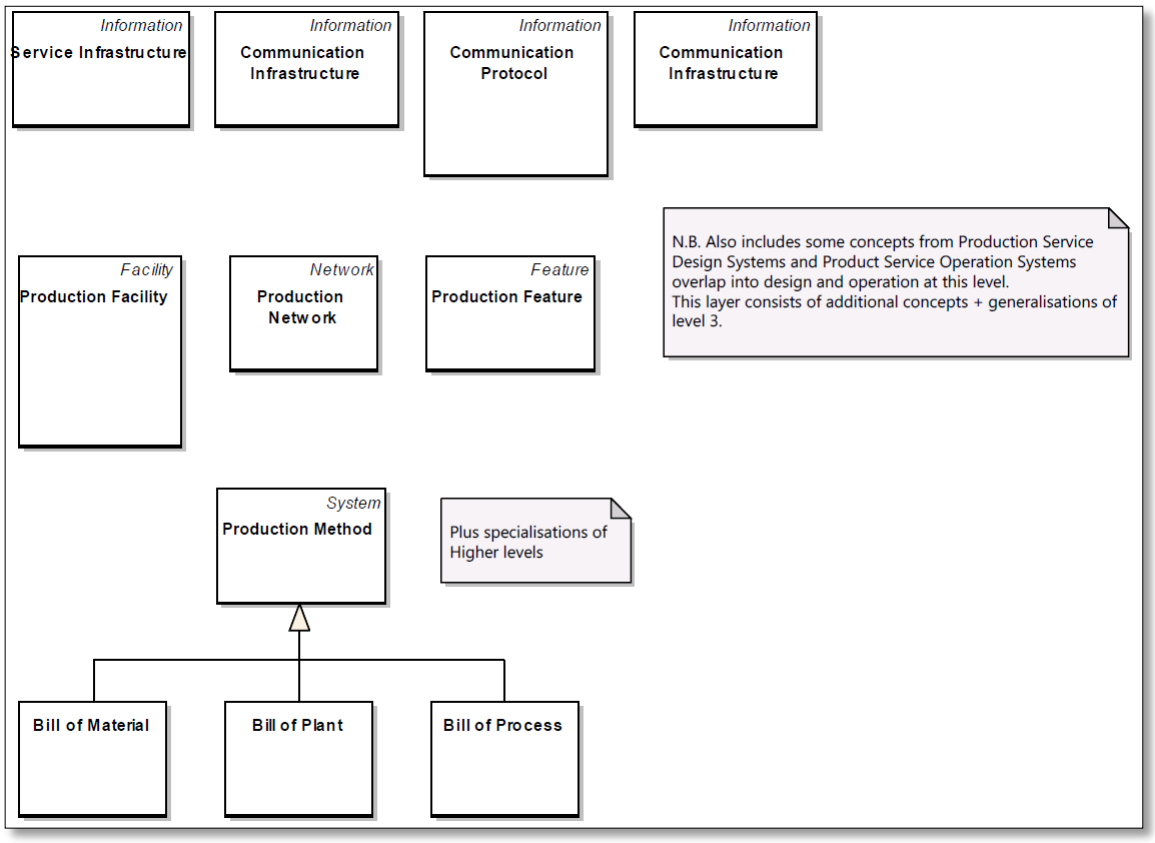


Figure 6-3: Level 4 reference ontology basics

6.3 Reference Ontology Level 4: Roles

The level 4 Roles are illustrated using a UML Class diagram as shown in Figure 6-4 and the KFL code can be found in annex D. The concepts Designer, Production Engineer, Producer and Service Engineer are specialised directly from "Actor" Role in level 2. The remaining concepts are specialisations of sustainability and Energy Consumption concepts from level 2.

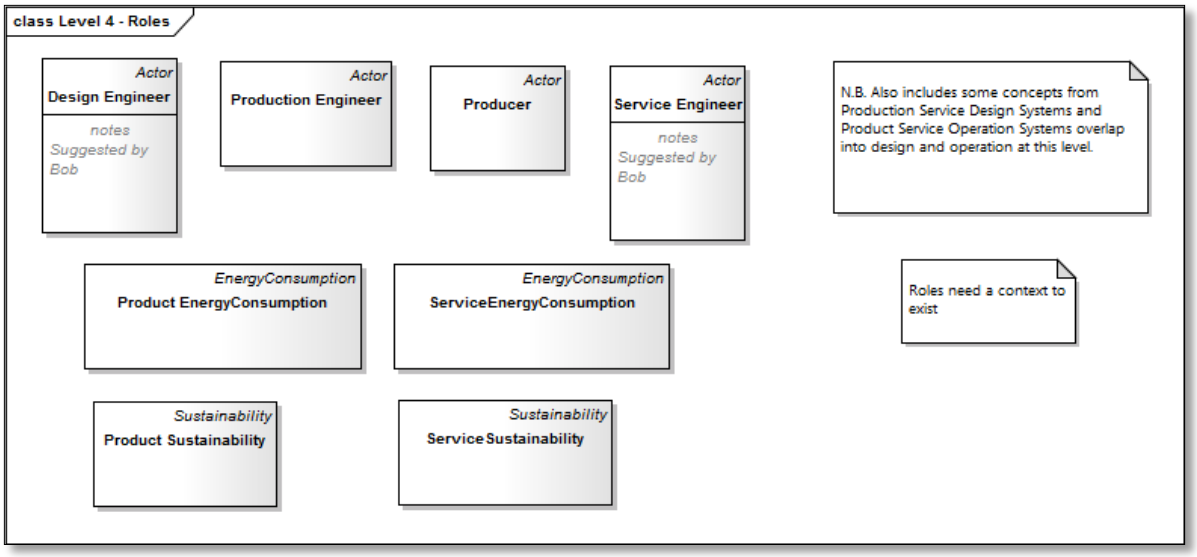


Figure 6-4: Level 4 reference ontology Roles

6.4 Reference Ontology Level 4: Risk

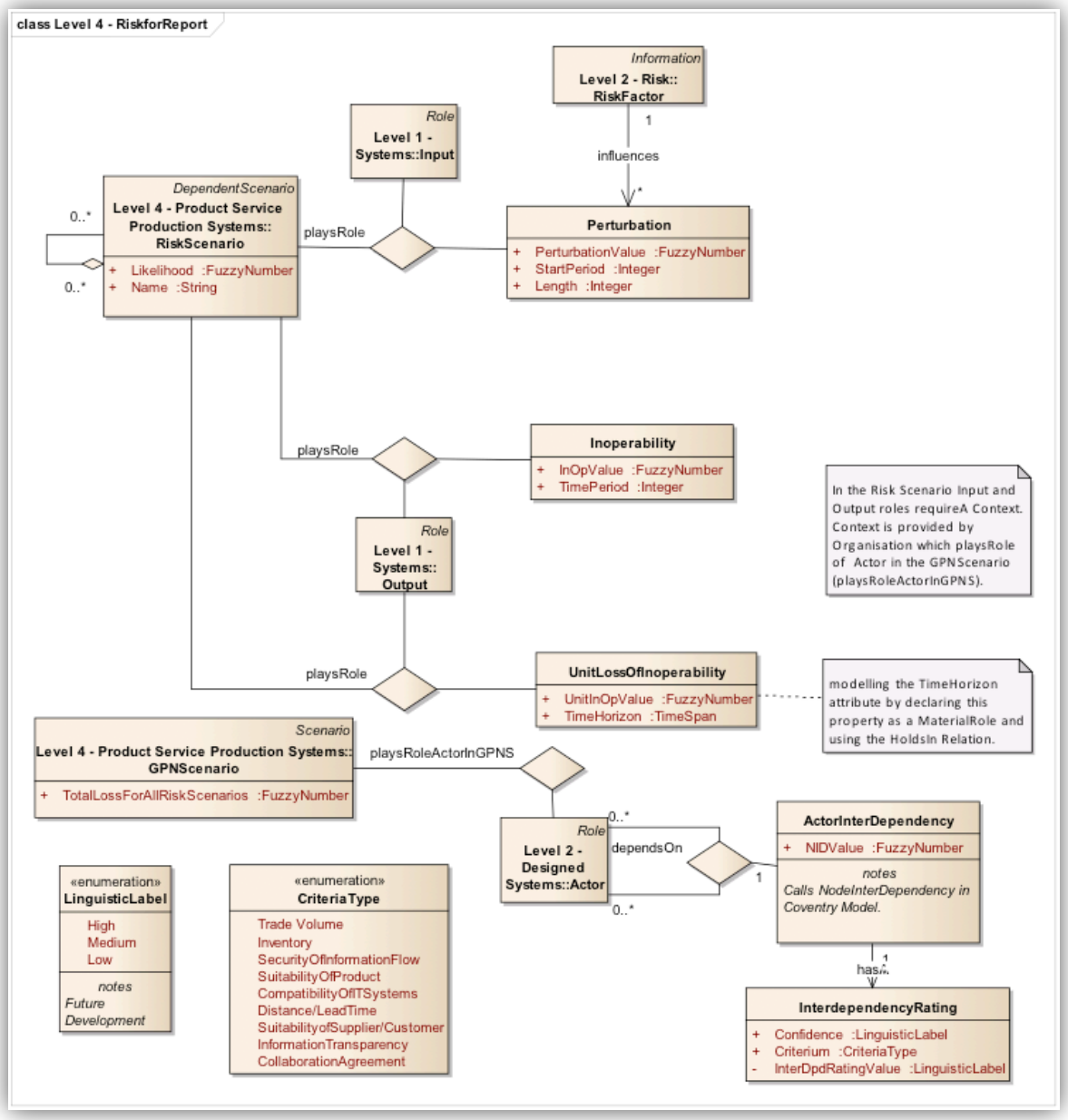


Figure 6-5: Level 4 risk concepts

Figure 6-5 illustrates the Level 4 Product Service Product Risk concepts. These concepts playRoles within the GPNScenario and RiskScenario, so are located at Level 4. The level 1 playsRole relation is shown in the contexts of the Risk concepts. To make Figure 6-5 clearer, the TimeSpan concept is omitted from this relation. An Actor plays a Role in the GPN Scenario (playsRoleActorInGPNS a specialisation of the level 2 playsRoleActor relation). An Actor has an interdependency upon others Actors within the GPNScenario and the interdependency has ratings. The Organisation which plays the Role of the Actor contains Input and Output Roles in the RiskScenario. A Perturbation playsRole Input in the RiskScenario. Inoperability and UnitLossOfInoperability playRole Output in the RiskScenario. A RiskFactor influences the Perturbation.

The full KFL model is provided in Annex D and provides the current status of the ontological requirements for the risk work in WP2 and WP4.

6.4.1 Properties

Properties defined in KFL are those represented in as UML classes in Figure 6-6. Annex B provides the complete list of properties referring to Risk Factors in Level 2. Two representative terms are presented as examples.

6.4.1.1 Perturbation

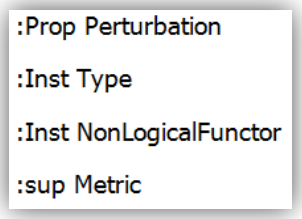


Figure 6-6: Level 2 Perturbation in KFL

The property Perturbation (representing an agitation or disturbance) is set out in Figure 6-8. It is an instance of a Type (Inst Type) and a non-logical functor (Inst NonLogicalFunctor), it also inherits from metric as it is a measure (sup Metric).

6.4.1.2 PerturbationValue

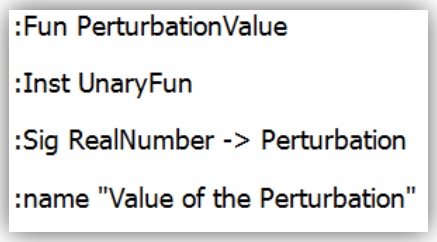


Figure 6-7: Level 2 PerturbationValue in KFL

Functions are used to produce additional entities from one or more parameters. Functions use arguments to refer to a property and return an instance, hence a function term is an expression consisting of the function name and argument sequence. Figure 6-9 shows an example of this for PerturbationValue, it is an instance of a Unary Function (UnaryFun), which is a function with one argument. 'Sig' specifies the function properties for the arguments. The Sig directive consists of two parts, values on the left of the arrow indicate the arguments to the function; the value on the right of the arrow is the property instantiated by the entire function term, hence for PerturbationValue, values assigned to this instantiate perturbations. An example of this is PerturbationValue a fuzzy number 0.3 (PerturbationValue 0.3).

6.5 Reference Ontology Level 4: Scenario

The Scenario concept initially introduced at level 1 is developed in more detail at Level 4 of the reference ontology as it is used to apply to production network scenarios within FLEXINET and

scenarios within a potential production network. Figure 6-8 below provides an UML overview of the Level 4 scenario concepts.

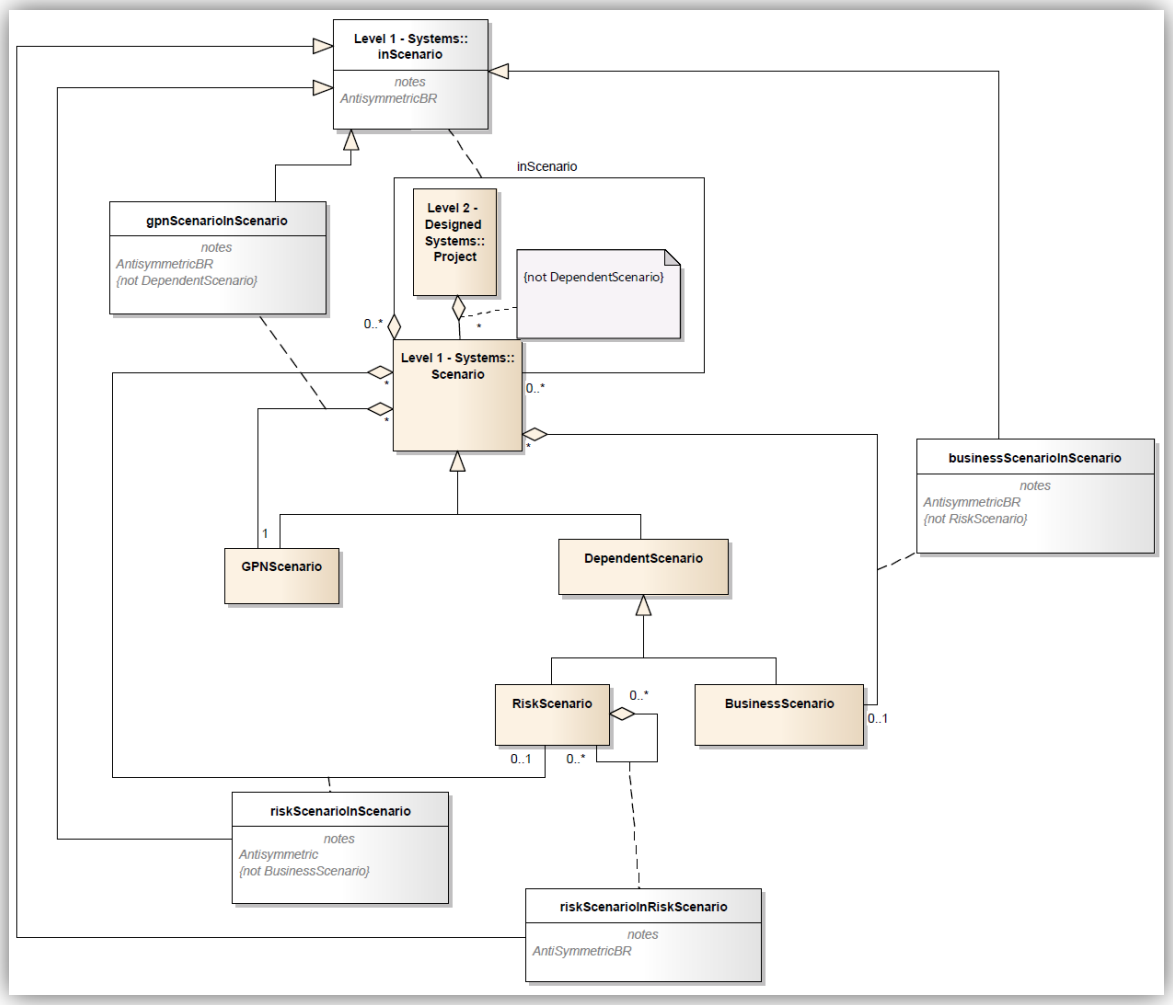


Figure 6-8: Level 4 scenario concepts

Figure 6-8 shows that a Scenario is specialised into a GPNScenario and a DependentScenario. A DependentScenario depends on the structure of a GPNScenario and is subclassed into RiskScenario and BusinessScenario. To enable a clear evaluation capability and a distinct segregation of alternative scenarios a "Scenario" may contain one GPNScenario and up to one RiskScenario and up to one BusinessScenario. A constraint exists that if a Scenario contains a DependentScenario it must contain one GPNScenario because a DependentScenario relies on the structure of the GPNScenario. For example, the GPNScenario could define the suppliers within a production network and a RiskScenario could define the risk information related to those suppliers. For a specific GPN, multiple DependentScenarios can be modelled, but in each case the reference to the GPNScenario will be duplicated.

It can be seen from Figure 6-8 that the "inScenario" relation is specialised into the relations gpnScenarioInScenario, riskScenarioInScenario, businessScenarioInScenario and riskScenarioInRiskScenario. These specialisations are needed to clearly distinguish between the different types of scenarios. Figure 6-8 shows the constraints placed upon the sub-relations of

"inScenario". For example, a GPNScenario may not be contained within a DependentScenario (gpnScenarioInScenario not DependentScenario) and a RiskScenario may not be contained within a BusinessScenario (riskScenarioInScenario not BusinessScenario), etc.

