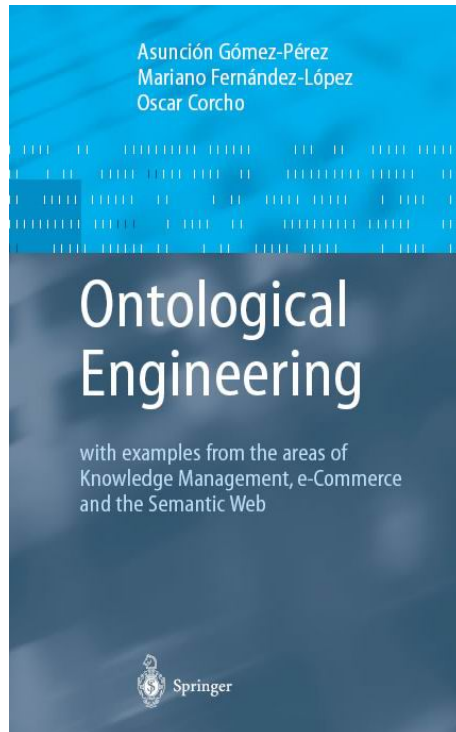# Ontological Engineering

Asunción Gómez-Pérez (asun@fi.upm.es)
Mari Carmen Suárez -Figueroa (mcsuarez@fi.upm.es)
Boris Villazón (bvilla@delicias.dia.fi.upm.es)

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References

Asunción Gómez-Pérez
Mariano Fernández-López
Oscar Corcho

Ontological Engineering

with examples from the areas of
Knowledge Management, e-Commerce
and the Semantic Web

Springer

http://www.neon-project.org/

1. NeOn Deliverables
   – D5.3.1
   – D5.3.2
   – D5.4.1
   – D5.4.2

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Index

❑ **Introduction and State of the art**

❑ Scenarios in Ontology Building

❑ Methodological Guidelines for Ontology Specification

❑ Quick Search of Existing Knowledge Resources

❑ Guidelines for Ontology development project Planning

❑ Methodological Guidelines for Non Ontological Resource Reuse and Reengineering

❑ Methodological Guideliness for Ontology Reuse

❑ Creating the final Ontology Model
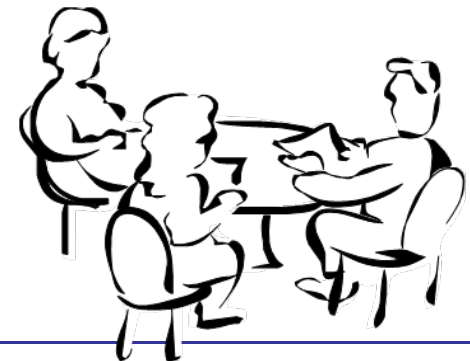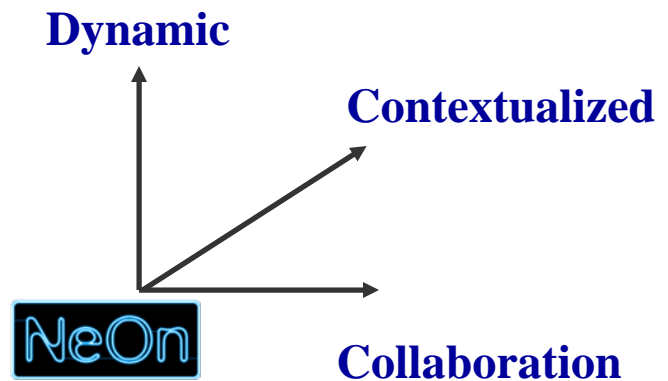
I want to build my ontology
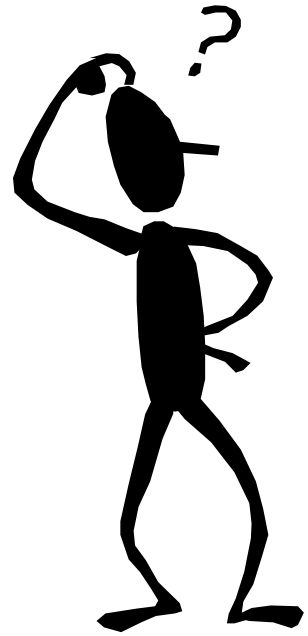
- Which are the key process and activities in ontology development?

- Which activities do I need in my development?

- When should I carry out each activity?

- Where is the relationship of one activity with the others?

- How do I collect the requirements of my ontology?

- Where can I find ontologies with the goal of reusing them?