6.5.1 Properties

Figure 6-9 below shows the KFL code which describes the specialisation of the Scenario properties. The ":sup Scenario" definition indicates that GPNScenario and DependentScenario have Scenario as a superclass. The superclass of RiskScenario and Business Scenario is DependentScenario (":sup DependentScenario"). The partitionedBy definition within the DependentScenario property specifies that a DependentScenario can be specialised into either a RiskScenario or a BusinessScenario.

```
:Prop GPNScenario
:Inst Type
:sup Scenario
:disjointWith DependentScenario
:rem "A GPNscenario provides a view upon a Global Production Network."

:Prop DependentScenario
:Inst Type
:sup Scenario
:rem "A DependentScenario is contained within another <sym>1SYSCtx.Scenario</sym> and is
dependent on the structure of a <sym>4PSPCtx.GPNScenario</sym>."
:partitionedBy (listof RiskScenario BusinessScenario)

:Prop RiskScenario
:Inst Type
:sup DependentScenario
:rem "A RiskScenario provides a view of risk factors upon a Global Production Network system."

:Prop BusinessScenario
:Inst Type
:sup DependentScenario
:rem "A BusinessScenario provides a view of qualitative and quantitative cost factors upon a
Global Production Network system."
```

Figure 6-9: Level 4 Scenario in KFL

6.5.2 Relationships

An example of an "inScenario" sub-relation ("riskScenarioInScenario") is given in Figure 6-10 below. The ":supRel inScenario" definition states that the relation shown has "inScenario" as a super-relation. The functionalArg statement specifies that in this relation there can only be one riskscenario (FunctionalArg riskScenarioinScenario 1). This is because in the ":Sig" definition RiskScenario occupies position 1.

```
:Rel riskScenarioInScenario
:Inst BinaryRel
:Inst RigidRel
:Inst AntisymmetricBR
:supRel inScenario
:Sig RiskScenario Scenario
:Args "component RiskScenario" "compound Scenario"
:lex "RiskScenario ?1 is contained within Scenario ?2"
:rem "Only one RiskScenario can be contained within a Scenario.
RiskScenario is IN compound Scenario. Given that Risk Scenario and
compound Scenario are not identical, then it is not the case that
compound is IN Risk."
(functionalArg riskScenarioInScenario 1)
```

Figure 6-10: Level 4 riskSCenarioInScenario Relationship in KFL

6.5.3 Constraints

The following code is an example of a constraint placed upon an "inScenario" sub-relation. The integrity constraint states that for all gpnScenarioInScenario relations the relation cannot hold between a GPNScenario and a DependentScenario (see Figure 6-11). All the constraints upon "inScenario" sub-relations utilise this format. The use of variables within the integrity constraint definition (e.g. GPNScenario ?x) enables the user to identity the data within the knowledge base which generated the integrity constraint. For example, if there is instance of a GPNScenario "GPNScenarioGlobal3" contained within DependentScenario instance "ScenarioRiskView1" then "GPNScenarioGlobal3" will correspond to variable ?x, "ScenarioRiskView1" will correspond to variable ?y and the integrity constraint triggered will state:

"HARD A GPNScenario cannot be contained within (gpnScenarioinScenario) a DependentScenario. The relation gpnScenarioInScenario does not hold between the GPNScenario GPNScenarioGlobal3 and the DependentScenario ScenarioRiskView1."

```
(=> (gpnScenarioInScenario ?x ?y)
(not (DependentScenario ?y))
)
:IC hard "A GPNScenario cannot be contained within
(gpnScenarioinScenario) a DependentScenario. The relation
gpnScenarioInScenario does not hold between the GPNScenario ?x
and the DependentScenario ?y."
```

Figure 6-11: Level 4 integrity constraint for GPNScenario

Figure 6-12 shows a further example of an integrity constraints necessary to define the operation of Scenarios for global production networks. The constraint in Figure 6-12 below states that for each BusinessScenario contained within a Scenario, a GPNScenario must be present in the same Scenario. This constraint is needed as a Business Scenario depends on the structure of a GPNScenario,

therefore when a BusinessScenario is present a GPNScenario must also be present. A similar constraint exists for a RiskScenario.

```
(=> (and(BusinessScenario ?bizS)
    (inScenario ?bizS ?compound))
            (exists (?gpnS)
            (and (GPNScenario ?gpnS)
                (inScenario ?gpnS ?compound)
    )))
:IC hard "A BusinessScenario requires a GPNScenario to exist within the
same compound scenario as the Business Scenario.
```

Figure 6-12: Level 4 integrity constraint for BusinessScenario

The constraint in Figure 6-13 specifies that for each DependentScenario contained within a Scenario every system within the DependentScenario should also be present within the GPNScenario.

```
(=> (and(System ?system)
        (Scenario ?compound)
        (DependentScenario ?dpndS)
        (GPNScenario ?gpnS)
        (inScenario ?dpndS ?compound)
        (inScenario ?gpnS ?compound)
        (systemContainsRole ?system ?dpndRole)
        (playsRole ?rolePlayer ?dpndRole ?dpndS)
    )
    (exists (?gpnRole)
        (playsRoleActorInGPNS ?system ?gpnRole ?gpnS))
)

:IC hard "Given that a DependentScenario is in the same compound Scenario as the
GPNScenario then a node in the DependentScenario must also be present in the GPNScenario.
DependentScenario ?dpndS and GPNScenario ?gpnS are InScenario ?compound. System ?system
systemContainsRole ?dpndRole which playsRole ?rolePlayer in DependentScenario ?dpndS.
?system should play a Role in ?gpnS but does not."
```

Figure 6-13: Level 4 integrity constraint for Roles within a DependentScenario

7 End User Ontology Level 5

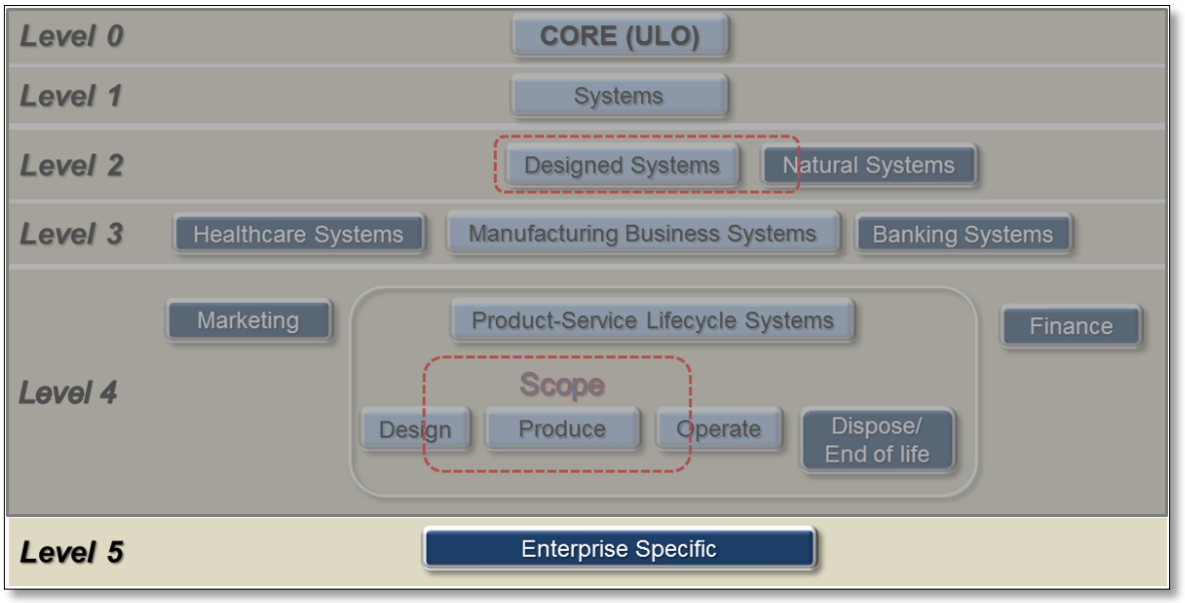


Figure 7-1: FLEXINET Reference ontology level 5

The area of focus in chapter 7 is the Level 5 FLEXINET enterprise specific or end user ontologies as highlighted in Figure 7-1. These therefore cover the KSB, INDESIT and CustomDrinks ontologies. Each of the end user ontologies have had the concepts specialised from the reference ontology. The following sections explain the three End User Ontologies and the further developments and updates that have been created since D3.1. The Level 5 KFL code for this level resides in a separate end user Annex entitled "FXNT_D3.2_Level5_Annex" that can be found on the FLEXINET portal at:

http://www.flexinet-fof.eu/Intranet/SharedDocuments/Forms/AllItems.aspx?RootFolder=%2fIntranet%2fSharedDocuments%2fDELIVERABLES%2fD3.2&FolderCTID=&View=%7B03D38F61-9F28-44EE-A00C-885A9EB1C83D%7D

7.1 End User Ontology Level 5: CustomDrinks

The PTA recommendations (11/09/2014) have been followed and the model has been linked to environ (external) and risk factor concepts. These are illustrated in Figure 7-2. Environmental Factors, Economic, Technological, Social, Political, Environmental and Legal have been considered and relationships and constraints added. Regarding the Risk Factor, either External or internal factors could be an influence, so the Network or the Production Assets have been considered as potential sources for impact. The updates are presented in UML Class diagrams in Figure 7-2 and Figure 7-3. The highlighted section shows the CustomDrinks production related concepts both in Figure 7-2 and Figure 7-3 with the latter figure also highlighting the link to the key production properties and relations.

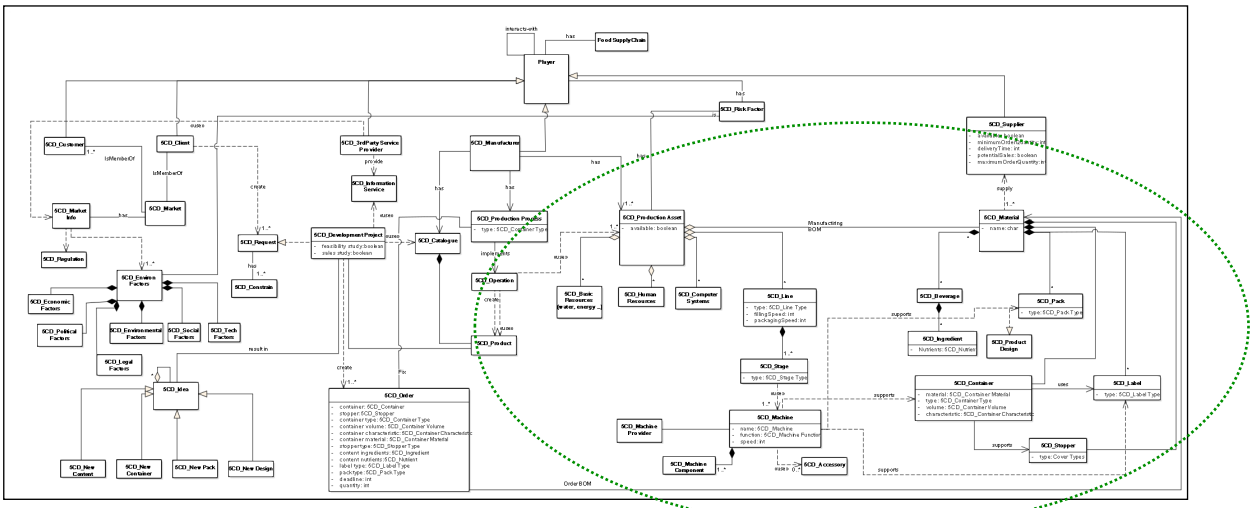


Figure 7-2: Level 5 Custom-Drinks UML representation.

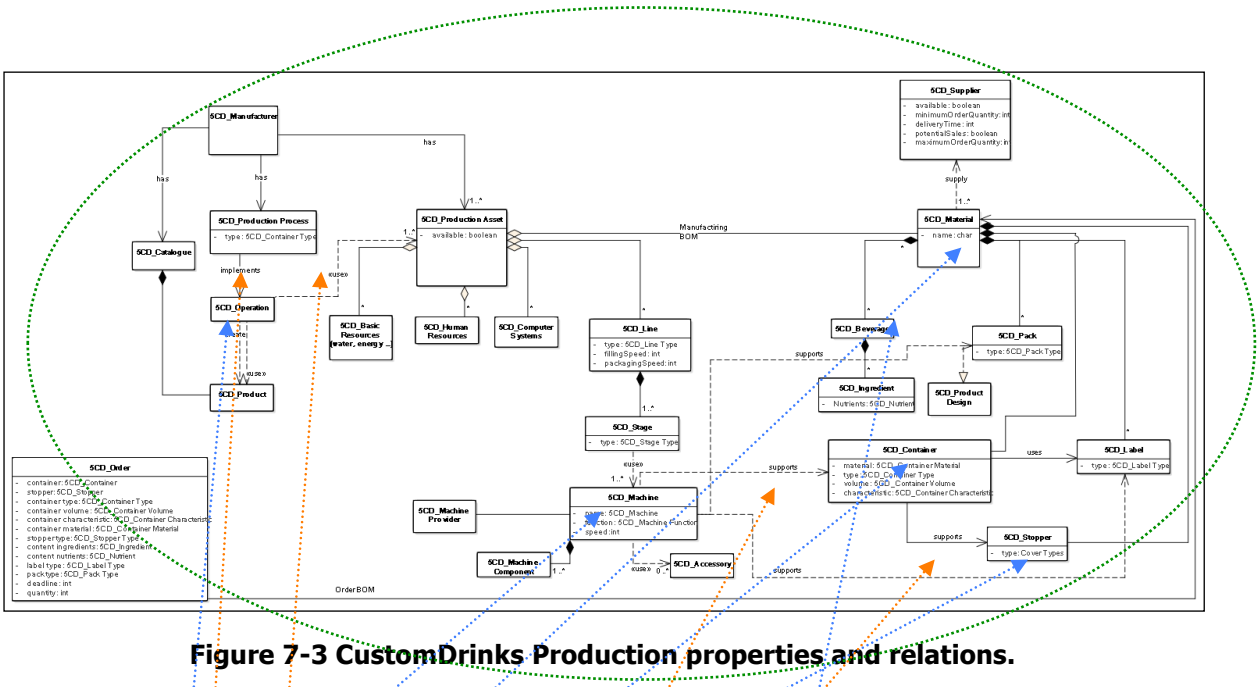


Figure 7-3 CustomDrinks Production properties and relations.

Properties: Operation, Machine, Material, Container, Stopper, Beverage

Relations:

Production Process Implements Operation

Operation Uses Production Assets

Machine Supports Container Type

Machine Supports Stopper Type

The full listing of the Level 5 code for CustomDrinks is listed in Annex F within the separate D3.2 End User Annex.

7.2 End User Ontology Level 5: INDESIT

The INDESIT level 5 end user ontology has been updated and extended since D3.1 was delivered. The latest view of the concept and relations are illustrated as a UML class diagram in Figure 7-4. The changes made to the model fall into the two following sub-sections.

7.2.1 D1.3 use case model changes

The FLEXINET end user Use Cases that have been developed in D1.3 have provided further end user perspectives and information, these have been studied and used to further develop the understanding of the INDESIT perspective, changes to the model have been made accordingly. These have been verified by INDESIT in meetings to discuss the changes and further help elicit concepts and relationships, thus elaborating the model. Six concepts have been added to the model, these being:

- 5IND_Customer
- 5IND_Requirement
- 5IND_Department
- 5IND_Feedback
- 5IND_Idea
- 5IND_Prototype

Their roles is to represent the front development processes of INDESIT, from the development of Requirements from a Customer facilitated by an INDESIT department, the subsequent idea generated from those requirements and then the creation of prototypes from those ideas. Both Prototype and Idea link to Cost, Product, Service and Component as these concepts are used in the process of product-service development at INDESIT (see Figure 7-4).

7.2.2 Environ and risk factor changes

The model has been linked to environ (external) and risk factor concepts, relationships and constraints. The following concepts have been added to the model:

- 5IND_Risk Factor
- 5IND_Legal Factor
- 5IND_Political Factor
- 5IND_Technological Factor

Relationships have been created for these to represent the model concepts that they influence and affect (see Figure 7-4). Legal, Political and Technological factors affect three of the concepts in the model, but Risk factors influence seven of the concepts. It must be noted that the number of these relationships per concept does not signify importance, nor measure magnitude for any given concept in the model.

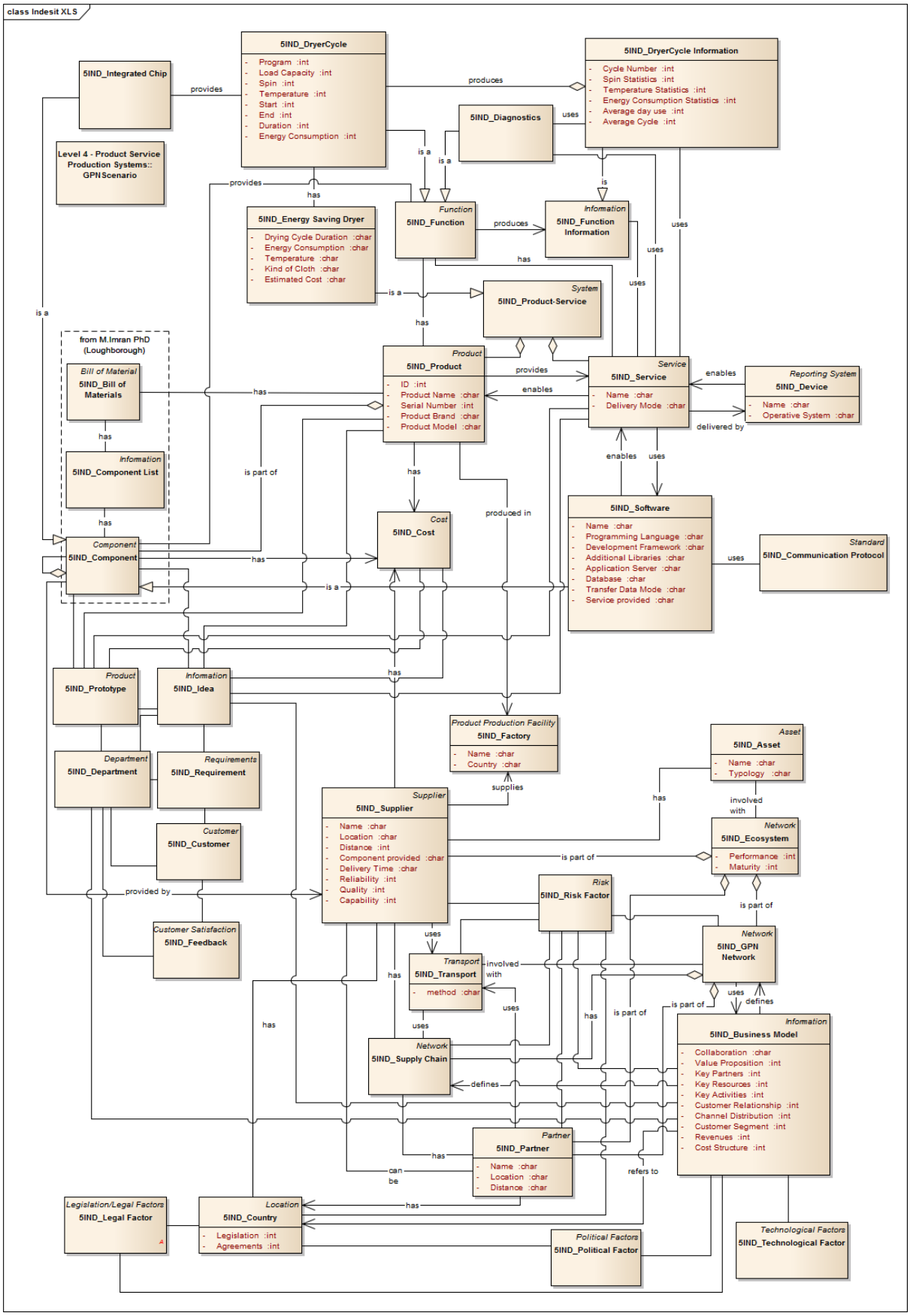
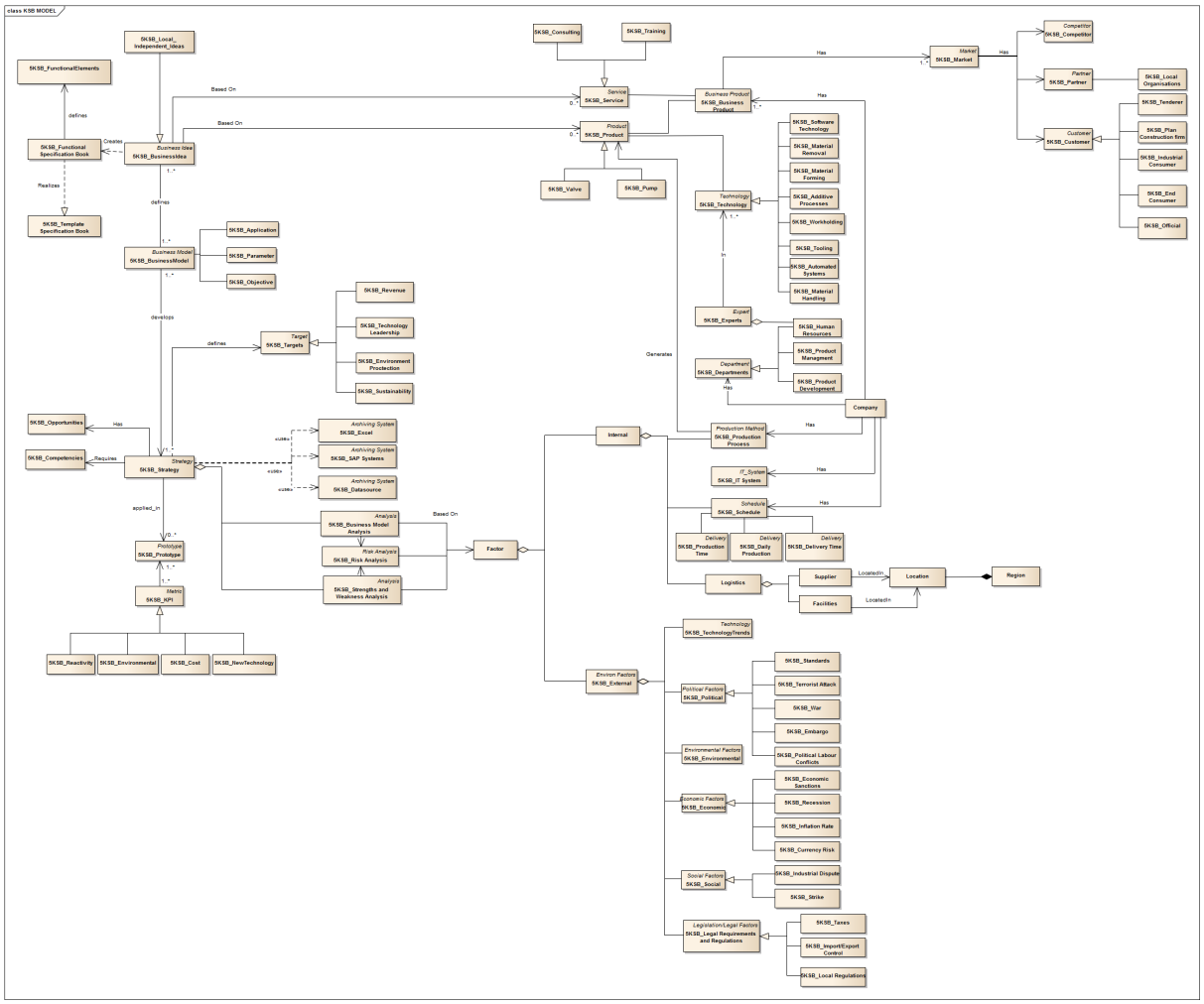


Figure 7-4: Updated INDESIT UML Model

The full listing of the Level 5 code for INDESIT is listed in Annex F, within the separate D3.2 'End User' document.