- How can I reuse exiting knowledge resources?
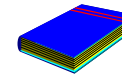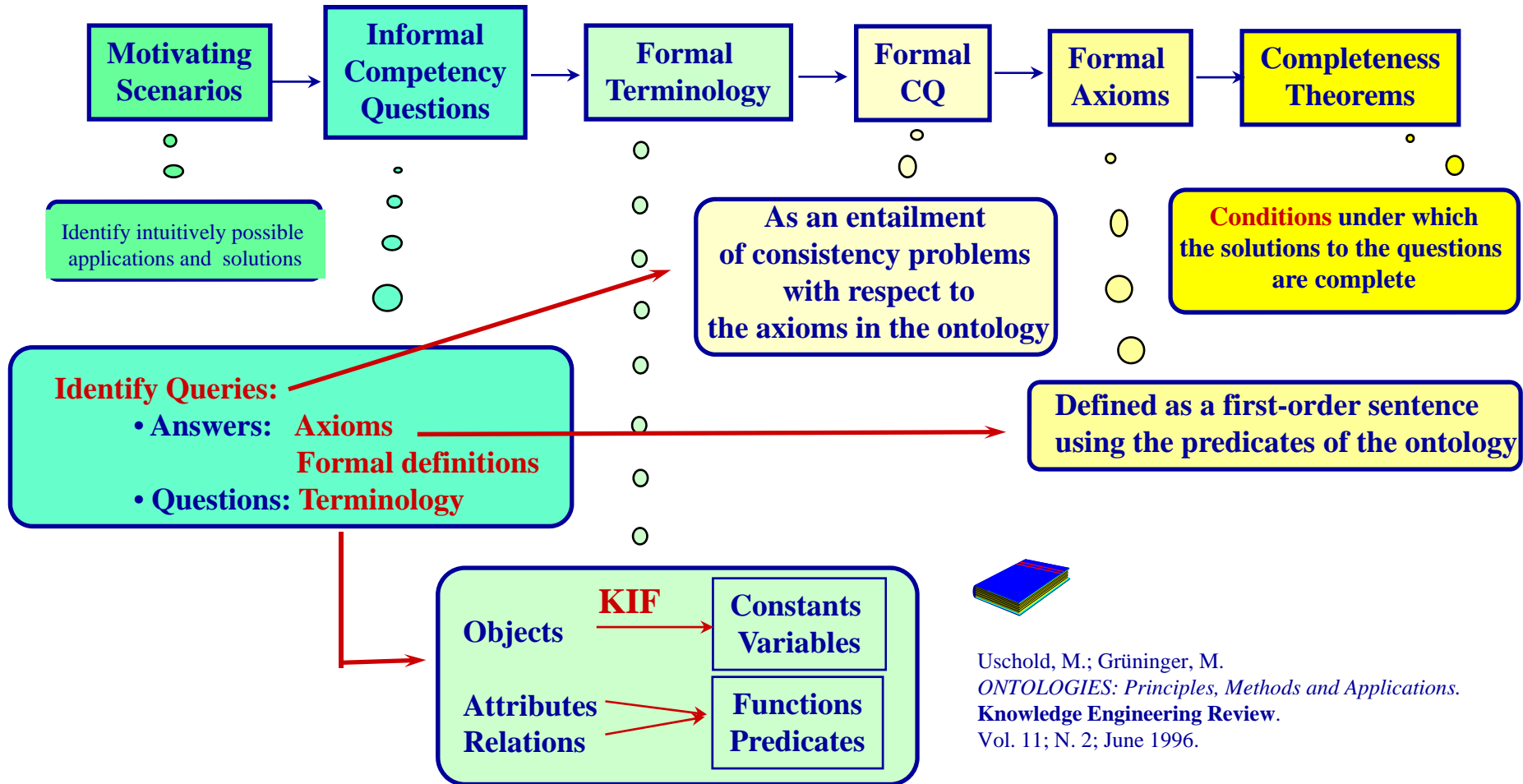
- ...

Most relevant methodologies

Methodologies for building single ontologies

- Uschold and King's method
- Grüninger and Fox's methodology
- KACTUS approach
- METHONTOLOGY
- SENSUS method
- On-To-Knowledge
- DILIGENT

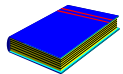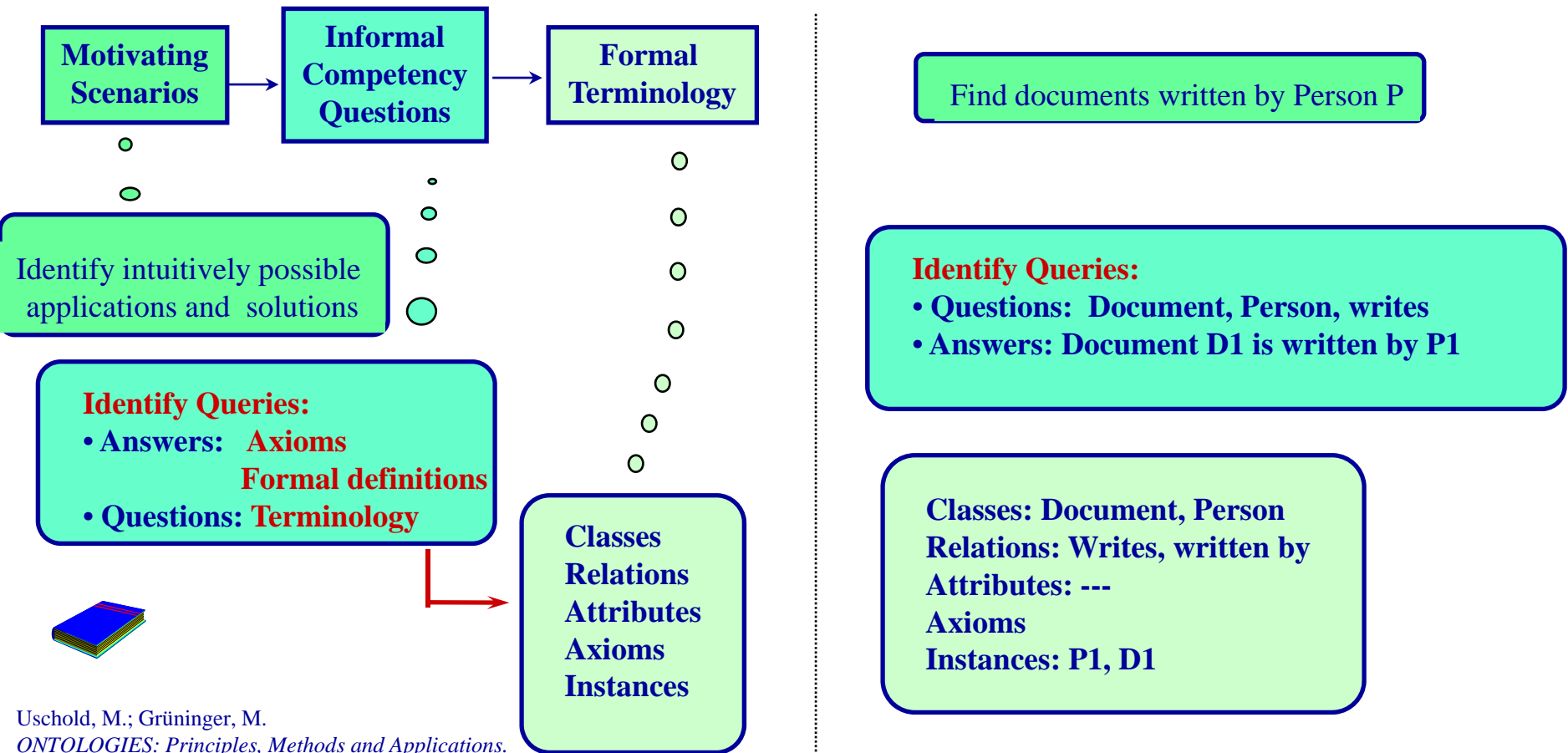NeOn methodology for building ontology networks

Dynamic

Contextualized

NeOn

Collaboration

TOVE Methodology

```
Motivating  →  Informal      →  Formal        →  Formal  →  Formal   →  Completeness
Scenarios      Competency       Terminology      CQ         Axioms      Theorems
               Questions
```

Identify intuitively possible applications and solutions

Identify Queries:
- **Answers:** **Axioms**
                Formal definitions
- **Questions:** **Terminology**

As an entailment of consistency problems with respect to the axioms in the ontology

Conditions under which the solutions to the questions are complete

Defined as a first-order sentence using the predicates of the ontology

KIF

| Objects | → | Constants Variables |

| Attributes Relations | → | Functions Predicates |

Uschold, M.; Grüninger, M.
ONTOLOGIES: Principles, Methods and Applications.
Knowledge Engineering Review.
Vol. 11; N. 2; June 1996.

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Getting terminology using Competency Questions

Motivating Scenarios → **Informal Competency Questions** → **Formal Terminology**

Find documents written by Person P

Identify intuitively possible applications and solutions

Identify Queries:
- **Answers:** Axioms
  Formal definitions
- **Questions:** Terminology

Identify Queries:
- **Questions:** Document, Person, writes
- **Answers:** Document D1 is written by P1

Classes
Relations
Attributes
Axioms
Instances

Classes: Document, Person
Relations: Writes, written by
Attributes: ---
Axioms
Instances: P1, D1

Uschold, M.; Grüninger, M.
ONTOLOGIES: Principles, Methods and Applications.
Knowledge Engineering Review.
Vol. 11; N. 2; June 1996.

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Uschold Methodology

1. Identify Purpose and Scope

2. Building the ontology

      • **Ontology Capture**

      • **Ontology Coding**

      • **Integrating existing ontologies**

- **Identify key concepts and relationships**
- **Produce unambiguous text definitions**
- **Identify terms to refer to such concepts and relations**

- **Commit to a meta-ontology**
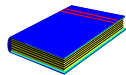- **Choose a representation language**
- **Write the code**

How and whether to reuse ontologies that already exist

3. Evaluation

4. Documentation

5. Guideliness for each phase

Uschold, M.; Grüninger, M. *ONTOLOGIES: Principles, Methods and Applications.* **Knowledge Engineering Review**. Vol. 11; N. 2; June 1996.