7.3 End User Ontology Level 5: KSB



Error! Reference source not found. **the KSB specific enterprise ontology for Level 5.**

When dealing with new business ideas based on new (or existing) products or services, the strategy developed is strongly influenced by external factors, technologies and markets. In this context, risk analyses are carried out within the context of this strategy. To this end STEEP factors are taken into account.

We highlight three main terms that influence the assessment or analysis of new products and services:

- 5KSB_Technology: This concept is related to the Technology term in level 2. Experts in technology (5KSB_Experts) will play a main role when evaluating a new Technology on a new Service or Product. Additional terms referring to types of Technologies have been added to the level 5. 5KSB_Software, 5KSB_Tooling, etc. are specific technologies more focused on the manufacturing environment of KSB.

- 5KSB_ExternalFactors: External Factors at level 5 are specialisations of the EnvironFactors term in level 2. These factors encompass or provide the list factors influencing KSB new Ideas. Additionally, 5KSB_Markets provide along with external factors the knowledge base to evaluate and analyse new ideas and their associate risks.

Note that terms such as Product and Service have been specialised into 5KSB_Product and 5SB_Service. They are more specialised terms focused on Pump Industry.

Finally, terms provided in lower levels of the reference ontology such as Location, Country, Regions or Facilities will give support to the level 5 providing a GPN perspective.

The full listing of the Level 5 code for KSB is listed in Annex F, within the separate 'D3.2 End User Annex'.

8 Revised End User Competency Questions

Section 8 sets out a revised set of end user competency questions. The initial questions were described in D3.1 to explicitly state the questions against which the end users would like responses from the FLEXINET toolset. As the ontology has developed so has the understanding and comprehension of the FLEXINET approach and the end users' appreciation of the kinds of questions they would like to ask.

8.1 Revised KSB Competency Questions

The KSB set of competency questions have been refined from their initial set, the updates to these are presented below (from the KSB ontology):

1. Which are the necessary technologies for a new Product, new Service or New Business Idea?
2. Do we have experts in these technologies? If so, where are they located?
3. If not, do we have Partners with the expertise in these technologies? If so, where are they located?
4. Which technologies affect new products or services for a specific market.?
5. List of new ideas by Location. Affinity of the idea to a specific market (taking into account technology).
6. Are the new potential new Product affected by Standards or Regulations?
7. Given a definition a business model and a strategy, how are they affected by external factors?
8. What are the outputs of defined indicators for a defined strategy?

8.2 Revised INDESIT Competency Questions

The INDESIT set of competency questions have been refined from their initial set, the updates to these are presented below:

Competency questions related to 'Product-Service Co-Evolution':

- For a chosen product version, do the product outputs meet the requirements of the related services and their inputs?
- For a chosen service version, do the services outputs meet the requirements of the related products and their inputs?
- For a chosen product, list the compatible services.
- For a chosen service, list the compatible products.

Competency questions related to 'Product-Service Ideation':

- For a chosen keyword, list the related product-service concepts.
- List the product-service concepts that have been tested?
- For a chosen product-service concept, list the failure reasons?
- For a chosen product-service concept, list the related technical solutions.

Competency questions related to 'Global Production Networks':

- For a chosen set of factors, list the partners who meet them.
- For a chosen stakeholder, do their capabilities meet the requirements of our network?
- For a chosen stakeholder, what is the GPN network performance?
- List the partners/stakeholders that have the level of reliability needed to develop a specific product-service?
- List the partners/stakeholders that have lower costs than the current configuration of partners/stakeholders?

8.3 Revised CustomDrinks Competency Questions

The CD set of competency questions have been refined from their initial set, the updates to these are presented below:

- List Requests by Client.
- List Machines by Manufacturer.
- List Container_Types by Manufacturer.
- List Cover_Types supported by a given Container.
- List Ingredients for a given Beverage.
- List Nutrients for a given Beverage.
- List Label_Types used by a given Container.
- List Materials provided by a given Supplier.
- List Containers supported by a given Machine.
- List available Components and Accessories for a Machine.
- List existing Machines for a given Stage.
- List available Production_Assets for the current time.
- List Machines compliant with a certain speed.
- Do we have Suppliers providing a given Material (a type of Stopper)?
- Which is the minimum order amount, the delivery time and the price per unit for such a Material from the Supplier?
- Which are the Environ Factors impacting a specific Market?
- Which are the Clients members of a given Market.
- Which are the Operations performed by a given Production_Process
- Which are the Operations involved in the creation of a given Product
- List Orders related to a given Production_Asset
- Is the new Product requested affected by Environ Factors such as standards or regulations?

- Affinity of the Request regarding available Technologies (i.e. for instance is the resealable cap available in the CD GPN?
- List Development_Projects classified as not feasible
- Which Constraints of the Client's Request are related to the Production_Assets referring to the concept Product of CustomDrinks: Beverage/Container/Label?
- Which past Requests are related to the current request?
- For a given established constraint (value of the minimum order amount, delivery time or price per unit), list the GPN Suppliers who meet it.
- List the GPN Suppliers that have similar (a predefined value for the threshold) network performance in terms of price, quantity, time for a given Material.
- Which Products from my Catalogue are compatible with the Request?

9 Conclusions

D3.2 has delivered the initial formal ontologies that have been produced within the FLEXINET project. The outputs from D3.1 have been further developed to better represent the end user perspectives, but also the upper reference levels of the ontology have been expanded and refined. These have been accomplished by using the developments in WP2 and WP4 but, also the end user use cases in D1.3.

There are a number of aspects that will be addressed prior to the delivery of D3.3:

i. Constraints, rules and relations need to be understood, developed and represented to fit with our end user test cases
ii. The business rules coming from D2.2 will be modelled along with the recently improved understanding of the business model ontological requirements
iii. The requirements coming from D4.1 will be explored and modelled where possible
iv. The ontology queries need to be advanced to be able to represent a variety of more complex questions that the end users would like to ask of the ontology. By doing this, the ontology will be able to successfully support the FLEXINET services and applications.
v. By producing more intricate queries, this will place an onus upon growing and improving the reference and end user levels with the ontology, and the fact base, needed to answer those queries.
vi. It has been noted that the CustomDrinks level 5 ontology is slightly out of synchronisation with the reference ontology upper levels. The WP3 partners are aware of this and will work towards harmonising the CD end user ontology with the reference ontology.
vii. The initial level 5 formal ontologies are representative of the end users viewpoints but, as the project work progresses with the setup and testing of the FLEXINET software, it is inevitable that there will be changes to the ontologies both at level 5 and potentially the reference levels. Hence it will be important to work closely with WP5 and WP6 to ensure that the changes that are necessary, are elicited, captured and incorporated into the next release of the formal ontologies. This implies potential changes to the properties that currently reside within them and the associated relationships, axioms rules and queries.

10 References

Banathy, B. H., 1992. A systems view of education: Concepts and principles for effective practice. Educational Technology.

Highfleet Ontology Library Reference, 2014. Baltimore, MA: HIGHFLEET Inc.

International Standards Society, 2008. ISO/IEC 15288:2008 Systems and Software Engineering – System lifecycle processes. Genève: ISO.

International Standards Society, 2007. ISO/IEC 24707:2007 Information technology -- Common Logic (CL): a framework for a family of logic-based languages. Genève: ISO.

Oxford English Dictionary, http://www.oed.com/

11 Annex A: Level 1 Ontology KFL Code

Contained herein is the KFL (Knowledge Framework Language) code for the FLEXINET Level 1 ontology:

11.1 Level 1 Context

:Use MLO

:Ctx 1SYSCtx

:Inst UserContext

:supCtx MLO

:Ctx 1SYSCtx

:Inst UserContext

:supCtx MLO

11.2 Level 1 Properties

:Use 1SYSCtx

:Prop Basic

:Inst Type

:Inst NonLogicalFunctor

:sup Particular

:partitionedBy (listof System Energy Material Information)

:rem "A Basic concept is independent of the <sym>1SYSCtx.System</sym> or context, its definition does not depend on another concept.

A Basic can be classified as <sym>1SYSCtx.System</sym>, <sym>1SYSCtx.Information</sym>, <sym>1SYSCtx.Material</sym> or <sym>1SYSCtx.Energy</sym>."

:referenceRem "2014 FLEXINET D3.1"

:Prop System

:Inst Type

:sup Basic

:sup MLO.Object

:rem "A group of inter-related objects played by <sym>1SYSCtx.Role</sym>s. An <sym>MLO.Object</sym> is anything that has a location in time and space."

:referenceRem "2014 FLEXINET D3.1"

(disjointSubProps System)

:Prop Energy

:Inst Type

:Inst NonLogicalFunctor

:sup Basic

:rem "The capacity of a body or <sym>1SYSCtx.System</sym> to do work. Could be an integer so modelled as a <sym>MLO.NonLogicalFunctor</sym>.

Properties subsumed by Energy should also be subsumed by <sym>MLO.ConcreteEntity</sym> or <sym>MLO.AbstractEntity</sym>"

:referenceRem "Collins English Dictionary. http://www.collinsdictionary.com/dictionary/english/energy."

(disjointSubProps Energy)

:Prop Material

:Inst Type

:sup Basic

:sup MLO.Object

:rem "A physical substance that things can be made from. An <sym>MLO.Object</sym> is anything that has a location in time and space."

:referenceRem "Cambridge Dictionaries Online. http://dictionary.cambridge.org/dictionary/british/material."

(disjointSubProps Material)

:Prop Information

:Inst Type

:Inst NonLogicalFunctor

:sup Basic

:rem "Information is data put in context; it is related to other pieces of data. Could be a number so modelled as a <sym>MLO.NonLogicalFunctor</sym>. Properties subsumed by Information should also

be subsumed by <sym>MLO.ConcreteEntity</sym> or <sym>MLO.AbstractEntity</sym>."

:referenceRem "Liew,A. 2007. Understanding Data, Information, Knowledge And Their Inter-Relationships. Journal of Knowledge Management Practice, Vol. 8, No. 2"

(disjointSubProps Information)

:Prop Role

:Inst Type

:sup MLO.AbstractEntity

:disjointWith Basic

:rem "The Role type includes all of the types of <sym>MLO.AbstractEntity</sym> terms that participate in systems.

A Role cannot exist without a context. A <sym>1SYSCtx.System</sym> provides a context for the Roles it contains.

To aid efficiency all Roles are declared as pairwise disjoint. A Basic can play more than one role."

:referenceRem "2014 FLEXINET D3.1"

(disjointSubProps Role)

:Prop Input

:Inst Type

:sup Role

:rem "An input represents what is brought into and is transformed or consumed by the system to produce outputs."

:referenceRem "2014 FLEXINET D3.1"

:Prop Output

:Inst Type

:sup Role

:rem "An output represents what is brought out from or is produced by the <sym>1SYSCtx.System</sym>."

:referenceRem "2014 FLEXINET D3.1"

:Prop Resource

:Inst Type

:sup Role

:rem "A resource is used by or supports the execution of the <sym>1SYSCtx.System</sym>. "

:referenceRem "2014 FLEXINET D3.1"

:Prop Control

:Inst Type

:sup Role

:rem "A control is a condition required to produce correct system <sym>1SYSCtx.Output</sym>. "

:referenceRem "2014 FLEXINET D3.1"

11.3 Level 1 Relations

:Use 1SYSCtx

:Rel affectsState

:Inst BinaryRel

:Inst RigidRel

:Inst AsymmetricBR

:Sig Particular Role

:Args "Affector" "Role"

:lex "?1 affects Role ?2"

:rem "affectsState is unidirectional so is an AsymmetricBR"

:Rel basicAffectsState

:Inst BinaryRel

:Inst RigidRel

:supRel affectsState

:Sig Basic Role

:Args "Basic" "Role"

:lex "Basic entity ?1 affects Role ?2"

:rem "basicAffectsState holds between Basic individuals and Role individuals."

:Rel roleAffectsState

:Inst BinaryRel

:Inst RigidRel

:supRel affectsState

:Sig Role Role

:Args "Role" "Role"

:lex "Role ?1 affects Role ?2"

:rem "roleAffectsState holds between Role individuals and Role individuals."

:Rel playsRole

:Inst TernaryRel

:Inst NonRigidRel

:Sig Basic Role Scenario

:Args "Basic" "Role" "Scenario"

:lex "Basic entity ?1 plays Role ?2 in Scenario ?3"

:rem "To provide a <sym>RootCtx.TimeSpan</sym> use the ECLIF operator <sym>holdsIn</sym>."

:Rel requiresA

:Inst BinaryRel

:Inst RigidRel

:Sig Role System

:Args "Role" "System"

:lex "Role ?1 depends on System ?2"

:rem "A role requires a context provided by one system."

(functionalArg requiresA 2)

;;;renamed 'dependsOn relation' as clashes with a existing RootCtx relation.

:Rel basicComposedOfBasic

:Inst BinaryRel

:Inst RigidRel

:Inst AntisymmetricBR

:Sig Basic Basic

:Args "sup" "sub"

:lex "?1 is composedOf ?2"

:rem "sup is composed of sub. Given that sup and sub are not identical, then it is not the case that sub is composed of sup."

;;;==========

;;; Testing Relation composedOfBasic

;;;Sample facts

;;;(Information Report)

;;;(Information Picture)

;;;(Information Document)

;;;(basicComposedOfBasic Report Picture)

;;;(basicComposedOfBasic Report Document)

;;; Query

;;;(setof ?y (basicComposedOfBasic Report ?y) ?l)

;;;==========

:Rel roleComposedOfRole

:Inst BinaryRel

:Inst RigidRel

:Inst AntisymmetricBR

:Sig Role Role

:Args "sup" "sub"

:lex "?1 is composedOf ?2"

:rem "sup is composed of sub. Given that sup and sub are not identical, then it is not the case that sub is composed of sup."

:Rel systemContainsRole

:Inst BinaryRel

:Inst RigidRel

:Sig System Role

:Args "System" "Role"

:lex "System ?1 contains Role ?1"

11.4 Level 1 Axioms

:Use 1SYSCtx

```
(=> (Role ?r)
    (exists (?s)
                (and (System ?s)
                        (requiresA ?r ?s))))
```

:IC hard "The Role ?r requiresA System to provide a context."

11.5 Level 1 Rules

:Use 1SYSCtx

```
(=> (requiresA ?x ?y)
     (systemContainsRole ?y ?x))
;;;A Role requiring a System as a context implies that the System contains the Role
;;;Could use inverserel instead of this rule

(=> (systemContainsRole ?x ?y)
     (requiresA ?y ?x))
;;;A System containing a Role implies that the Role requires the System as a context
```

12 Annex B: Level 2 Ontology KFL Code

12.1 Context

:Use ../1SYSCtx

:Ctx 2DSCtx

:Inst UserContext

:supCtx ../1SYSCtx

:Ctx 2DSEnvironCtx

:Inst UserContext

:supCtx ../1SYSCtx

12.2 Level 2 Properties: Basics

:Name "Level 2 Reference Ontology - Basics"

:Description "Level 2 properties - Derived from Level 1 Basics property"

:Use 2DSCtx

;;Derived from Hastilow/IMKS. note: Ideally a level 0 concept. Is feature a sub-category of material. Don't think so it applies to material

:Prop Feature

:Inst Type

:sup MLO.Object

:name "Feature"

:rem "A distinctive attribute or aspect of something"

:referenceRem "Oxford Dictionaries. http://www.oxforddictionaries.com/definition/english/feature"

:disjointWith Role

:disjointWith Scenario

:disjointWith Project

:Prop InformationStructure

:Inst Type

:sup Information

:sup MLO.AbstractEntity

:name "Information Structure"

:rem "The arrangement of and relations between the parts or elements of something complex (related to information)"

:referenceRem "Oxford Dictionaries. http://www.oxforddictionaries.com/"

;;Derived from Esmond data type. We don't need to model data itself (we just assert it).

:Prop InformationType

:Inst Type

:sup Information

:sup MLO.AbstractEntity

:name "Information Type"

:rem "A category of information having common characteristics."

:referenceRem "Oxford Dic. (interpreted)"

:Prop Status

:Inst Type

:sup Information

:sup MLO.AbstractEntity

:name "Status"

:rem "Current state of affairs. - Business Dic."

:referenceRem "http://www.businessdictionary.com/definition/status.html"

:Prop TimeStamp

:Inst Type

:sup Information

:sup MLO.AbstractEntity

:name "Time Stamp"

:rem "A timestamp is a sequence of characters or encoded information identifying when a certain event occurred, usually giving date and time of day, sometimes accurate to a small fraction of a second."

:referenceRem "Wikipedia"

:Prop TraceabilityItem

:Inst Type

:sup Information

:sup MLO.Object

:name "Traceability Item"

:rem "An item or an object whose application, location, and/or history of an activity has been traced by means of recorded data."

:referenceRem "http://www.businessdictionary.com/"

:Prop Metric

:Inst Type

:Inst NonLogicalFunctor

:sup Information

:sup MLO.AbstractEntity

:name "Metric"

:rem "A system or standard of measurement; a criterion or set of criteria stated in quantifiable terms"

:referenceRem "Oxford English Dictionary. http://www.oed.com"

(disjointSubProps Metric)

:Prop Distance

:Inst Type

:sup Metric

:name "Distance"

:rem "The amount of space between two things"

:referenceRem "Oxford Dictionary. http://www.oxforddictionaries.com/us/definition/american_english/distance"

:Prop Cost

:Inst Type

:sup Metric

:name "Cost"

:rem "It is usually a monetary valuation of effort, material, resources, time and utilities consumed, risks incurred, and opportunity forgone in production and delivery of a product or service."