SENSUS as a basis for a domain-specific ontology (I)

Linking Domain Specific Terms to a broad Coverage Ontology

To identify the terms in SENSUS that are relevant to a particular domain and then prune the skeletal ontology using heuristics
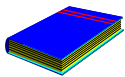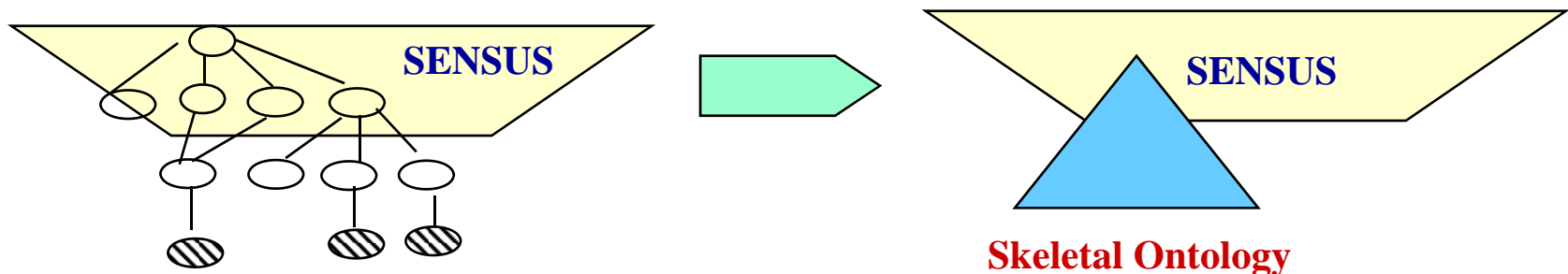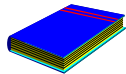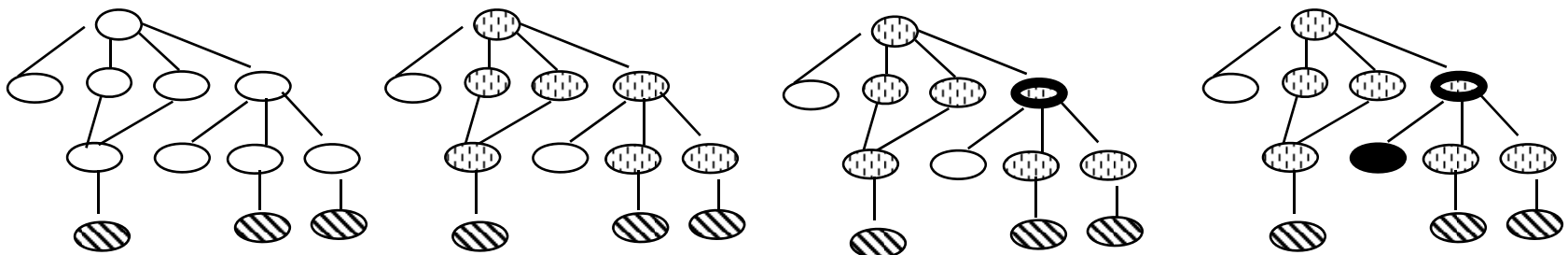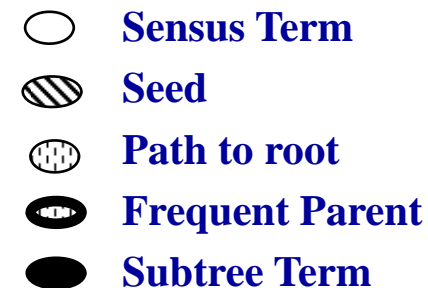

B. Swartout; R. Patil; k. Knight; T. Russ. *Toward Distributed Use of Large-Scale Ontologies* **Ontological Engineering.** AAAI-97 Spring Symposium Series. 1997. 138-148.

SENSUS as a basis for a domain-specific ontology (II)

METHOD

1. **Identify "seed" terms**

2. **Link seed terms to SENSUS by hand**

3. **Include nodes on the path to root**
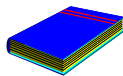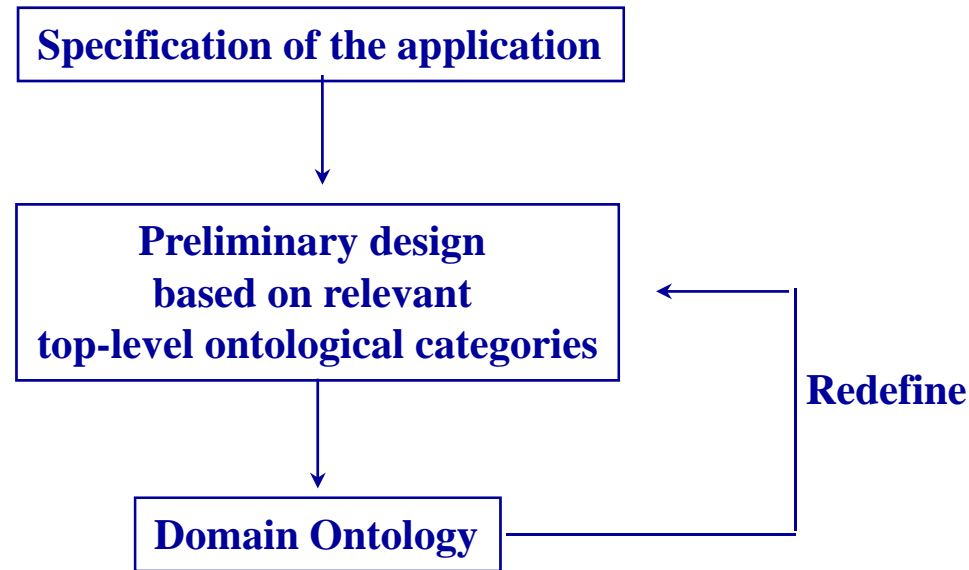
4. **Add entire subtrees using the heuristic:**

   If many nodes in a subtree are relevant,

   the other nodes in the subtree are relevant

◯	**Sensus Term**
▨	**Seed**
▨	**Path to root**
⬬	**Frequent Parent**
⬤	**Subtree Term**

B. Swartout; R. Patil; k. Knight; T. Russ. *Toward Distributed Use of Large-Scale Ontologies*
Ontological Engineering. AAAI-97 Spring Symposium Series. 1997. 138-148.
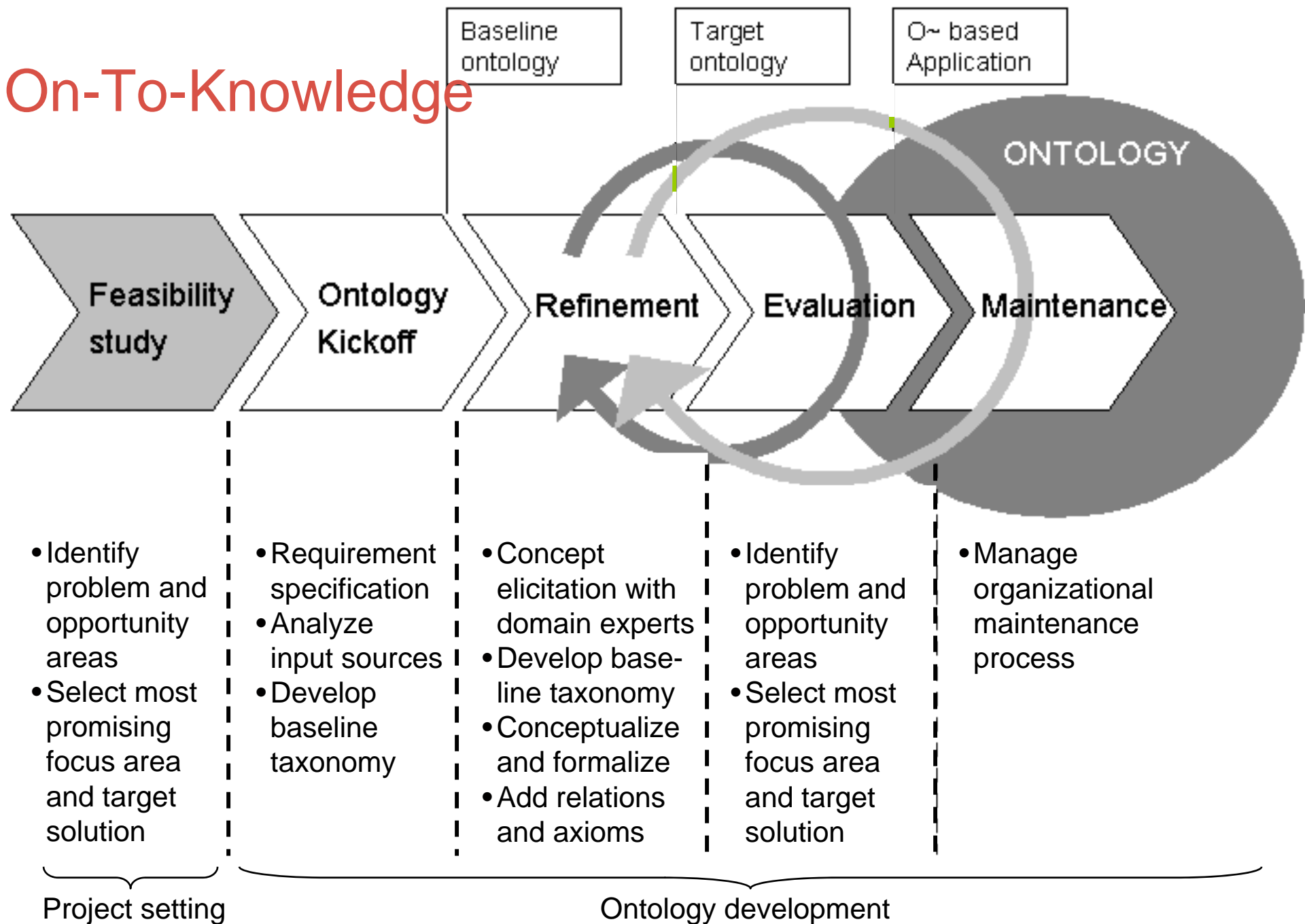
Bernara, Laresgoiti, Corera Methodology