:referenceRem "http://www.businessdictionary.com/"

:Prop AuthorityLevel

:Inst Type

:sup Metric

:name "Authority Level"

:rem "Level for the right, power or ability to control, command or decide"

:referenceRem "PMP 7: Project Cost Management"

:Prop Prediction

:Inst Type

:sup Information

:sup MLO.Object

:name "Prediction"

:rem "Estimate or forecast of conditions and events in the project's future based on information and knowledge available at the time of the prediction."

:referenceRem "PMP 7: Project Cost Management and WSDOT Glossary for Cost Risk Estimating Management"

(disjointSubProps Prediction)

:Prop Estimate

:Inst Type

:sup Prediction

:name "Estimate"

:rem "An approximate judgment or calculation, as of the value, amount, time, size, or weight of something"

:referenceRem "PMP 7: Project Cost Management and WSDOT Glossary for Cost Risk Estimating Management"

:Prop Quote

:Inst Type

:sup Prediction

:name "Quote"

:rem "An estimation of what a cost or price is likely to be"

:referenceRem "http://www.businessdictionary.com/"

:Prop Decision

:Inst Type

:sup Information

:sup MLO.Object

:name "Decision"

:rem "A judgment, conclusion, or resolution reached or given; verdict"

:referenceRem "Collins Dictionary. http://collinsdictionary.com"

(disjointSubProps Decision)

:Prop Agreement

:Inst Type

:sup Decision

:name "Agreement"

:rem "An arrangement (typically one which is legally binding) made between two or more parties and agreed by mutual consent. Also: a document or instrument embodying this"

:referenceRem "Oxford English Dictionary. http://www.oed.com"

:Prop SupplyAgreement

:Inst Type

:sup Agreement

:name "Supply Agreement"

:rem "A supply agreement states the terms and conditions under which one company (manufacturer) will manufacture and supply goods to another (buyer). A supply contract may be exclusive or non-exclusive, include standards on product quality, and should state how product orders will be handled"

:referenceRem "http://contracts.onecle.com/type/183.shtml"

:Prop Visualisation

:Inst Type

:sup Information

:sup MLO.Object

:name "Visualisation"

:rem "Is the set of (interactive) visual representations of abstract data to reinforce human cognition."

:referenceRem "http://en.wikipedia.org/wiki/Information_visualization"

:Prop Report

:Inst Type

:sup Visualisation

:name "Report"

:rem "A document containing information organised in a narrative, graphic, or tabular form, prepared on ad hoc, periodic, recurring, regular, or as required basis. Reports may refer to specific periods, events, occurrences, or subjects, and may be communicated or presented in oral or written form."

:referenceRem "http://www.businessdictionary.com/"

:Prop Standard

:Inst Type

:sup Information

:sup MLO.Object

:name "Standard"

:rem "set of mandatory requirements established by consensus and maintained by a recognised body to prescribe a disciplined uniform approach or specify a product, that is, mandatory conventions and practices."

:referenceRem "BS ISO/IEC IEEE 24765:2010"

:Prop Equipment

:Inst Type

:sup Material

:name "Equipment"

:rem "A set of tools, materials, devices, kit, etc, assembled for a specific purpose"

:referenceRem "Wordreference Dic."

:Prop Plan

:Inst Type

:sup Information

:sup MLO.Object

:name "Plan"

:rem "Written account of intended future course of action (scheme) aimed at achieving specific goal(s) or objective(s) within a specific timeframe. It explains in detail what needs to be done, when, how, and by whom, and often includes best case, expected case, and worst case scenarios."

:referenceRem "http://www.businessdictionary.com/"

:Prop Response

:Inst Type

:sup Information

:name "Response"

:rem "Reaction to an event, occurrence, or situation, aimed at its containment or control."

:referenceRem "http://www.businessdictionary.com/"

:Prop MarketInformation

:Inst Type

:sup Information

:sup MLO.AbstractEntity

:name "Market Information"

:rem "Information compiled from internal and external sources about a target group of consumers. The type of market intelligence most useful to a marketing department might include data on existing clients, targeted consumer habits, product and market trends, and what the competition is doing (market intelligence)"

:referenceRem "http://www.businessdictionary.com/definition/market-intelligence.html"

:Prop CustomerDemand

:Inst Type

:sup Information

:sup MLO.AbstractEntity

:name "Customer Demand"

:rem "Desire for certain good or service supported by the capacity to purchase it."

:referenceRem "http://www.businessdictionary.com/"

:Prop CustomerSatisfaction

:Inst Type

:sup Information

:sup MLO.AbstractEntity

:name "Customer Satisfaction"

:rem "a measure of how happy customers feel when they do business with a company."

:referenceRem "http://dictionary.cambridge.org/dictionary/business-english/customer-satisfaction"

:Prop BusinessModel

:Inst Type

:sup Information

:sup MLO.AbstractEntity

:name "Business Model"

:rem "Description of means and methods a firm employs to earn the revenue projected in its plans."

:referenceRem "http://www.businessdictionary.com/"

:Prop DeliveryModel

:Inst Type

:sup Information

:sup MLO.AbstractEntity

:name "Delivery Model"

:rem "Model to represent the act of delivering or distributing goods, services, etc."

:referenceRem "Collins Dic. (interpreted)"

:Prop Location

:Inst Type

:sup Information

:sup MLO.Object

:name "Location"

:rem "A site or position; situation"

:referenceRem "Collins Dic."

:Prop HumanFactors

:Inst Type

:sup Information

:sup MLO.AbstractEntity

:name "Human Factors"

:rem "The characteristics of human beings that are applicable to the design of systems and devices of all kinds."

:referenceRem "http://www.mistakeproofing.com/glossary.html#H"

:Prop Skills

:Inst Type

:sup Information

:sup MLO.AbstractEntity

:name "Skills"

:rem "Something, especially a trade or technique, requiring special training or proficiency."

:referenceRem "Collins Dic."

12.3 Level 2 Relationships: Basic

:Use 2DSCtx

:Rel LocationHasZoneType

:Inst BinaryRel

:Inst RigidRel

:Sig Location ZoneType

:Args "Location" "ZoneType"

:lex "?1 has ZoneType ?2"

:rem "A location has one zoneType. ZoneType is a qualitative metric."

:exampleRem "(locationHasZoneType Paris 2DSCtx.Area/City)"

(functionalArg LocationHasZoneType 2)

12.4 Level 2 Properties: System

:Use 2DSCtx

:Prop Collaboration

:Inst Type

:sup System

:rem "Cooperative arrangement in which two or more parties (which may or may not have any previous relationship) work jointly towards a common goal."

:referenceRem "http://www.businessdictionary.com/"

:Prop Network

:Inst Type

:sup System

:rem "An interconnected or interrelated chain, group, or system."

:referenceRem "http://www.collinsdictionary.com/"

:Prop Insurance

:Inst Type

:sup System

:rem "The act, system, or business of providing financial protection for property, life, health, etc, against specified contingencies, such as death, loss, or damage, and involving payment of regular premiums in return for a policy guaranteeing such protection."

:referenceRem "http://www.collinsdictionary.com/"

:Prop Produce

:Inst Type

:sup System

:rem "To bring (a thing) into existence from its raw materials or elements, or as the result of a process"

:referenceRem "Oxford English Dictionary http://www.oed.com/view/Entry/151978?rskey=wjgvrK&result=2&isAdvanced=false#eid"

:Prop Operate

:Inst Type

:sup System

:rem "To run something, such as a piece of machinery, or a business."

:referenceRem "http://www.businessdictionary.com/"

:Prop Design

:Inst Type

:sup System

:rem "Realisation of a concept or idea into a configuration, drawing, model, mould, pattern, plan or specification (on which the actual or commercial production of an item is based) and which helps achieve the item's designated objectives."

:referenceRem "http://www.businessdictionary.com/"

:Prop DataCollection

:Inst Type

:sup System

:rem "The collection of data from surveys, or from independent or networked locations via data capture, data entry, or data logging."

:referenceRem "http://www.businessdictionary.com/"

:Prop Finance

:Inst Type

:sup System

:rem “the management of a supply of money”

:referenceRem "Cambridge Online dictionary, http://dictionary.cambridge.org/dictionary/british/finance"

:Prop Logistics

:Inst Type

:sup System

:rem "The management of materials flow through an organisation, from raw materials through to finished goods."

:referenceRem "http://www.collinsdictionary.com/"

:Prop Software

:Inst Type

:sup System

:rem "Organised information in the form of operating systems, utilities, programs, and applications that enable computers to work."

:referenceRem "http://www.businessdictionary.com/"

:Prop Dispose

:Inst Type

:sup System

:rem "to arrange or settle (matters) by placing into correct or final condition ."

:referenceRem "http://www.collinsdictionary.com/"

:Prop Supply

:Inst Type

:sup System

:rem “the act or process of providing something that is needed”

:referenceRem "Macmillan dictionary, http://www.macmillandictionary.com/dictionary/american/supply"

:Prop Manage

:Inst Type

:sup System

:rem "To control something, such as a project, team of people, or idea."

:referenceRem "http://www.businessdictionary.com/"

:Prop NaturalSystems

:Inst Type

:sup System

:rem "Natural Systems are living systems of all kinds, including the solar system and the Universe as examples."

:referenceRem "Flexinet D3.1"

:Prop Person

:Inst Type

:sup NaturalSystems

:rem "an individual human being."

:referenceRem "http://www.collinsdictionary.com/"

:Prop Organisation

:Inst Type

:sup System

:disjointWith Facility

:rem "A social unit of people that is structured and managed to meet a need or to pursue collective goals."

:referenceRem "http://www.businessdictionary.com/"

:Prop Facility

:Inst Type

:sup System

:rem "Permanent, semi-permanent, or temporary commercial or industrial property such as a building, plant, or structure, built, established, or installed for the performance of one or more specific activities or functions."

:referenceRem "http://www.businessdictionary.com/"

(disjointSubProps Facility)

:Prop ReportingSystem

:Inst Type

:sup System

:rem "Mechanism for organising and/or monitoring the information of a particular interest in a organisation."

:referenceRem "FLEXINET ¿? Definition TBR"

:Prop Automation

:Inst Type

:sup System

:rem "The use of methods for controlling industrial processes automatically, esp by electronically controlled systems, often reducing manpower."

:referenceRem "http://www.collinsdictionary.com/"

:Prop ControlSystems

:Inst Type

:sup System

:rem "Procedures designed and established to check, record, regulate, supervise, authenticate, and (if necessary) restrict, the access to an asset, resource, or system."

:referenceRem "http://www.businessdictionary.com/"

:Prop Virtualisation

:Inst Type

:sup System

:rem "Virtualisation, in computing, refers to the act of creating a virtual (rather than actual) version of something, including but not limited to a virtual computer hardware platform, operating system (OS), storage device, or computer network resources."

:referenceRem "http://en.wikipedia.org/wiki/Virtualization"

:Prop Interface

:Inst Type

:sup System

:rem "The point of interaction or communication between a computer and any other entity, such as a printer or human operator."

:referenceRem "http://www.thefreedictionary.com/interface"

:Prop Inspection

:Inst Type

:sup System

:rem "Critical appraisal involving examination, measurement, testing, gauging, and comparison of materials or items."

:referenceRem "http://www.businessdictionary.com"

:Prop ArchievingSystem

:Inst Type

:sup System

:partitionedBy (listof DocumentManagementSystem DatabaseSystem DataStorageSystem)

:rem "system to store (documents, data, etc) in an archive or other repository."

:referenceRem "http://www.collinsdictionary.com/"

:Prop DocumentManagementSystem

:Inst Type

:sup ArchievingSystem

:rem "A document management system (DMS) is a system (based on computer programs in the case of the management of digital documents) used to track and store documents."

:referenceRem "http://en.wikipedia.org/wiki/Document_management_system"

:Prop DatabaseSystem

:Inst Type

:sup ArchievingSystem

:rem "A database is an organised collection of data. The data are typically organised to model aspects of reality in a way that supports processes requiring information. For example, modelling the availability of rooms in hotels in a way that supports finding a hotel with vacancies."

:referenceRem "http://en.wikipedia.org"

:Prop DataStorageSystem

:Inst Type

:sup ArchievingSystem

:rem "Technology consisting of computer components and recording media used to retain digital data."

:referenceRem "http://en.wikipedia.org"

:Prop Diagnosis

:Inst Type

:sup System

:partitionedBy (listof FMEA RiskAnalysis Simulation RootCauseAnalysis)

:rem "Thorough analysis of facts or problems in order to gain understanding and aid future planning."

:referenceRem "http://www.collinsdictionary.com/"

:Prop FMEA

:Inst Type

:sup Diagnosis

:rem "Failure Mode and Effects Analysis, FMEA, was one of the first systematic techniques for failure analysis."

:referenceRem "http://en.wikipedia.org/wiki/Failure_mode_and_effects_analysis"

:Prop RiskAnalysis

:Inst Type

:sup Diagnosis

:rem "Risk analysis is the science of risks and their probability and evaluation."

:referenceRem "http://en.wikipedia.org"

:Prop Simulation

:Inst Type

:sup Diagnosis

:rem "Simulation is the imitation of the operation of a real-world process or system over time."

:referenceRem "http://en.wikipedia.org/wiki/Simulation"

:Prop RootCauseAnalysis

:Inst Type

:sup Diagnosis

:rem "Root cause analysis (RCA) is a method of problem solving that tries to identify the root causes of faults or problems."

:referenceRem "http://en.wikipedia.org/wiki/Root_cause_analysis"

:Prop Analysis

:Inst Type

:sup System

:partitionedBy (listof BooleanAnalysis StatisticalAnalysis)

:rem "A systematic examination and evaluation of data or information, by breaking it into its component parts to uncover their interrelationships."

:referenceRem "http://www.businessdictionary.com"

:Prop BooleanAnalysis

:Inst Type

:sup Analysis

:rem "Analysis to detect deterministic dependencies between the items of a questionnaire or similar data-structures in observed response patterns"

:referenceRem "http://en.wikipedia.org/wiki/Boolean_analysis"

:Prop StatisticalAnalysis

:Inst Type

:sup Analysis

:rem "Study of the collection, interpretation, presentation and organisation of data."

:referenceRem "http://en.wikipedia.org/wiki/Statistics"

:Prop Department

:Inst Type

:sup System

:rem "Specialised functional area within an organisation or a division, such as accounting, marketing, planning."

:referenceRem "http://www.businessdictionary.com"

:Prop Inventory

:Inst Type

:sup System

:rem "An itemised catalogue or list of tangible goods or property, or the intangible attributes or qualities."

:referenceRem "http://www.businessdictionary.com"

:Prop Transport

:Inst Type

:sup System

:rem "the moving of goods or people from one place to another."

:referenceRem "http://www.businessdictionary.com"

:Prop SustaimentProcess

:Inst Type

:sup System

:partitionedBy (listof Training Monitor Maintenance)

:rem "The process of maintenance"

:Prop Training

:Inst Type

:sup SustaimentProcess

:rem "Organised activity aimed at imparting information and/or instructions to improve the recipient's performance or to help him or her attain a required level of knowledge or skill."

:referenceRem "http://www.businessdictionary.com"

:Prop Monitor

:Inst Type

:sup SustaimentProcess

:rem "To check, supervise, watch, or keep track of. "

:referenceRem "http://www.businessdictionary.com"

:Prop Maintenance

:Inst Type

:sup SustaimentProcess

:partitionedBy (listof EquipmentMaintenance SoftwareMaintenance InfraestructureMaintenanceFacility)

:rem "The actions taken to preserve the operation of devices, particularly of electromechanical equipment, to ensure that the devices can perform their intended functions when needed."

:referenceRem "http://www.thefreedictionary.com/"

;;;:rem "the process of keeping equipment in a useable condition or returning it to that condition when it fails. Maintenance involves either preventive maintenance, corrective maintenance, or modifications."

:Prop EquipmentMaintenance

:Inst Type

:sup Maintenance

:rem "Equipment maintenance is a broad term used to describe the various processes that are employed to keep equipment in proper working order."

:referenceRem "http://www.wisegeek.com/what-is-equipment-maintenance.htm"

:Prop SoftwareMaintenance

:Inst Type

:sup Maintenance

:rem "Software maintenance in software engineering is the modification of a software product after delivery to correct faults, to improve performance or other attributes."

:referenceRem "http://en.wikipedia.org"

:Prop InfraestructureMaintenanceFacility

:Inst Type

:sup Maintenance

:rem ""

:referenceRem ""

:Prop KnowledgeMaintenance

:Inst Type

:sup SoftwareMaintenance

:rem ""

:referenceRem ""

12.5 Level 2 Relationships: System

:Use 2DSCtx

;;;==========

:Rel OrganisationComposedOfFacility

:Inst BinaryRel

:Inst RigidRel

:Sig Organisation Facility

:Args "organisation" "facility"

:lex "?1 is composedOf ?2"

:rem "An organisation is composed of facilities."

;;;==========

:Rel FacilityHasDepartment

:Inst BinaryRel

:Inst RigidRel

:Sig Facility Department

:Args "facility" "department"

:lex "?1 has ?2"

:rem "Relation to describe that a facility has a department."

;;;==========

:Rel FacilityLocatedInLocation

:Inst BinaryRel

:Inst RigidRel

:Sig Facility Location

:Args "Facility" "Location"

:lex "?1 located in ?2"

:rem "Relation to describe that a facility is located in a site or position."

12.6 Level 2 Properties: Actor Roles

:Use 2DSCtx

:Prop Actor

:Inst Type

:sup Role

:rem "An Actor is a <sym>1SYSCtx.Role</sym> which is able to fulfil a non-functional requirement. Actors are processes that perform functions.

A Actor is played by a <sym>1SYSCtx.System</sym> which is a subtype of <sym>1SYSCtx.Basic</sym>."

(disjointSubProps Actor)

;;;metaproperty - needed to refer to types of actor in risk section of ontology

:Prop ActorType

:Inst MetaProperty

:sup Type

:name "Type of the Actor"

:metaPropFor Actor

:Prop Order

:Inst ActorType

:sup Actor

:rem "A confirmed request by one party to another to buy, sell, deliver, or receive goods or services under specified terms and conditions."

:referenceRem "http://www.businessdictionary.com/"

:Prop Offer

:Inst ActorType

:sup Order

:rem "Voluntary but conditional promise submitted by a buyer or seller (offeror) to another (offeree) for acceptance, and which becomes legally enforceable if accepted by the offer."

:referenceRem "http://www.businessdictionary.com/"

:Prop Technology

:Inst ActorType

:sup Actor

:rem "The purposeful application of information in the design, production, and utilisation of goods and services, and in the organisation of human activities."

:referenceRem "http://www.businessdictionary.com/"

:Prop Employee

:Inst ActorType

:sup Actor

:rem "An individual who works part-time or full-time under a contract of employment, whether oral or written, express or implied, and has recognised rights and duties. Also called worker."

:referenceRem "http://www.businessdictionary.com/"

:Prop Supervisor

:Inst ActorType

:sup Actor

:rem "Person in the first-line management who monitors and regulates employees in their performance of assigned or delegated tasks."

:referenceRem "http://www.businessdictionary.com/"

:Prop Competitor

:Inst ActorType

:sup Actor

:rem "Any person or entity which is a rival against another. In business, a company in the same industry or a similar industry which offers a similar product or service. "

:referenceRem "http://www.businessdictionary.com/"

:Prop Customer

:Inst ActorType

:sup Actor

:rem "party that receives or consumes products (goods or services) and has the ability to choose between different products and suppliers. "

:referenceRem "http://www.businessdictionary.com/"

:Prop Partner

:Inst ActorType

:sup Actor

:rem "Individual who joins with other individuals (partners) in an arrangement (partnership) where gains and losses, risks and rewards, are shared among the partners."