Build a preliminary ontology for refinement and augment with new definitions

```
        ┌─────────────────────────────┐
        │ Specification of the application │
        └─────────────────────────────┘
                      │
                      ▼
        ┌─────────────────────────────┐
        │      Preliminary design      │ ◄──┐
        │      based on relevant       │    │
        │  top-level ontological categories │   Redefine
        └─────────────────────────────┘    │
                      │                     │
                      ▼                     │
        ┌─────────────────────────────┐    │
        │      Domain Ontology         │ ───┘
        └─────────────────────────────┘
```
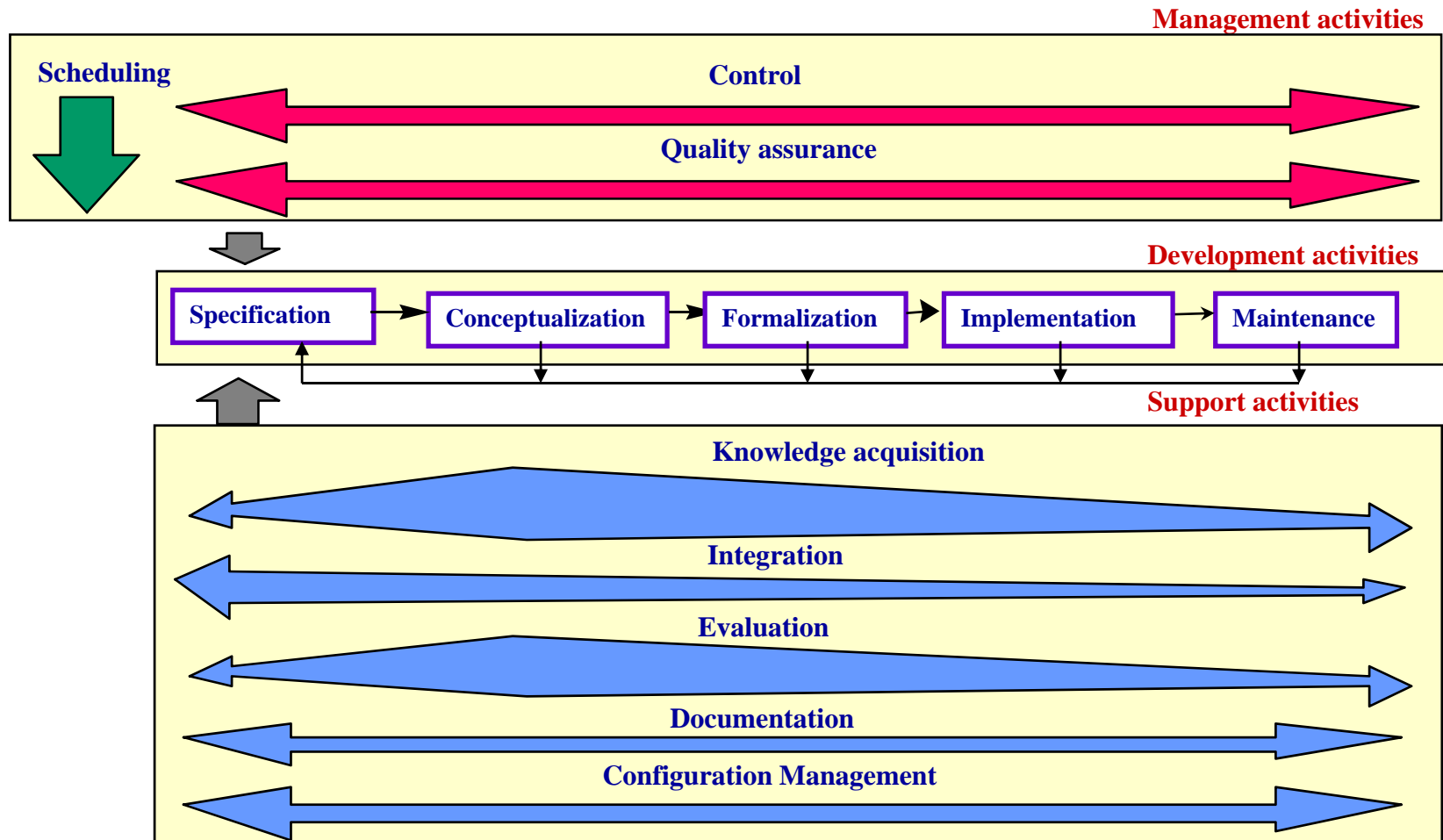
A. Bernaras; I. Laresgoiti; J. Corera. *Building and reusing ontologies for electrical network applications*
ECAI96. 12th European Conference on Artificial Intelligence. 1996. 298-302

On-To-Knowledge

|	Baseline ontology	Target ontology	O~ based Application

ONTOLOGY

Feasibility study	Ontology Kickoff	Refinement	Evaluation	Maintenance
• Identify problem and opportunity areas • Select most promising focus area and target solution	• Requirement specification • Analyze input sources • Develop baseline taxonomy	• Concept elicitation with domain experts • Develop base-line taxonomy • Conceptualize and formalize • Add relations and axioms	• Identify problem and opportunity areas • Select most promising focus area and target solution	• Manage organizational maintenance process

Project setting

Ontology development

Methontology

Limitations of current methodologies

- Methontology, On-To-Knowledge are for building ontologies from scratch
- They lack guidelines for:
    - building ontologies by reusing and reengineering existing knowledge aware resources
    - for contextualizing an existing ontology and plugging it in with existing ontologies that might be in continuous evolution
    - Building ontologies in a collaborative way
    - software developers that need to include ontologies into their IT developments

NeOn Ontology Development Paradigm

Whose emphasis is on

❑ the *reuse and reengineering of knowledge aware resources*

❑ the *collaborative and argumentative ontology development*

❑ the *building of ontology networks*, as opposed to custom-building new ontologies from scratch.
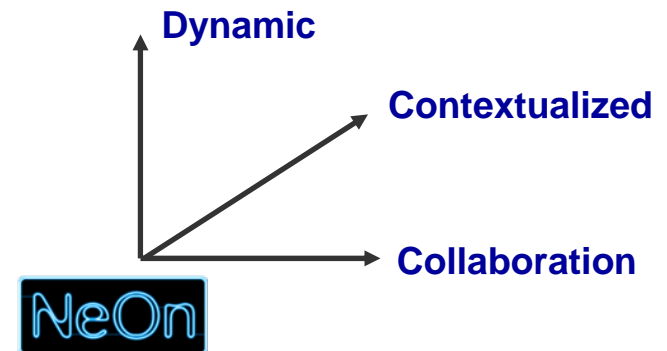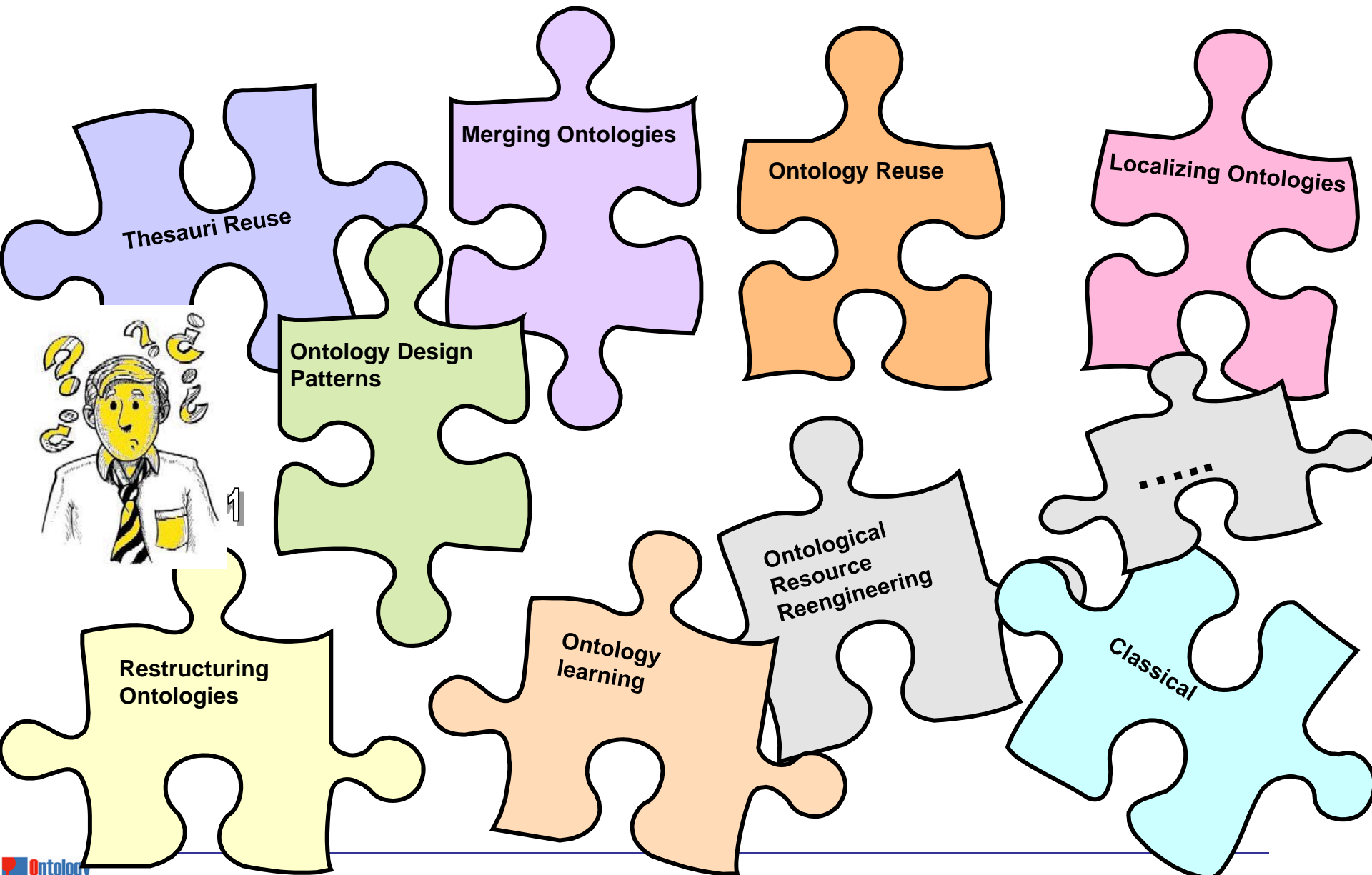
Ontology Networks