:referenceRem "http://www.businessdictionary.com/"

:Prop Supplier

:Inst ActorType

:sup Actor

:rem "A party that supplies goods or services. A supplier may be distinguished from a contractor or subcontractor, who commonly adds specialised input to deliverables. Also called vendor."

:referenceRem "http://www.businessdictionary.com/"

:Prop FinancePerson

:Inst ActorType

:sup Actor

:rem "a person in charge? of the financial affairs of an organisation"

:Prop Service

:Inst ActorType

:sup Actor

:rem "Performance of activities, work, or duties associated with a product."

:referenceRem "BS ISO/IEC IEEE 24765:2010"

:Prop MaintenanceEngineer

:Inst ActorType

:sup Actor

:rem "Engineer who maintains a system."

:Prop Designer

:Inst ActorType

:sup Actor

:rem "a person who devises and executes designs, as for works of art, clothes, machines, etc"

:referenceRem "http://www.collinsdictionary.com/"

:Prop Operator

:Inst ActorType

:sup Actor

:rem "Individual or organisation that operates the system; entity that performs the operation of a system."

:referenceRem "BS ISO/IEC IEEE 24765:2010"

:Prop LogisticsPerson

:Inst ActorType

:sup Actor

:rem ""

:rem "Person involved in Logistics activities"

:referenceRem "¿¿"

:Prop MaterialControlPerson

:Inst ActorType

:sup Actor

:rem ""

:referenceRem ""

:Prop Delivery

:Inst ActorType

:sup Actor

:rem "Formal and voluntary transfer of possession by actual (physical) delivery, constructive delivery (by an agreement or understanding), or symbolic delivery (by documents) Also called presentation or presentment."

:referenceRem "http://www.businessdictionary.com/"

:Prop Solution

:Inst ActorType

:sup Actor

:rem "Answer(s) suggested or implemented to try and solve a question or problem. "

:referenceRem http://www.businessdictionary.com/

12.7 Level 2 Properties: Environ Factors

:Use ../2DSEnvironCtx

;;;Can an economic factor also be a political factor etc? Do I need or not need disjointsubProps for EnvironFactor?

:Prop EnvironFactor

:Inst Type

:sup Information

:sup MLO.Object

:rem "Environ Factors influence actors in global production networks.

Conceptually, an Environ factor influences certain business model component. (An environ factor has a unique name.

Environ Factor inherits this relation from Object)"

:referenceRem "2014 FLEXINET D2.1"

:Prop PoliticalFactor

:Inst Type

:sup EnvironFactor

:rem "Political factors identify to what degree a government intervenes in the economy. Also, political factors determine health, education and infrastructure of a nation to a certain extent."

:referenceRem "2014 FLEXINET D2.1"

(disjointSubProps PoliticalFactor)

:Prop SocialFactor

:Inst Type

:sup EnvironFactor

:rem "Social factors determine the cultural dimension which includes aspects like health consciousness, population growth rate, age distribution (demographics), career attitudes and safety. They are influencing a company's products and services and particularly how a company operates."

:referenceRem "2014 FLEXINET D2.1"

(disjointSubProps SocialFactor)

:Prop EnvironmentalFactor

:Inst Type

:sup EnvironFactor

:rem "Environmental factors are concerned with the general environment like weather, climate and climate change."

:referenceRem "2014 FLEXINET D2.1"

(disjointSubProps EnvironmentalFactor)

:Prop EconomicFactor

:Inst Type

:sup EnvironFactor

:rem "Economic factors have a major impact on a company's business operations and decision-making."

:referenceRem "2014 FLEXINET D2.1"

(disjointSubProps EconomicFactor)

:Prop TechnologicalFactor

:Inst Type

:sup EnvironFactor

:rem "Technological factors are related to R&D activities, automation, technology incentives."

:referenceRem "2014 FLEXINET D2.1"

(disjointSubProps TechnologicalFactor)

:Prop LegalFactor

:Inst Type

:sup EnvironFactor

:rem "Legal factors are concerned with the legal environment of an actor in a market."

:referenceRem "2014 FLEXINET D2.1"

(disjointSubProps LegalFactor)

;;;

;;;definitions to be provided by WP2

;;;Political Factors

:Prop EconomicPolicy

:Inst Type

:sup PoliticalFactor

:Prop TaxPolicy

:Inst Type

:sup PoliticalFactor

:Prop GovtInterferenceMarkets

:Inst Type

:sup PoliticalFactor

:name "Level of Government Interference with Markets"

:Prop TradePolicy

:Inst Type

:sup PoliticalFactor

:Prop TradeRestrictions

:Inst Type

:sup PoliticalFactor

:Prop Tariffs

:Inst Type

:sup PoliticalFactor

:Prop TradeUnions

:Inst Type

:sup PoliticalFactor

:Prop Infrastructure

:Inst Type

:sup PoliticalFactor

:Prop PublicTransportation

:Inst Type

:sup PoliticalFactor

:Prop Highways

:Inst Type

:sup PoliticalFactor

:Prop WaterAndEnergyInfrastructure

:Inst Type

:sup PoliticalFactor

:Prop CommunicationAndPostalServices

:Inst Type

:sup PoliticalFactor

:Prop Education

:Inst Type

:sup PoliticalFactor

:Prop PublicHealth

:Inst Type

:sup PoliticalFactor

:Prop PoliticalStability

:Inst Type

:sup PoliticalFactor

:Prop GovernmentFundedResearch

:Inst Type

:sup PoliticalFactor

:Prop InternationalOrganisations-membership

:Inst Type

:sup PoliticalFactor

:Prop Legislation

:Inst Type

:sup PoliticalFactor

:Prop CurrentLegislation

:Inst Type

:sup PoliticalFactor

:Prop FutureExpectedLegislation

:Inst Type

:sup PoliticalFactor

:Prop InternationalLegislation

:Inst Type

:sup PoliticalFactor

:Prop PolicyAndValuesOfPoliticalPartyInPower

:Inst Type

:sup PoliticalFactor

:Prop RegulatoryBodiesAndProcesses

:Inst Type

:sup PoliticalFactor

:Prop GovernmentPolicy

:Inst Type

:sup PoliticalFactor

:Prop GovernmentTermAndChange

:Inst Type

:sup PoliticalFactor

:Prop Lobbying-PressureGroups

:Inst Type

:sup PoliticalFactor

:Prop HomeMarket

:Inst Type

:sup PoliticalFactor

:Prop International

:Inst Type

:sup PoliticalFactor

:Prop WarsAndConflicts

:Inst Type

:sup PoliticalFactor

;;;

;;;Social Factors

:Prop Culture

:Inst Type

:sup SocialFactor

:Prop HealthConsciousness

:Inst Type

:sup SocialFactor

:Prop Demographics

:Inst Type

:sup SocialFactor

:Prop SocialMobility

:Inst Type

:sup SocialFactor

:Prop CareerAttitudes

:Inst Type

:sup SocialFactor

:Prop PopulationGrowthRates

:Inst Type

:sup SocialFactor

:Prop LivingStandard

:Inst Type

:sup SocialFactor

:Prop QualityOfLife

:Inst Type

:sup SocialFactor

:Prop LeisureFacilities

:Inst Type

:sup SocialFactor

:Prop Security

:Inst Type

:sup SocialFactor

:Prop Values

:Inst Type

:sup SocialFactor

:Prop Ethics

:Inst Type

:sup SocialFactor

:Prop ConsumerBuyingPatterns

:Inst Type

:sup SocialFactor

:Prop Religion

:Inst Type

:sup SocialFactor

:Prop Consumption

:Inst Type

:sup SocialFactor

:Prop ConsumerAttitudesAndOpinions

:Inst Type

:sup SocialFactor

:Prop BuyingAccessAndTrends

:Inst Type

:sup SocialFactor

:Prop LifeStyleTrends

:Inst Type

:sup SocialFactor

:Prop LifeStyle

:Inst Type

:sup SocialFactor

:Prop FashionAndRoleModels

:Inst Type

:sup SocialFactor

:Prop MediaViews

:Inst Type

:sup SocialFactor

:Prop LawChangesAffectingSocialFactors

:Inst Type

:sup SocialFactor

:Prop PublicRelations

:Inst Type

:sup SocialFactor

:Prop BrandCompanyTechnologkyImage

:Inst Type

:sup SocialFactor

:Prop AdvertisingAndPublicity

:Inst Type

:sup SocialFactor

:Prop MajorEventsAndInfluences

:Inst Type

:sup SocialFactor

:Prop ClimateChange

:Inst Type

:sup SocialFactor

;;;

;;;Environmental Factors

:Prop Weather

:Inst Type

:sup EnvironmentalFactor

:Prop Climate

:Inst Type

:sup EnvironmentalFactor

:Prop EnvironmentalIssues

:Inst Type

:sup EnvironmentalFactor

:Prop EnergyConsumption

:Inst Type

:sup EnvironmentalFactor

:Prop Infracture

```
:Inst Type
:sup EnvironmentalFactor

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;;Economic Factors

:Prop EconomicGrowth
:Inst Type
:sup EconomicFactor

:Prop InterestRate
:Inst Type
:sup EnvironmentalFactor

:Prop Inflation
:Inst Type
:sup EnvironmentalFactor

:Prop ExchangeRate
:Inst Type
:sup EnvironmentalFactor

:Prop LabourMarket
:Inst Type
:sup EnvironmentalFactor

:Prop LabourMarketSize
:Inst Type
:sup EnvironmentalFactor

:Prop UnemploymentRate
:Inst Type
```

:sup EnvironmentalFactor

:Prop EducationLevel-HumanCapital

:Inst Type

:sup EnvironmentalFactor

:Prop LabourProductivity

:Inst Type

:sup EnvironmentalFactor

:Prop LabourCosts

:Inst Type

:sup EnvironmentalFactor

:Prop PurchasingPower

:Inst Type

:sup EnvironmentalFactor

:Prop FinancialSector

:Inst Type

:sup EnvironmentalFactor

:Prop Competition-MarketConcentration

:Inst Type

:sup EnvironmentalFactor

:Prop EconomyAsAWhole

:Inst Type

:sup EnvironmentalFactor

:Prop HomeEconomySituation

:Inst Type

:sup EnvironmentalFactor

:Prop HomeEconomyTrends

:Inst Type

:sup EnvironmentalFactor

:Prop BusinessCycles

:Inst Type

:sup EnvironmentalFactor

:Prop OverseasEconomiesAndTrends

:Inst Type

:sup EnvironmentalFactor

:Prop Taxation

:Inst Type

:sup EnvironmentalFactor

:Prop GeneralTaxationIssues

:Inst Type

:sup EnvironmentalFactor

:Prop TaxSpecificToProduct-Services

:Inst Type

:sup EnvironmentalFactor

:Prop MarketAndTradeCycles

:Inst Type

:sup EnvironmentalFactor

:Prop SpecificIndustryFactors

:Inst Type

:sup EnvironmentalFactor

:Prop MarketRoutesAndDistributionTrends

:Inst Type

:sup EnvironmentalFactor

:Prop Customer-end-userDrivers

:Inst Type

:sup EnvironmentalFactor

:Prop ConsumerConfidence

:Inst Type

:sup EnvironmentalFactor

;;;

;;;TechnologicalFactors

:Prop RAndDActivities

:Inst Type

:sup TechnologicalFactor

:Prop Automation

:Inst Type

:sup TechnologicalFactor

:Prop TechnologyIncentives

:Inst Type

:sup TechnologicalFactor

:Prop RateOfTechnlogicialChange

:Inst Type

:sup TechnologicalFactor

:Prop NewProducts

:Inst Type

:sup TechnologicalFactor

:Prop NewBusinessProcess

:Inst Type

:sup TechnologicalFactor

:Prop CompetingTechnologyDevelopment

:Inst Type

:sup TechnologicalFactor

:Prop Associated-DependentTechnologies

:Inst Type

:sup TechnologicalFactor

:Prop ReplacementTechnologySolutions

:Inst Type

:sup TechnologicalFactor

:Prop MaturityOfTechnology

:Inst Type

:sup TechnologicalFactor

:Prop ManufacturingMaturityAndCapacity

:Inst Type

:sup TechnologicalFactor

:Prop InformationAndCommunications

:Inst Type

:sup TechnologicalFactor

:Prop GlobalCommunications

:Inst Type

:sup TechnologicalFactor

:Prop ConsumerBuyingMechanism-Technology

:Inst Type

:sup TechnologicalFactor

:Prop TechnologyLegislation

:Inst Type

:sup TechnologicalFactor

:Prop InnovationPotential

:Inst Type

:sup TechnologicalFactor

:Prop TechnologyAccess

:Inst Type

:sup TechnologicalFactor

:Prop Licensing

:Inst Type

:sup TechnologicalFactor

:Prop IntellectualPropertyIssues

:Inst Type

:sup TechnologicalFactor

;;

;;;Legal Factors

:Prop ConsumerLaw

:Inst Type

:sup LegalFactor

:Prop EnvironmentalLaw

:Inst Type

:sup LegalFactor

:Prop CompetitionLaw-CartelLaw

:Inst Type

:sup LegalFactor

:Prop LabourLaw

:Inst Type

:sup LegalFactor

:Prop HealthLaw

:Inst Type

:sup LegalFactor

:Prop SecurityLaw

:Inst Type

:sup LegalFactor

:Prop CoporateLaw

:Inst Type

:sup LegalFactor

:Prop DistributionLaws

:Inst Type

:sup LegalFactor

:Prop IPLaw

:Inst Type

:sup LegalFactor

12.8 Level 2 Relationships: Environ Factors

:Use ../2DSEnvironCtx

;;;An environ factor has a unique name. Every Object in the ontology has a name.

;;;Environ Factor inherits this relation from Object.

:Rel hasEnvironFactorDescription

:Inst BinaryRel

:Inst RigidRel

:Sig EnvironFactor String

:Args "Environ Factor" "Description"

:lex "?1 is described by ?2"

:rem "An Environ Factor may only have one description."

(functionalArg hasExternalFactorDescription 2)

:Rel hasEnvironFactorValue

:Inst BinaryRel

:Inst RigidRel

:Sig EnvironFactor Top

:Args "Environ Factor" "Qualitative or quantitative value"

:lex "?1 has value ?2"

:rem "A certain value is provided by each factor that can be used for risk assessment or economic valuation purposes.

An Environ Factor may only have one value. Sig arg 2 is Top to hold either a qualitative or quantitative type value."

(functionalArg hasEnvironFactorValue 2)

;;

;;;Quantitative Environ Factor Value Relations

:Rel hasEconomicPolicyValue

:Inst BinaryRel

:Inst RigidRel

:supRel hasEnvironFactorValue

:Sig EconomicPolicy Percent

:Args "Economic Policy" "Percentage income tax rate"

:lex "?1 has value of Percentage income tax rate of ?2"

:Rel hasTaxPolicyValue

:Inst BinaryRel

:Inst RigidRel

:supRel hasEnvironFactorValue

:Sig TaxPolicy Percent

:Args "Tax Policy" "added value tax rate"

:lex "?1 has value of Percentage added value tax rate of ?2"

;;

;;;Qualitative External Factor Value relations

:Rel hasGovtInterferenceValue

:Inst BinaryRel

:Inst RigidRel

:supRel hasEnvironFactorValue

:Sig GovtInterferenceMarkets HMLType

:Args "Level of Government Interference with Markets" "Measure of High Medium Low"

:lex "?1 has value of Level of Government Interference with Markets of ?2"

:rem "A relation between the Level of Government Interference with Markets and its value."

:exampleRem "(hasGovtInterferenceValue varInfer 2DSCtx.Low)"

12.9 Level 2 Properties: Risk

:Use ../2DSCtx

:Prop RiskFactor

:Inst Type

:sup Information

:sup MLO.Object

:rem "An internal or external factor that may influence a Global Production Network adversely."

:referenceRem "2014 FLEXINET D2.1"

:Prop OrganisationSpecificRiskFactor

:Inst Type

:sup RiskFactor

:Prop RegionalRiskFactor

:Inst Type

:sup RiskFactor

:Prop LocationSpecificRiskFactor

:Inst Type

:sup RiskFactor

:Prop Incident

:Inst MLO.EventType

:sup MLO.Event

:Prop Resilience

:Inst Type

:sup Metric

:rem "Resilience is the ability of a Global Production network node to react to the disruptive event and its agility to compensate for inoperability that has arisen"

:referenceRem "2014 FLEXINET D2.1"

12.10 Level 2 Relationships: Risk

:Use 2DSCtx

;;;Relations of Resilience Property

:Rel resilienceHasValue

:Inst AsymmetricBR

:Inst RigidRel

:Sig Resilience FuzzyNumber

:Args "Resilience" "FuzzyNumber"

:lex "?1 has Value ?2"

:rem "One Resilience has one value. A Value does not have a Resilience."

:exampleRem "(resilienceHasValue res1 (fuzzyValTripleFN 0.1 0.2 0.3))"

(functionalArg resilienceHasValue 1)

(functionalArg resilienceHasValue 2)

:Rel resilienceHasActorType

:Inst AsymmetricBR

:Inst RigidRel

:Sig Resilience ActorType

:Args "Resilience" "ActorType"

:lex "?1 has ActorType ?2"

:rem "One Resilience has one ActorType. An ActorType does not have a Resilience."

:exampleRem "(resilienceHasActorType res1 2DSCtx.Supplier)"

(functionalArg resilienceHasActorType 1)

(functionalArg resilienceHasActorType 2)

:Rel OrganisationHasResilience

:Inst AsymmetricBR

:Inst RigidRel

:Sig Organisation Resilience

:Args "Organisation" "Resilience"

:lex "?1 has resilience ?2"

:rem "One Organisation has Resilience(s). Unidirectional relation."

(functionalArg OrganisationHasResilience 1)

;;;

;;;Relations of IncidentReport Property

:Rel OrganisationHasIncident

:Inst BinaryRel

:Inst RigidRel

:Sig Organisation Incident

:Args "Organisation" "Incident"

:lex "?1 has associated Incident ?2"

:rem "Organisation(s) have Incident(s). Bidirectional relation."

:Rel IncidentHasCause

:Inst BinaryRel

:Inst RigidRel

:Sig Incident String

:Args "Incident" "Description of Cause"

:lex "?1 has cause ?2"

:rem "One Incident has cause(s). Unidirectional relation."

(functionalArg IncidentHasCause 1)

:Rel IncidentHasConsequence

:Inst AsymmetricBR

:Inst RigidRel

:Sig Incident String

:Args "Incident" "Description of Consequence"

:lex "?1 has consequence ?2"

:rem "One Incident has consequence(s). Unidirectional relation."

(functionalArg IncidentHasConsequence 1)

:Rel IncidentHasSolution

:Inst AsymmetricBR

:Inst RigidRel

:Sig Incident String

:Args "Incident" "Description of Solution"

:lex "?1 has preventitive solution ?2"

:rem "One Incident has solution(s) to prevent it. Unidirectional relation."

(functionalArg IncidentHasSolution 1)

:Rel IncidentHasLessonsLearned

:Inst AsymmetricBR

:Inst RigidRel

:Sig Incident String

:Args "Incident" "Description of LessonsLearned"

:lex "?1 has lessons learned ?2"

:rem "One Incident has LessonsLearned(s) from it. Unidirectional relation."

(functionalArg IncidentHasLessonsLearned 1)

:Rel IncidentHasLocation

:Inst AsymmetricBR

:Inst RigidRel

:Sig Incident Location

:Args "Incident" "Location"

:lex "?1 has location ?2"

:rem "One Incident has location(s). Unidirectional relation."

(functionalArg IncidentHasLocation 1)

;;;Not sure we need this relation as incidentHasOrganisation and OrganisationHasLocation but it's in the Coventry model.

;;;using the Highfleet builtin occursAt Relation to model FromDate and ToDate of Incident

;;;e.g. (occursAt Incident1 (Span (Date "2002") (Date "2003")))

;;;The query (hasStartTime Test ?time) returns the FromDate

;;;The query (hasEndTime Test ?time) returns the ToDate

12.11 Level 2 Axiom: Risk

```
:Use 2DSCtx

;;later exchange resilience has value for any relation with a fuzzy value.
;; try out  (or (?relation ?var1 (fuzzyValTripleFN ?l ?m ?h)) - binary
;; (?relation ?var1 (fuzzyValTripleFN ?l ?m ?h) ?var2)))-ternary

(=>
        (resilienceHasValue ?resilence (fuzzyValTripleFN ?l ?m ?h))
        (and (lteNum ?l ?m)
                (lteNum ?m ?h)))
:IC hard "Fuzzy value triple ?l must be <= ?m must be <= ?h"
;;copied from an example supplied by Lindsey Spratt

(=>
        (resilienceHasValue ?resilence (fuzzyValTripleFN ?l ?m ?h))
        (and (lteNum  0 ?l)
        (lteNum ?l 1)
        (lteNum  0 ?m)
        (lteNum ?h 1)
        (lteNum  0 ?h)
        (lteNum ?h 1))
)
:IC hard "Fuzzy value triple 0 <= ?l <= 1,  0 <= ?m <= 1, 0 <= ?h <= 1"
;;copied from an example supplied by Lindsey Spratt
```

12.12 Level 2 Designed Systems - Risk Properties

```
:Name "Level 2 Designed Systems - Risk Properties"
:Description "This file contains the definition of risk properties which occur at the Designed Systems level of the FLEXINET Project reference ontology but is placed within a separate folder called 2DS_Risk as they form a specialised subset of level 2. More Risk properties are defined at level 4PSP."
```

:Use ../2DSCtx

:Prop RiskFactor

:Inst Type

:sup Information

:sup MLO.Object

:rem "An internal or external factor that may influence a Global Production Network adversely."

:referenceRem "2014 FLEXINET D2.1"

:Prop OrganisationSpecificRiskFactor

:Inst Type

:sup RiskFactor

:Prop RegionalSpecificRiskFactor

:Inst Type

:sup RiskFactor

:Prop LocationSpecificRiskFactor

:Inst Type

:sup RiskFactor

:Prop Incident

:Inst MLO.EventType

:sup MLO.Event

:Prop Resilience

:Inst Type

:sup Metric

:rem "Resilience is the ability of a Global Production network node to react to the disruptive event and its agility to compensate for inoperability that has arisen"

:referenceRem "2014 FLEXINET D2.1"

12.13 Level 2 Designed Systems - Risk Relations

Name "Level 2 Designed Systems - Risk Relations"

:Description "This file contains the definition of the risk relations identified at level 2 in the context of the FLEXINET Project - placed in folder 2DS_Risk as they form a specialised subset of the reference ontology. More risk relations are defined at level 4PSP."

:Use 2DSCtx

;;;==========

;;;Relations of Resilience Property

:Rel resilienceHasValue

:Inst BinaryRel

:Inst RigidRel

:Sig Resilience FuzzyNumber

:Args "Resilience" "FuzzyNumber"

:lex "?1 has Value ?2"

:rem "Resilience has one value."

:exampleRem "(resilienceHasValue res1 (fuzzyValTripleFN 0.1 0.2 0.3))"

(functionalArg resilienceHasValue 2)

:Rel resilienceHasActorType

:Inst BinaryRel

:Inst RigidRel

:Sig Resilience ActorType

:Args "Resilience" "ActorType"

:lex "?1 has ActorType ?2"

:rem "Resilience has ActorType(s)."

:exampleRem "(resilienceHasActorType res1 2DSCtx.Supplier)"

:Rel organisationHasResilience

:Inst BinaryRel

```
:Inst RigidRel
:Sig Organisation Resilience
:Args "Organisation" "Resilience"
:lex "?1 has resilience ?2"
:rem "One Organisation has Resilience(s)."
(functionalArg organisationHasResilience 1)

;;;=================================================
;;;Relations of Incident Property
:Rel organisationHasIncident
:Inst BinaryRel
:Inst RigidRel
:Sig Organisation Incident
:Args "Organisation" "Incident"
:lex "?1 has associated Incident ?2"
:rem "Organisation(s) have Incident(s)."

:Rel incidentHasCause
:Inst BinaryRel
:Inst RigidRel
:Sig  Incident String
:Args "Incident" "Description of Cause"
:lex "?1 has cause ?2"
:rem "Incident has cause(s)."

:Rel incidentHasConsequence
:Inst BinaryRel
:Inst RigidRel
:Sig  Incident String
:Args "Incident" "Description of Consequence"
:lex "?1 has consequence ?2"
:rem "Incident has consequence(s)."
```

:Rel incidentHasSolution

:Inst BinaryRel

:Inst RigidRel

:Sig Incident String

:Args "Incident" "Description of Solution"

:lex "?1 has preventitive solution ?2"

:rem "Incident has solution(s) to prevent it."

:Rel incidentHasLessonsLearned

:Inst BinaryRel

:Inst RigidRel

:Sig Incident String

:Args "Incident" "Description of LessonsLearned"

:lex "?1 has lessons learned ?2"

:rem "Incident has LessonsLearned(s) from it."

:Rel incidentHasLocation

:Inst BinaryRel

:Inst RigidRel

:Sig Incident Location

:Args "Incident" "Location"

:lex "?1 has location ?2"

:rem "Incident has location(s)."

;;;Not sure we need this relation as incidentHasOrganisation and OrganisationHasLocation but it's in the Coventry model.

;;;using the Highfleet builtin occursAt Relation to model FromDate and ToDate of Incident

;;;e.g. (occursAt Incident1 (Span (Date "2002") (Date "2003")))

;;;The query (hasStartTime Test ?time) returns the FromDate

;;;The query (hasEndTime Test ?time) returns the ToDate

```
:Rel riskFactorHasIncident
:Inst BinaryRel
:Inst RigidRel
:Sig  RiskFactor Incident
:Args "RiskFactor" "Incident"
:lex "?1 has occurrence Incident ?2"
:rem "RiskFactor(s) have Incident(s) of occurrence."

;;;=================================================
;;;Relations of RiskFactor Property

;;using builtIn Highfleet name relation

:Rel isExampleRF
:Inst UnaryRel
:Sig RiskFactor
:lex "?1 is true"
:rem "The RiskFactor is a member of the FLEXINET RiskFactor example library."

:Rel riskFactorHasDataSource
:Inst BinaryRel
:Inst RigidRel
:Sig  RiskFactor String
:Args "RiskFactor" "DataSource"
:lex "?1 has data source ?2"
:rem "Risk has DataSource(s)."

:Rel riskFactorHasMitigationMethod
:Inst BinaryRel
:Inst RigidRel
:Sig  RiskFactor String
:Args "RiskFactor" "MitigationMethod"
```

:lex "?1 has MitigationMethod ?2"

:rem "RiskFactor(s) have mitigation method(s)."

;;;might change modelling of mitigation method to a system property later?

:Rel riskFactorHasDescription

:Inst BinaryRel

:Inst RigidRel

:Sig RiskFactor String

:Args "RiskFactor" "Description"

:lex "?1 has description ?2"

:rem "Risk has One Description."

(functionalArg riskFactorHasDescription 2)

:Rel riskFactorHasActorType

:Inst BinaryRel

:Inst RigidRel

:Sig RiskFactor ActorType

:Args "RiskFactor" "ActorType"

:lex "?1 has ActorType ?2"

:rem "RiskFactor(s) have ActorType(s)."

:exampleRem "(riskFactorHasActorType FoodSafety 4PSPCtx.Producer)"

:Rel riskFactorInfluences

:Inst BinaryRel

:Inst RigidRel

:Sig RiskFactor String

:Args "RiskFactor" "production metric influenced"

:lex "?1 influences ?2"

:rem "Risk has influence on production processes/metrics."

(functionalArg riskFactorInfluences 2)

:Rel riskFactorDeptValueOnRF

:Inst TernaryRel

:Inst RigidRel

:Sig RiskFactor FuzzyNumber RiskFactor

:Args "RiskFactor" "FuzzyNumber" "RiskFactor"

:lex "?1 has an interdependency of ?2 upon ?3"

:rem "A RiskFactor has a dependency value upon a RiskFactor. There is only one dependency value for a given pair of RiskFactors."

:exampleRem "(riskFactorDeptValueOnRF rf1 (fuzzyValTripleFN 0.1 0.2 0.3) rf2)"

(functionalArg riskFactorDeptValueOnRF 2)

:Rel riskFactorAppliesToOrganisation

:Inst BinaryRel

:Inst RigidRel

:Sig OrganisationSpecificRiskFactor Organisation

:Args "OrganisationSpecificRiskFactor" "Organisation"

:lex "?1 applies to Organisation ?2"

:rem "RiskFactor(s) apply to Organisation(s). An OrganisationSpecificRiskFactor must apply to an organisation."

(totalArg riskFactorAppliesToOrganisation 1)

:Rel riskFactorAppliesToRegion

:Inst BinaryRel

:Inst RigidRel

:Sig RegionalSpecificRiskFactor ZoneType

:Args "RegionalSpecificRiskFactor" "Region"

:lex "?1 applies to Region ?2"

:rem "RiskFactor(s) apply to Region(s). An RegionalSpecificRiskFactor must apply to a Region."

(totalArg riskFactorAppliesToRegion 1)

:Rel riskFactorAppliesToLocation

:Inst BinaryRel

:Inst RigidRel

:Sig LocationSpecificRiskFactor Location

:Args "LocationSpecificRiskFactor" "Location"

:lex "?1 applies to Location ?2"

:rem "RiskFactor(s) apply to Location(s). An LocationSpecificRiskFactor must apply to a Location."

(totalArg riskFactorAppliesToLocation 1)

12.14 Level 2 Properties: Disparate Roles

Name "Level 2 Reference Ontology - Disparate Roles"

:Description "Level 2 Roles - Disparate roles"

:Use 2DSCtx

:Prop Target

:Inst Type

:sup Role

:rem "result, level, or situation that an organisation or group wants or plans to achieve"

:referenceRem "http://dictionary.cambridge.org/dictionary/business-english/target_1"

:Prop Requirements

:Inst Type

:sup Role

:rem "a condition or capability that must be met or possessed by a system, system component, product, or service to satisfy an agreement, standard, specification, or other formally imposed documents."

:referenceRem "BS ISO/IEC IEEE 24765:2010"

:Prop Product

:Inst Type

:sup Role

:rem "1. Something produced by effort, or some mechanical or industrial process. 2. an artifact that is produced, is quantifiable, and can be either an end item in itself or a component item."

:referenceRem "1. Collins Dic. 2. BS ISO/IEC IEEE 24765:2010"

:Prop Component

:Inst Type

:sup Product

:rem "A constituent part or aspect of something more complex"

:referenceRem "Collins Dic."

:Prop ProductRequest

:Inst Type

:sup Role

:rem "The act of asking for some product to be given or done"

:referenceRem "WordReference Dic.(interpreted)"

:Prop ProductHistory

:Inst Type

:sup Role

:rem "A continuous, systematic telling of past events to get a product"

:referenceRem "WordReference Dic. (interpreted)"

:Prop Asset

:Inst Type

:sup Role

:rem "Something valuable that an entity owns, benefits from, or has use of, in generating income."

:referenceRem "http://www.businessdictionary.com/"

:Prop Storage

:Inst Type

:sup Role

:rem "Space or area reserved for storing"

:referenceRem "Collins Dic."

:Prop Specification

:Inst Type

:sup Role

:rem "A detailed description of the criteria for the constituents, construction, appearance, performance, etc, of a material, apparatus, etc, or of the standard of workmanship required in its manufacture"

:referenceRem "Collins Dic."

12.15 Level 2 Properties: Qualifier Roles

:Use 2DSCtx

:Prop Qualifier

:Inst Type

:sup Role

:rem "A Qualifier is a <sym>1SYSCtx.Role</sym> which is able to fulfil a non-functional requirement.

Qualifiers define how a <sym>1SYSCtx.System</sym> will operate by controlling the system processes. A Qualifier is played by <sym>1SYSCtx.Information</sym> which is a subtype of <sym>1SYSCtx.Basic</sym>."

:referenceRem "2014 FLEXINET D3.1"

(disjointSubProps Qualifier)

:Prop Robustness

:Inst Type

:sup Qualifier

:rem "the degree to which a system or component can function correctly in the presence

stressful environmental conditions."

:referenceRem "BS ISO/IEC IEEE 24765:2010"

:Prop Mitigation

:Inst Type

:sup Qualifier

:rem "An effort to reduce the impact and likelihood of risk"

:referenceRem "2014 FLEXINET D2.1"

:Prop Capacity

:Inst Type

:sup Qualifier

:rem ""

:referenceRem "2013 Hastilow, N. Manufacturing Systems Interoperability in Dynamic Change Environments. PhD Thesis Loughborough University."

:Prop Capability

:Inst Type

:sup Qualifier

:rem "process capability is a characterisation of the ability of a process to meet current or projected business goals."

:referenceRem "BS ISO/IEC IEEE 24765:2010"

:Prop Functionality

:Inst Type

:sup Capability

:rem "The capabilities of the various computational, user interface, input, output, data management and other features provided by a product."

:referenceRem "BS ISO/IEC IEEE 24765:2010"

:Prop Availability

:Inst Type

:sup Qualifier

:rem "Derived from Hastilow Thesis - performance metric.

1. The degree to which a system or component is operational and accessible when required for use.

2. ability of a component or service to perform its required function at a stated instant or over a stated period of time."

:referenceRem "BS ISO/IEC IEEE 24765:2010"

:Prop Reliability

:Inst Type

:sup Qualifier

:rem "The ability of a system or component to perform its required functions under stated conditions for a specified

period of time."

:referenceRem "BS ISO/IEC IEEE 24765:2010"

:Prop Solvency

:Inst Type

:sup Reliability

:rem ""

:Prop Consistency

:Inst Type

:sup Qualifier

:rem "Derived from Hastilow Thesis - quality metric.

The degree of uniformity, standardisation, and freedom from contradiction among the documents or parts of

a system or component."

:referenceRem "BS ISO/IEC IEEE 24765:2010"

:Prop Compliance

:Inst Type

:sup Qualifier

:rem "The state or fact of according with or meeting rules or standards."

:referenceRem "Oxford Dictionaries Online. http://www.oxforddictionaries.com/us/definition/american_english/compliance."

:Prop Sustainability

:Inst Type

:sup Qualifier

:rem "Able to be maintained at a certain rate or level."

:referenceRem "Oxford Dictionaries Online. http://www.oxforddictionaries.com/us/definition/american_english/sustainable#sustainable."

:Prop EnergyConsumption

:Inst Type

:sup Qualifier

:rem "the amount of energy used."

:referenceRem "Collins English Dictionary.
http://www.collinsdictionary.com/dictionary/english/energy-consumption."

:Prop FeasibilityStudy

:Inst Type

:sup Qualifier

:rem "Derived from Custom Drinks.

A study to identify and analyse a problem and its potential solutions in order to determine their viability,

costs, and benefits."

:referenceRem "BS ISO/IEC IEEE 24765:2010"

:Prop Performance

:Inst Type

:sup Qualifier

:rem " the degree to which a system or component accomplishes its designated functions within given constraints,

such as speed, accuracy, or memory usage."

:referenceRem "BS ISO/IEC IEEE 24765:2010"

:Prop Quality

:Inst Type

:sup Qualifier

:rem "1. the degree to which a system, component, or process meets specified requirements.

2. ability of a product, service, system, component, or process to meet customer or user needs, expectations, or requirements.

3. the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs.

4. conformity to user expectations, conformity to user requirements, customer satisfaction, reliability, and level of defects present.

5. the degree to which a set of inherent characteristics fulfils requirements.

6. the degree to which a system, component, or process meets customer or user needs or expectations."

:referenceRem "BS ISO/IEC IEEE 24765:2010"

:Prop Uncertainty

:Inst Type

:sup Qualifier

:rem "the result of not having accurate or sufficient knowledge of a situation."

:referenceRem "BS ISO/IEC IEEE 24765:2010"

:Prop Risk

:Inst Type

:sup Qualifier

:partitionedBy (listof ExternalRisk DemandRisk InformationRisk ControlRisk SupplyRisk ProductionRisk LogisticsRisk)

:rem "Risk is defined as a possible loss in the future or otherwise unwanted consequences as a result of actions taken now"

:referenceRem "Samantra, C., & Sahu, N. (2013). Decision-making in selecting reverse logistics alternative using interval-valued fuzzy sets combined with VIKOR approach."

:Prop ExternalRisk

:Inst Type

:sup Risk

:rem "these are general geopolitical, environmental or economic issues which can affect a GPN, but are outside its control."

:referenceRem "2014 FLEXINET D2.1"

:Prop DemandRisk

:Inst Type

:sup Risk

:rem "the risk is related to uncertainty in customer demand."

:referenceRem "2014 FLEXINET D2.1"

:Prop InformationRisk

:Inst Type

:sup Risk

:rem "these risks are related to problems with IT systems, management and control mechanisms in the GPNs.

Is this part of Information and Control?"

:referenceRem "2014 FLEXINET D2.1"

:Prop ControlRisk

:Inst Type

:sup Risk

:rem "is this part of Information And Control?"

:Prop SupplyRisk

:Inst Type

:sup Risk

:rem "the risks affect the GPNs from the suppliers' side."

:referenceRem "2014 FLEXINET D2.1"

:Prop ProductionRisk

:Inst Type

:sup Risk

:rem "these risks are inherited in the core production process in the GPNs."

:referenceRem "2014 FLEXINET D2.1"

:Prop LogisticsRisk

:Inst Type

:sup Risk

:rem "these risks are related to transportation, inventory and other logistics activities that connect the partners in the GPNs."

:referenceRem "2014 FLEXINET D2.1"

12.16 Level 2 Properties: Metric

:Use ../2DSCtx

:Prop QuantitativeMeasure

:Inst Type

:Inst NonLogicalFunctor

:sup Metric

:sup Quantity

:rem "a measure of ...amount or size."

:referenceRem "Collins English Dictionary.
http://www.collinsdictionary.com/dictionary/english/quantitative."

:Prop QualitativeMeasure

:Inst Type

:sup Metric

:rem "a measure relating to ...quality of something rather than its quantity."

:referenceRem "Oxford Dictionaries Online.
http://www.oxforddictionaries.com/us/definition/american_english/qualitative."

;;;

;;;Quantitative measures

:Prop Percent

:Inst Type

:Inst NonLogicalFunctor

:sup QuantitativeMeasure

:rem "One part in every hundred."

:referenceRem "Oxford Dictionaries Online.
http://www.oxforddictionaries.com/us/definition/american_english/percent."

:Fun %

:Inst UnaryFun

:Inst MeasureFun

:Sig RealNumber -> Percent

:name "percentage"

:Prop FuzzyNumber

:Inst Type

:Inst NonLogicalFunctor

:sup QuantitativeMeasure

:Fun fuzzyValTripleFN

:Inst TernaryFun

:Sig NonNegReal NonNegReal NonNegReal -> FuzzyNumber

:Args "low" "mid" "high" -> "FuzzyNumber"

;;;

;;;Qualitative measures

;;;N.B. The values of qualitative measures are modelled as classes not instances. Facts about instances

;;;form part of a knowledge base and should not appear in the ontology.

;;;The use of HMLType in a signature restricts the arg values to a list of High, Medium and Low.

;;;There appears to be no way to create a restricted list.

;;;"coveredBy" relates to properties not insts as in insts of facts, consts or metaproperties (as below).

:Prop HMLType

:Inst MetaProperty

:sup Type

:name "Measure of High Medium Low"

:Prop High

:Inst HMLType

:sup QualitativeMeasure

:Prop Medium

:Inst HMLType

:sup QualitativeMeasure

:Prop Low

:Inst HMLType

:sup QualitativeMeasure

;;;

:Prop ZoneType

:Inst MetaProperty

:sup Type

:name "Measure of Position in Geographical Hierarchy"

:Prop {Area/City}

:Inst ZoneType

:sup QualitativeMeasure

:Prop {State/Province}

:Inst ZoneType

:sup QualitativeMeasure

:Prop Country

:Inst ZoneType

:sup QualitativeMeasure

:Prop Region

:Inst ZoneType

:sup QualitativeMeasure

:Prop Global

:Inst ZoneType

:sup QualitativeMeasure

12.17 Level 2 Relationships: Role

:Use 2DSCtx

:Rel playsRoleQualifier

:Inst TernaryRel

:Inst NonRigidRel

:supRel playsRole

:Sig Information Qualifier Scenario

:Args "Information" "Qualifier" "Scenario"

:lex "Information entity ?1 plays Qualifier Role ?2 in Scenario ?3"

:rem "A Qualifier is played by a <sym>1SYSCtx.Basic</sym> which is a subtype of <sym>1SYSCtx.Information</sym>."

:Rel playsRoleActor

:Inst TernaryRel

:Inst NonRigidRel

:supRel playsRole

:Sig System Actor Scenario

:Args "System" "Actor" "Scenario"

:lex "System entity ?1 plays Actor Role ?2 in Scenario ?3"

:rem "An Actor is played by a <sym>1SYSCtx.Basic</sym> which is a subtype of <sym>1SYSCtx.System</sym>."

:Rel requiresInputOfType

:Inst BinaryRel

:Inst NonRigidRel

:Sig Service Type

:Args "Service" "Type"

:lex "Service ?1 requires input of type ?2"

;;;could instantiate this as an intentional relation?

13 Annex C: Level 3 Ontology KFL Code

13.1 Level 3 Context

:Use ../2DSCtx

:Ctx 3MBSCtx

:Inst UserContext

:supCtx ../2DSCtx

13.2 Level 3 Properties: Basics

:Name "Level 3 Reference Ontology - Basics"

:Description "Level 3 properties - Derived from Level 2 Basics property"

:Use 3MBSCtx

:Prop ManufacturingAuthorityLevel

:Inst Type

:sup Metric

:name "Manufacturing Authority Level"

:rem "Level for the right, power or ability to control, command or decide into a manufacturing domain"

:referenceRem "http://www.wordreference.com/definition/authority (Adapted)"

:Prop ManufacturingStandard

:Inst Type

:sup Standard

:name "Manufacturing Standard"

:rem "Something considered to be a basis of comparison into a manufacturing domain"

:referenceRem "http://www.wordreference.com/definition/standard (Adapted)"

:Prop ManufacturingBusinessModel

:Inst Type

:sup BusinessModel

:name "Manufacturing Business Model"

:rem "Description of means and methods a manufacturer employs to earn the revenue projected in its plans."

:referenceRem "http://www.businessdictionary.com/definition/business-model.html"

:Prop ProductProductionFacility

:Inst Type

:sup Facility

:name "Product Production Facility"

:rem "The means or equipment facilitating the performance of a product"

:referenceRem "http://www.wordreference.com/definition/Facility (Adapted)"

:Prop ServiceProvisionFacility

:Inst Type

:sup Facility

:name "Service Provision Facility"

:rem "The means or equipment facilitating the performance of a service"

:referenceRem "http://www.wordreference.com/definition/Facility (Adapted)"

:Prop ManufacturingOrganisation

:Inst Type

:sup Organisation

:name "Manufacturing Organisation"

:rem "Organisation for the production of goods, esp by industrial processes"

:referenceRem "http://www.wordreference.com/definition/manufacturing"

:Prop ManufacturingAutomation

:Inst Type

:sup Automation

:name "Manufacturing Automation"

:rem "The use of methods for controlling industrial processes automatically, esp by electronically controlled systems, often reducing manpower"

:referenceRem "http://www.wordreference.com/definition/Automation"

:Prop ManufacturingControl

:Inst Type

:sup ControlSystems

:name "Manufacturing Control"

:rem "Activities involved in handling materials, parts, assemblies, and subassemblies, from their raw or initial stage to the finished product stage in an organised and efficient manner. It may also include activities such as planning, scheduling, routing, dispatching, storage, etc."

:referenceRem "http://www.businessdictionary.com/definition/production-control.html"

:Prop ManufacturingVirtualisation

:Inst Type

:sup Virtualisation

:name "Manufacturing Virtualisation"

:rem "Constructing and manipulating abstract (mathematical and/or graphical) representations of manufacturing situations, simulated with the help of a computer system. Also called computer simulation."

:referenceRem "http://www.businessdictionary.com/definition/computer-modeling.html"

:Prop ManufacturingNetwork

:Inst Type

:sup Network

:name "Manufacturing Network"

:rem "Any system or group of interrelated or interconnected elements esp. over a manufacturing area"

:referenceRem "http://www.wordreference.com/definition/network (Adapted)"

13.3 Level 3 Properties: Roles

:Use 3MBSCtx

:Prop Manufacturer

:Inst Type

:sup Actor

:rem "Entity that makes a good through a process involving raw materials, components, or assemblies, usually on a large scale with different operations divided among different workers."

:referenceRem "http://www.businessdictionary.com/"

:Prop ManufacturedProduct

:Inst Type

:sup Product

:rem "Product that has been made from a raw material, esp as a large-scale operation using machinery."

:referenceRem "http://www.collinsdictionary.com/"

13.4 Level 3 Relationships

:Use 3MBSCtx

:Rel ManufacturerProduceManufacturedProduct

:Inst TernaryRel

:Inst NonRigidRel

:Sig Manufacturer ManufacturedProduct Scenario

:Args "Manufacturer" "ManufacturedProduct" "Scenario"

:lex "Manufacturer ?1 produce ManufacturedProduct?2 in Scenario ?3"

:rem "A Manufacturer produces a ManufacturedProduct."

14 Annex D: Level 4 Ontology KFL Code

14.1 Level 4 Context: Product Service Lifecycle Systems

:Use ../3MBSCtx

:Ctx 4PSLSCtx

:Inst UserContext

:supCtx ../3MBSCtx

14.2 Level 4 Context: Product Service Systems

:Use ../4PSLSCtx

:Ctx 4PSPCtx

:Inst UserContext

:supCtx ../4PSLSCtx

14.3 Level 4 Properties: Basics

:Use 4PSPCtx

:Prop ServiceInfrastructure

:Inst Type

:sup Information

:sup MLO.Object

:name "Service Infrastructure"

:rem "The resources required for a ... <sym>2DSCtx.Service</sym>"

:referenceRem "http://www.merriam-webster.com/dictionary/infrastructure"

:Prop CommunicationInfrastructure

:Inst Type

:sup Information

:sup MLO.Object

:name "Communication Infrastructure"

:rem "The resources required for ... the means of sending or receiving information."

:referenceRem "http://www.merriam-webster.com/dictionary/infrastructure;http://www.oxforddictionaries.com/us/definition/american_english/communication"

:Prop CommunicationProtocol

:Inst Type

:sup Information

:sup MLO.AbstractEntity

:name "Communication Protocol"

:rem "Communication protocols are formal descriptions of digital message formats and rules."

:referenceRem "http://www.techopedia.com/definition/25705/communication-protocol"

:Prop ProductionFeature

:Inst Type

:sup Information

:sup Feature

:name "Production Feature"

:rem "A <sym>2DSCtx.Feature</sym> relating specifically to the Production domain."

14.4 Level 4 Properties: Systems

:Use 4PSPCtx

:Prop ProductionFacility

:Inst Type

:sup Facility

:name "Production Facility"

:rem "A <sym>2DSCtx.Facility</sym> related specifically to the Production domain."

:Prop ProductionNetwork

:Inst Type

:sup Network

:name "Production Network"

:rem "A <sym>2DSCtx.Network</sym> related specifically to the Production domain."

:Prop ProductionMethod

:Inst Type

:sup System

:name "Production Method"

:rem "Processes and techniques that are used to manufacture a <sym>2DSCtx.Product</sym>."

:referenceRem "http://encyclopedia2.thefreedictionary.com/Production+methods"

:partitionedBy (listof BOM BOR BOP)

:Prop BOM

:Inst Type

:sup ProductionMethod

:name "Bill of Materials"

:rem "BOM lists the components required to build a <sym>2DSCtx.Product</sym> as well as information related to these components."

:referenceRem "Imran, M. 2013, Towards an Assembly Reference Ontology for Assembly Knowledge Sharing, PhD Thesis, Loughborough University, U.K."

:Prop BOR

:Inst Type

:sup ProductionMethod

:name "Bill of Resources"

:rem "BOR represents the required assembly resources to carry out the assembly processes for a particular <sym>2DSCtx.Product</sym>."

:referenceRem "Imran, M. 2013, Towards an Assembly Reference Ontology for Assembly Knowledge Sharing, PhD Thesis, Loughborough University, U.K."

:Prop BOP

:Inst Type

:sup ProductionMethod

:name "Bill of Process"

:rem "BOP lists the sequence of assembly processes for the production of a particular <sym>2DSCtx.Product</sym>."

:referenceRem "Imran, M. 2013, Towards an Assembly Reference Ontology for Assembly Knowledge Sharing, PhD Thesis, Loughborough University, U.K."

14.5 Level 4 Properties: Roles

:Use 4PSPCtx

:Prop DesignEngineer

:Inst Type

:sup Actor

:rem "The term it refers engineers who develop new products or processes with a primary emphasis on functional utility."

:referenceRem "http://en.wikipedia.org/wiki/Design_engineer"

:Prop ProductionEngineer

:Inst Type

:sup Actor

:rem "Person dedicate to the design and application of manufacturing techniques to produce a specific product."

:referenceRem "http://www.businessdictionary.com/"

:Prop Producer

:Inst Type

:sup Actor

:rem "a person or business enterprise that generates goods or services for sale "

:referenceRem "http://www.collinsdictionary.com/"

:Prop ServiceEngineer

:Inst Type

:sup Actor

:rem "someone who maintains and repairs equipment"

:referenceRem "http://www.collinsdictionary.com/dictionary/english/service-engineer"

:Prop ProductEnergyConsumption

:Inst Type

:sup EnergyConsumption

:rem "the amount of energy used by a Product."

:referenceRem "http://www.collinsdictionary.com"

:Prop ServiceEnergyConsumption

:Inst Type

:sup EnergyConsumption

:rem "the amount of energy used by a Service."

:referenceRem "http://www.collinsdictionary.com"

:Prop ProductSustainability

:Inst Type

:sup Sustainability

:rem "Ability to maintain or support a product over the long term."

:referenceRem "http://www.businessdictionary.com"

:Prop ServiceSustainability

:Inst Type

:sup Sustainability

:rem "Ability to maintain or support a service over the long term."

:referenceRem "http://www.businessdictionary.com"

14.6 Level 4 Relationships

:Use 4PSPCtx

:Rel playsRoleActorInGPNS

:Inst TernaryRel

:Inst NonRigidRel

:supRel playsRoleActor

:Sig System Actor GPNScenario

:Args "System" "Actor" "GPNScenario"

:lex "System entity ?1 plays Actor Role ?2 in GPNScenario ?3"

:rem "An Actor is played by a <sym>1SYSCtx.Basic</sym> which is a subtype of <sym>1SYSCtx.System</sym>. In a <sym>GPNScenario</sym> only Actor roles can be played."

14.7 Level 4 Risk Properties

:Name "Level 4 - Risk Properties"

:Description "This file contains the definition of risk properties which occur at the Product Service Production Systems level which is a sublevel of the Product Service Lifecycle Systems Level of the Flexinet Project reference ontology but is placed within a separate folder called 4PSP_Risk as they form a specialised subset of level 4.

Risk properties are defined at this level as they playRoles in level 4 scenarios."

:Use ../4PSPCtx

:Prop Perturbation

:Inst Type

:sup Metric

:rem "The direct effect of disruption on a Global Production Network node."

:referenceRem "2014 FLEXINET D2.1"

:Prop Inoperability

:Inst Type

:sup Metric

:rem "The reduced percentage of operability of a Global Production Network node as a result of the original disruption and propagation of that original disruption, compared with the expected level of operability. A value of 0% represents the normal operation of a node while a value of 100% express the total and complete suspension of activities in a node."

:referenceRem "2014 FLEXINET D2.1"

:Prop UnitLossOfInoperability

:Inst MaterialRole

:sup Metric

:rem "An average of inoperability over a time horizon. Modelled as a MaterialRole so a TimeHorizon can be applied to this property."

:referenceRem "??"

:Prop ActorInterDependency

:Inst Type

:sup Metric

:rem "The interdependency coefficient that presents a probability of a disruption propagation from node j to node i."

:referenceRem "2014 FLEXINET D2.1"

:Prop InterDependencyRating

:Inst Type

:sup Metric

;;;==========

;;;Criteria Type enumeration

:Prop CriteriaType

:Inst MetaProperty

:sup Type

:rem "The relationships between the network nodes."

:referenceRem "2014 FLEXINET D2.1"

:Prop TradeVolume

:Inst CriteriaType

:sup QualitativeMeasure

:Prop Inventory

:Inst CriteriaType

:sup QualitativeMeasure

:Prop SecurityOfInformationFlow

:Inst CriteriaType

:sup QualitativeMeasure

:Prop SuitabilityOfProduct

:Inst CriteriaType

:sup QualitativeMeasure

:Prop CompatibilityOfITSystems

:Inst CriteriaType

:sup QualitativeMeasure

:Prop {Distance/LeadTime}

:Inst CriteriaType

:sup QualitativeMeasure

:Prop {SuitabilityOfSupplier/Customer}

:Inst CriteriaType

:sup QualitativeMeasure

:Prop InformationTransparency

:Inst CriteriaType

:sup QualitativeMeasure

:Prop CollaborationAgreement

:Inst CriteriaType

:sup QualitativeMeasure

14.8 Level 4 Risk Relations

:Name "Level 4 Risk Relations"

:Description "This file contains the definition of the risk relations identified at level 4 in the context of the FLEXINET Project - placed in folder 4PSP_Risk as they form a specialised subset of the reference ontology. Risk relations are defined at this level as they play Roles with Risk and GPN Scenarios which occur at this level."

:Use ../4PSPCtx

;;;===

;;;Relations of RiskScenario Property

:Rel riskScenarioHasLikelihood

:Inst BinaryRel

:Inst RigidRel

:Sig RiskScenario FuzzyNumber

:Args "Resilience" "Likelihood Value"

:lex "?1 has LikeliHood Value ?2"

:rem "RiskScenario has one Likelihood value."

:exampleRem "(riskScenarioHasLikelihood riskS1 (fuzzyValTripleFN 0.1 0.2 0.3))"

(functionalArg riskScenarioHasLikelihood 2)

;;;the Description of the RiskScenario can be modelled using the defScenario relation inherited from Scenario.

;;;The name relation is a MLO default relation.

;;;===

;;;Relations of GPNScenario Property

:Rel gpnScenariohasTotalLossforAllRiskScenarios

:Inst BinaryRel

:Inst RigidRel

:Sig GPNScenario FuzzyNumber

:Args "Resilience" "Value of TotalLossforAllRiskScenarios"

:lex "?1 has TotalLossforAllRiskScenarios Value ?2"

:rem "GPNScenario has one Total Loss Value."

:exampleRem "(gpnScenariohasTotalLossforAllRiskScenarios GPNS1 (fuzzyValTripleFN 0.1 0.2 0.3))"

(functionalArg gpnScenariohasTotalLossforAllRiskScenarios 2)

;;;===

;;;Relations of RiskFactor Property

:Rel riskFactorInfluencesPerturbation

:Inst BinaryRel

:Inst RigidRel

:Sig RiskFactor Perturbation

:Args "RiskFactor" "Perturbation"

:lex "?1 influences Perturbation ?2"

:rem "One RiskFactor influences Perturbation(s)."

(functionalArg riskFactorInfluencesPerturbation 1)

;;;===

;;;Relations of Perturbation Property

:Rel perturbationHasValue

:Inst BinaryRel

:Inst RigidRel

:Sig Perturbation FuzzyNumber

:Args "Perturbation" "Perturbation Value"

:lex "?1 has Perturbation Value ?2"

:rem "Perturbation has one Perturbation value."

:exampleRem "(PerturbationHasValue perturb1 (fuzzyValTripleFN 0.1 0.2 0.3))"

(functionalArg perturbationHasValue 2)

:Rel perturbationHasStartPeriod

:Inst BinaryRel

:Inst RigidRel

:Sig Perturbation IntegerNumber

:Args "Perturbation" "Start Period"

:lex "?1 has Start Period ?2"

:rem "Perturbation has one Start Period."

(functionalArg perturbationHasStartPeriod 2)

:Rel perturbationHasLength

:Inst BinaryRel

:Inst RigidRel

:Sig Perturbation IntegerNumber

:Args "Perturbation" "Length"

:lex "?1 has Length ?2"

:rem "Perturbation has one Length."

(functionalArg perturbationHasLength 2)

;;;==

;;;Relations of Inoperability Property

:Rel inoperabilityHasValue

:Inst BinaryRel

:Inst RigidRel

:Sig Inoperability FuzzyNumber

:Args "Inoperability" "Inoperability Value"

:lex "?1 has Inoperability Value ?2"

:rem "Inoperability has one Inoperability value."

:exampleRem "(inoperabilityHasValue inop1 (fuzzyValTripleFN 0.1 0.2 0.3))"

(functionalArg inoperabilityHasValue 2)

:Rel inoperabilityHasTimePeriod

:Inst BinaryRel

:Inst RigidRel

:Sig Inoperability IntegerNumber

:Args "Inoperability" "TimePeriod"

:lex "?1 has TimePeriod ?2"

:rem "Inoperability has one TimePeriod."

(functionalArg inoperabilityHasTimePeriod 2)

;;;===

;;;Relations of UnitLossOfInoperability Property

:Rel unitLossOfInoperabilityHasValue

:Inst BinaryRel

:Inst RigidRel

:Sig UnitLossOfInoperability FuzzyNumber

:Args "UnitLossOfInoperability" "UnitLossOfInoperability Value"

:lex "?1 has UnitLossOfInoperability Value ?2"

:rem "UnitLossOfInoperability has one UnitLossOfInoperability value."

:exampleRem "(unitLossOfInoperabilityHasValue UnitInop1 (fuzzyValTripleFN 0.1 0.2 0.3))"

(functionalArg unitLossOfInoperabilityHasValue 2)

;;;The TimeHorizon attribute is modelled for UnitLossOfInoperability by declaring this property as a MaterialRole

;;;and using the HoldsIn Relation. e.g. (holdsIn (Date "2003") (UnitLossOfInoperability UnitLossEg))

;;;===

;;;Relations of ActorInterDependency Property

:Rel actorInterDependencyHasValue

:Inst BinaryRel

:Inst RigidRel

:Sig ActorInterDependency FuzzyNumber

:Args "ActorInterDependency" "ActorInterDependency Value"

:lex "?1 has ActorInterDependency Value ?2"

:rem "ActorInterDependency has one ActorInterDependency value."

:exampleRem "(actorInterDependencyHasValue actInd1 (fuzzyValTripleFN 0.1 0.2 0.3))"

(functionalArg actorInterDependencyHasValue 2)

:Rel actorInterDependencyHasRating

:Inst BinaryRel

:Inst RigidRel

:Sig ActorInterDependency InterDependencyRating

:Args "ActorInterDependency" "InterDependencyRating"

:lex "?1 has InterDependencyRating ?2"

:rem "ActorInterDependency has InterDependencyRating(s)."

;;;==========

;;;Relations of InterDependencyRating Property

:Rel ratingHasConfidence

:Inst BinaryRel

:Inst RigidRel

:Sig InterDependencyRating HMLType

:Args "InterDependencyRating" "Measure of High Medium Low"

:lex "?1 has a ?2 confidence value"

:rem "InterDependencyRating has One Confidence value."

:exampleRem "(ratingHasConfidence ratingEx 2DSCtx.Low)"

(functionalArg ratingHasConfidence 2)

:Rel ratingHasCriterium

:Inst BinaryRel

:Inst RigidRel

:Sig InterDependencyRating CriteriaType

:Args "InterDependencyRating" "Criterium used"

:lex "?1 uses ?2 as a criterium"

:rem "InterDependencyRating has One Criterium."

:exampleRem "(ratingHasCriterium ratingEx 4PSPCtx.TradeVolume)"

(functionalArg ratingHasCriterium 2)

:Rel ratingHasOrdinal

:Inst BinaryRel

:Inst RigidRel

:Sig InterDependencyRating HMLType

:Args "InterDependencyRating" "Measure of High Medium Low"

:lex "?1 has a ordinal value of ?2"

:rem "InterDependencyRating has One Ordinal value. An ordinal is an ordered category."

:exampleRem "(ratingHasConfidence ratingEx 2DSCtx.Low)"

(functionalArg ratingHasConfidence 2)

;;;==========

;;;Relations of Actor property (pertaining to Risk Ontology)

:Rel actorInterDependencyOnActor

:Inst TernaryRel

:Inst RigidRel

:Sig Actor ActorInterDependency Actor

:Args "Actor" "ActorInterDependency" "Actor"

:lex "?1 has ActorInterDependency ?2 upon ?3"

:rem "An Actor has an ActorInterDependency upon an Actor. There is only one ActorInterDependency property for a given pair of Actors."

(functionalArg actorInterDependencyOnActor 2)

15 Annex E: Simple Examples of Facts and Queries

Chapter 9 presents ontology queries that have been developed to answer end user questions. The generic queries are set out in section 9.1 against their respective levels, whilst sections 9.2, 9.3 and 9.4 detail a number of Level 5 enterprise specific ontology queries.

A query is request for information from the knowledge base and are created using ECLIF. ECLIF is a language designed for ontology authoring and database query in Highfleet products. It is a variant of the ISO Common Logic (ISO/IEC 24707:2007) CLIF concrete syntax, with constructs added to support ontology management, database applications and query processing.

15.1 Queries against Reference Ontology Based Facts

15.1.1 Level 2 Facility Queries

Figure 15-1 represents some facts describing the relationship between End Users' and Facilities. In the depicted example, KSB has three facilities and Custom Drinks has two (examples are arbitrary).

```
(OrganisationComposedOfFacility KSB PlantLead1Ger)
(OrganisationComposedOfFacility KSB OffShorePlant1)
(OrganisationComposedOfFacility KSB OffShorePlant3Ch)
(OrganisationComposedOfFacility CD PlantLead2Sp)
(OrganisationComposedOfFacility CD OffShorePlant2)
```

Figure 15-1: Level 2 example of Facts for OrganisationComposedOfFacility in Eclif

We do not consider Rules, Axioms and Constraints of Systems in level 2, although as WP5 applications develop, it may be reconsidered and hence add them to the ontology.

15.1.1.1 Examples of queries

Some examples of queries are put forward here, describing some questions and potential answers of the ontology and the knowledge base. The results will be shown in the native Highfleet software program. To show the expressiveness of ontology, we first describe in natural language the question we want to answer, then the transition into KFL is performed. Finally, the response with Highfleet is presented.

Question 1

- *Natural language*

'We would like to know the facilities that integrate our organisation.'

- *Query in KFL*

Figure 15-2 shows the resulting query in Highfleet.

```
(OrganisationComposedOfFacility KSB ?y)
```

Figure 15-2: Level 2 Query 'Facilities by Organisation'

- *Answer*

Figure 15-3 shows the answer. There are currently five Facilities related with KSB.

?y
OffShorePlant1
OffShorePlant3Ch
PlantChn101
PlantChn102
PlantLead1Ger

Figure 15-3: Level 2 result of query 'Facilities by Organisation'

Question 2

- *Natural language*

We would like to know "facilities of KSB" that include in their plants R&D Departments.

- *Query in KFL*

The resulting query in eclif can be seen in Figure 15-4.

```
(and (FacilityHasDeparment ?x RDServices)
(OrganisationComposedOfFacility KSB ?x)
(Organisation KSB))
```

Figure 15-4: Level 2 Query No. 2 for Systems

- *Answer*

In this case, Highfleet provides as a response two Facilities in the Organisation including R&D Services (see Figure 15-5).

?x
OffShorePlant1
PlantLead1Ger

Figure 15-5: Level 2 result of Query No.2 for Systems

15.1.2 Level 2 Partner and Competitor Queries

Two facts are presented as examples of a supplier (see Figure 15-6), one being a supplier that provides Pumps HCAV and the other being a supplier of SLS Laser Machines.

```
(Supplier SPumpsHCAV)
(Supplier SLaserSLSMachines)
```

Figure 15-6: Level 2 example of facts for Supplier

A required relation is needed to fulfil the constraint associated to the fact that all roles must exist in a context (see Figure 15-7).

```
(requiresA SPumpsHCAV Net1)
(requiresA SLaserSLSMachines Net1)
```

Figure 15-7: Level 2 required relation for Supplier

Figure 15-8 represents some facts included in the knowledge base.

```
(Partner HTEnterprise)
(requiresA HTEnterprise PlantLead1Ger)
```

Figure 15-8: Level 2 example of facts for Partner

Figure 15-9 shows one example of technology (although more specialised terms are defined in Level 5 for technologies (see Annex F)). Note that since technology is an Actor Role, a *requiresA* definition is needed.

```
(Design NewDesign)

(Technology ProgressiveCavitiyTech)
(requiresA ProgressiveCavitiyTech NewDesign)
```

Figure 15-9: Level 2 example of Technology

At this stage no rules, axioms or constraints are specifically assigned to Actor roles at level 2.

15.1.2.1 Queries execution

Question 1

- *Natural language*

We would like to know the facilities providing SLaserSLSMachines.

- *Query in KFL*

The query for this question in presented in Figure 15-10.

```
(and (Facility ?x) (playsRole ?x SLaserSLSMachines ?y))
```

Figure 15-10: Level 2 Query No.1 for Roles

- *Answer*

Figure 15-11 presents execution of the query with Highfleet. Considering the current knowledge base (facts), there is only one facility that supplies LaserMachines. Sc1 indicates the scenario in which this query is executing.

?x	?y
OffShorePlant3Ch	Sc1

Figure 15-11: Level 2 result of Query No.1 for Roles

Question 2

- *Natural language*

We want to know the list of competitors (for KSB).

- *Query in KFL*

Figure 15-12 shows a query that exemplifies the simplicity of the syntax to recover the list of competitors currently loaded in the knowledge base.

```
(Competitor ?x)
```

Figure 15-12: Level 2 Query No.2 for Roles

- *Answer*

Figure 15-13 shows that there are currently two competitors stored in the knowledge base.

?x
MyPumpIndustry2
MyPumpIndustry1

Figure 15-13: Level 2 result of Query No. 2 for Roles

15.1.3 Level 3 Manufacturer Query

Some facts are additionally shown in Figure 15-14. A requiresA rule is needed. In this case, Manufacturer "Mnf1" is assigned to an arbitrary System called Net1.

```
(Manufacturer Mnf1)
(requiresA Mnf1 Net1)
(Manufacturer Mnf2)
(requiresA Mnf2 Net1)
```

Figure 15-14: Level 3 Manufacturer in KFL

Figure 15-15 shows some example facts for ManufacturedProduct.

```
(ManufacturedProduct Output1Pumps)
(ManufacturedProduct Output2Pumps)
(requiresA Output1Pumps PlantChn101)
(requiresA Output2Pumps PlantChn101)
```

Figure 15-15: Level 3 example facts for ManufacturedProduct in KFL

15.1.3.1 Queries execution

Question

- *Natural language*

Plants where BasicPumps (a manufactured product) are produced.

- *Query in KFL*

Figure 15-16 shows the query implemented in eclif.

```
(and (Facility ?f)(requiresA Output1Pumps ?f)
(ManufacturerProduceManufacturedProduct ?x Outupt1Pumps ?z))
```

Figure 15-16: Level 3 example of Query Roles

- *Answer*

In Figure 15-17, we can see that only one result is found. Only one plant produce products of type Output1Pumps.

?f	?x	?z
PlantChn101	Mnf1	Sc1

Figure 15-17: Query Result for Roles: Level 3

15.1.4 Level 4 Engineer Query

Some instances of this property are shown in Figure 15-18. A requiresA rule is needed. Notice that system Design is used. Thus, the new engineer is created to be involved in design tasks.

```
(Design NewDesign)
(DesignEngineer Engineer1)
(requiresA Engineer1  NewDesign)
(DesignEngineer Engineer2)
(requiresA Engineer2  NewDesign)
```

Figure 15-18: Level 4 DesignEngineer facts in KFL

Figure Figure 15-19 shows some instances of ProductionEngineer.

```
(ProductionEngineer ProdEngineer1)
(requiresA ProdEngineer1  NewDesign)
(ProductionEngineer ProdEngineer2)
(requiresA ProdEngineer2  NewDesign)
```

Figure 15-19: Level 4 ProductionEngineer Facts in KFL

No relations, constraints or axioms are defined at this level.

15.1.4.1 Queries execution with Highfleet

Question

- *Natural language*

List of "Production Engineers" assigned to the design tasks.

- *Query in KFL*

Figure 15-20 shows the query in Highfleet.

```
(ProductionEngineer ?x)(requiresA ?x NewDesign)
```

Figure 15-20: Level 4 example of Query in Roles

- *Answer*

The result of the query can be seen in Figure 15-21. Two engineers are assigned to New Designs.

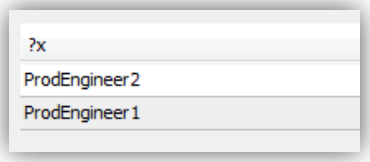


Figure 15-21: Level 4 result of Query with Roles

15.1.5 Level 4 System Query

This section provides some examples of initial queries developed for the FLEXINET reference ontology.

15.1.5.1 Queries execution with Highfleet

Question 1

The query shown in Figure 15-22 below requests the systems and the roles played by these systems within the scenario GPNScenarioGlobal3. The query results will return values for the variables (i.e. ?system, ?role) specified within the query. The playsRole relation exists between a basic, role and a scenario. The addition of the conjunctive clause (and System ?system) restricts the basic values returned to those of sub-property system. Figure 15-23 provides an examples of results which could be obtained by this query.

- *Natural Language*

"What are the systems and which roles do they play in GPN scenario No.3"

- *Query in KFL*

Figure 15-22 shows the query in Highfleet.

```
(and (System ?system)
        (playsRole ?system ?role GPNScenarioGlobal3)
)
```

Figure 15-22: Level 4 example of Query for GPN Scenario

- *Answer*

The result of the query can be seen in Figure 15-23. Three systems are found playing roles within GPN Scenario 3.

?system	?role
BrownsFarms	AppleSupplier
BioProducts	YeastSupplier
Tesco	PlantCustomer

Figure 15-23: Level 4 result of Query for GPN Scenario

Question 2

The next query specialises the previous one by confining the results returned to a list of systems which play roles in GPNScenarioGlobal3. The "setof" operator returns an ordered list of values corresponding to the variable specified (?system) which is one of the variables located within the contained query ("(and (System ?system)(playsRole ?system ?role GPNScenarioGlobal3))"). Figure 15-25 shows a possible results list for this query.

- *Natural Language*

"What are the systems which play roles in GPN scenario No.3"

- *Query in KFL*

Figure 15-24 shows the query in Highfleet.

```
(setof ?system (and (System ?system)
                    (playsRole ?system ?role GPNScenarioGlobal3)
               )
?systemsList )
```

Figure 15-24: Level 4 example of Query for GPN Scenario

- *Answer*

The result of the query can be seen in Figure 15-25. Three systems are found playing roles within GPN Scenario 3.

?systemsList
(listof BioProducts BrownsFarms Tesco)

Figure 15-25: Level 4 result of Query for GPN Scenario

16 Annex F: Key KFL constructs

Knowledge Frame Language (KFL) is a Common Logic based ontology development language which has been used for this research work. KFL uses directives to specify the ontology code whereas each directive starts with colons followed by a keyword and certain arguments. In order to understand KFL, the following concepts need to be understood.

- Contexts
- Properties
- Relations
- Functions
- Logic, Rules and Integrity Constraints

These are explained in the following sections.

16.1 Contexts

Contexts are very important in creating ontologies as they define specific point of view. Although we can create ontologies in IODE with a predefined context called Middle Level Ontology (MLO) however it is more convenient to define one's own context. We can create new context by writing a simple code in KFL as shown below. The first three fields (Ctx, Inst, supCtx) are mandatory for defining a new context in ontology while the last two are optional.

```
:Ctx ARO
:Inst UserContext
:supCtx MLO
:name "Assembly Reference Ontology"
:rem "The ARO context is used for the assembly domain"
```

Ctx (stands for context) defines the name of new concept (ARO in current case). We use UserContext as an instance of new context rather than SystemContext because we are defining our own context. The third field "supCtx" stands for super context of and we place MLO as super context of the ARO because it was default context. In the last two fields: name and rem (remarks), we can write anything within the inverted commas to elaborate the context code.

Once the context is defined, then we can use this context by writing the use directive as shown below.

```
:Use ARO
```

16.2 Properties

The term property refers to any taxonomic component while building an ontology in IODE. The term property is sometimes called class or category in other ontology development environments. Any concept/term is first represented as property in IODE and then relations, functions and logics are applied. When writing properties in KFL format, a user needs to write the following directives.

:Prop HandlingAF

:Inst Type

:sup AssemblyFeature

:name "Handling Assembly Feature"

:rem "Handling AF is used in resource evaluation"

The first three directives in the above code are mandatory while others are optional. Prop refers to property and represent the main concept e.g. HandlingAF in this case. Inst stands for "instance of" and represents property type. It has two kinds of properties in Upper Level Ontology (ULO) which are (1) Type and (2) MaterialRole. Types correspond to properties which do not change with the passage of time while MaterialRoles can change their status after sometime. In this work all the properties are instantiated under Type.

The third directive "sup" refers to super property relation and defines hierarchies of properties by this relation. For a property x to be super property of y, every instance of y should be an instance of x. For example an assembly feature is super property of handling AF as every instance of handling AF is an instance of the assembly feature.

The fourth and fifth directives are optional for properties where names and remarks (rem) define additional information related to the property as shown in the above example.

16.3 Relations

Properties are held together with the help of relationships. The sup property only defines hierarchy of properties and does not account for other relationships. A relation declaration consists of following directives.

:Rel hasTolerance

:Inst BinaryRel

:Sig Object Tolerance

:Args "Assembly Feature" "Tolerance"

Like properties, the first three directives are compulsory for relations. The :Rel line describes the wording of relationship e.g. what relation a property has with the other one. :Inst directive defines the kind of relation depending upon the arity (number of arguments) of the relation. For example,

BinaryRel (binary relation) in the above example connect two properties (Object and Tolerance) with each other. There are also other types of relations which are

- UnaryRel (one arguement)
- TernaryRel (three arguments)
- QuaternaryRel (four arguments)
- QuinaryRel (five arguments)
- Relation (Any number of arguments)

The :Sig directive should have a property for every argument position e.g. Object and Tolerance are two properties which have "hasTolerance" relationship.

16.4 Functions

Functions provide additional entities from one or more parameters and semantically differentiate between a description and what is described. Functions also allow parameters to be used for reasoning. Entities like fivePointTwoGrams or threePointTwoCentimetres would further complicate the model and make the parameters vague and unclear. KFL describes function in the following format to avoid the issues discussed above.

:Fun cm

:Inst UnaryFun

:Inst MeasureFun

:Sig RealNumber -> LengthDimension

This allows writing functions that describe length dimensions e.g. (cm 3.2). Similar to properties and relations, functions have three required directives which are Fun, Inst and Sig. It is also pertinent to note that except the first directive (Fun), the difference between a relation and function is the arrow in the :Sig directive. The text on the left side of arrow represents arguments to the function and text on the right side describes property instantiated by the function. Finally similar to relations, functions can also be classified by arity as follows.

- UnaryFunl (one arguement)
- BinaryFun (two arguments)
- TernaryFun (three arguments)
- QuaternaryFun (four arguments)
- QuinaryFun (five arguments)

16.5 Logic

Logics in KFL consist of rules and constraints. These rules and constraints are the mandatory part of heavyweight ontologies and thus differentiate the latter from the lightweight ontologies. Rules help to infer the existing information and create new information while constraints pre-empt any data inconsistency. Constraints in turn enhance the data quality and speed up the query response times. Rules and constraints will be extensively used in this research along with properties, relations, and functions.

16.5.1 Rules

As described above, rules infer new information from the existing statements and use implications. The implication operator is made up of an arrow and an equal size (as shown in the rule below). A rule consists of the antecedent and the consequent. The antecedent/s is/are the clause/clauses which help to infer new information. The consequent is the conclusive statement or the statement which is inferred using antecedents.

In KFL, the consequent will only be deduced if all the antecedent statements are true. For example in the following rule, the conclusive statement ((hasMinAllowableDimension ?p ?q+lower) will only be true if all the antecedent statements are true.

(<= (hasMinAllowableDimension ?p ?q+lower)

(and (Object ?p)

(hasDimensionWithTolerance ?p ?q (?tol ?lower ?upper))

(measurePlus ?q ?lower ?q+lower)

(or (= ?tol tolerance)

(= ?tol f7)

(= ?tol H8)

(= ?tol k6)

(= ?tol H7)

(= ?tol p6))))

:rem "The Object ?p has a minimum allowable dimension which is equivalent to its nominal dimension plus its lower deviation."

The above mentioned rule has also used conjunction and disjunction operators. The conjunction operator "and" combines two or more than two clauses to form the argument. The conjunction operator is true when all the clauses are true. The disjunction operator "or" combines two or more clauses and is true when at least one of the clauses is true.

16.5.2 Integrity Constraints (ICs)

Integrity Constraints (ICs) seem like rules apart from the fact that the IC directive starts with :IC. The IC directive represents the strength of the constraint and it shows the error messages in case of violation of constraints. The strength of IC can be categorized as

· Weak ICs

- Soft ICs
- Hard ICs
- Adamant ICs

A weak IC only shows an irregularity and does not indicate any problem. Soft IC is stronger than weak IC however it does not rollback a transaction. Hard IC is stronger than both of weak and soft ICs and could rollback a transaction. Adamant IC is strongest of all ICs and any violation of adamant IC could harm the integrity of logic engine. An example of hard integrity constrain is given below.

(=> (hasTolerance ?x (tolerance ?q1 ?q2))

(and (Object ?x)

(Dimension ?q1)

(Dimension ?q2)

(measureLT ?q1 ?q2)))

:IC hard "The lower deviation quantity of a Tolerance must always be less than its upper deviation quantity."

The above mentioned IC will prevent any attempt to assert first quantity of tolerance which is larger than the second quantity of tolerance.