The Semantic Web of the future will be characterized by using a very large number of **ontologies embedded in ontology networks** built by distributed teams in a collaborative way.
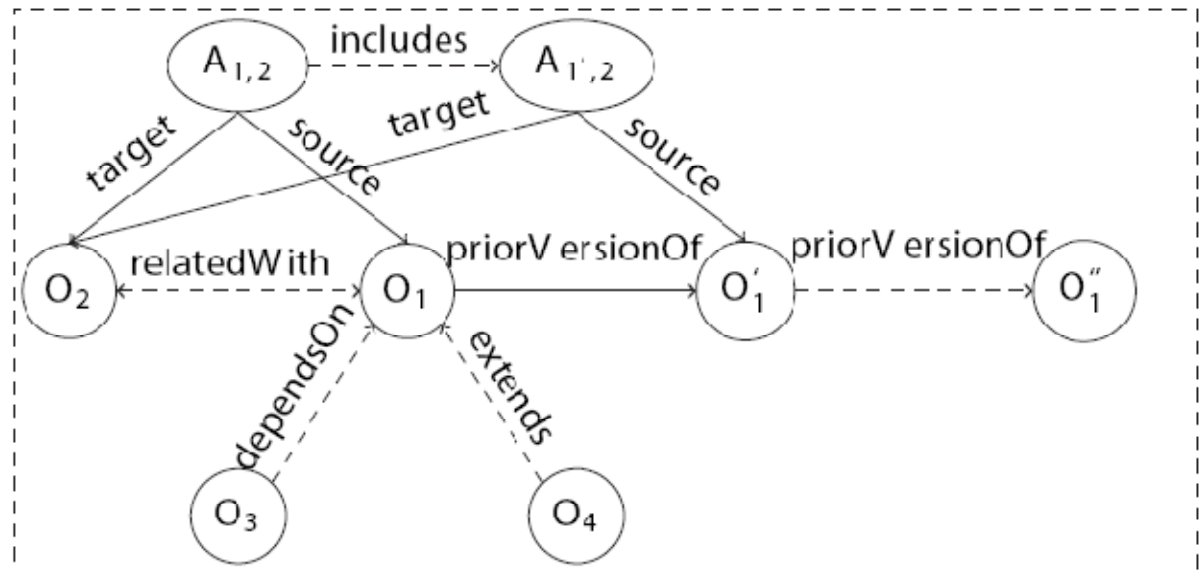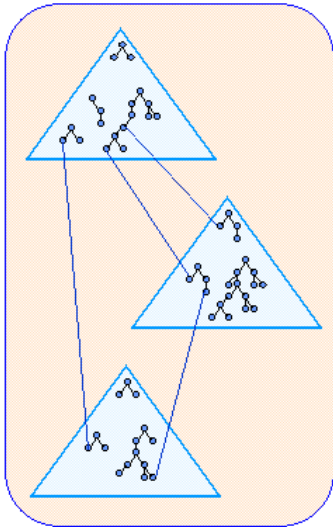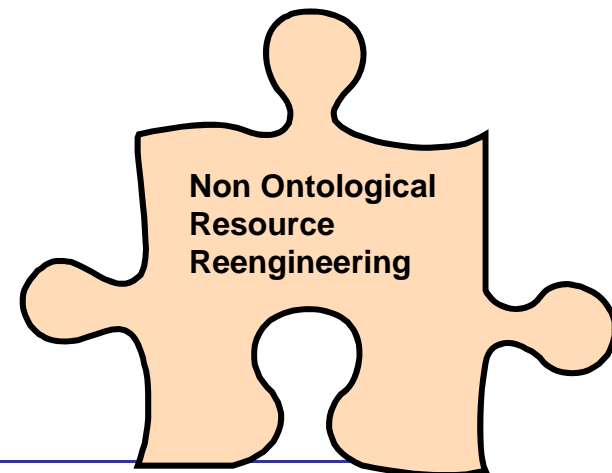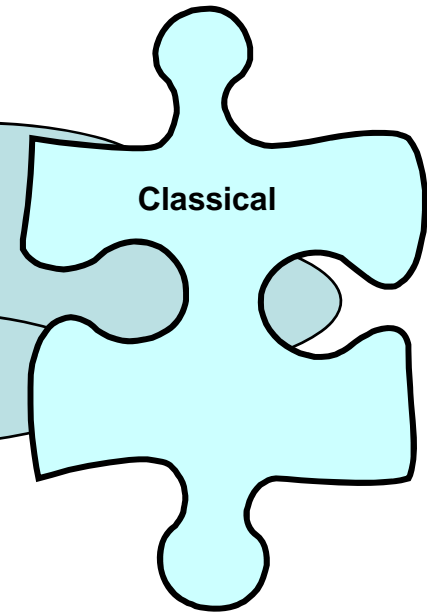
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- **NeOn Scenarios in Ontology Building**

- Methodological Guidelines for Ontology Specification

- Quick Search of Existing Knowledge Resources

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- Methodological Guidelines for Non Ontological Resource Reuse and Reengineering

- Methodological Guideliness for Ontology Reuse

- Creating the Ontology Model

Too many activities…

Thesauri Reuse

Merging Ontologies

Ontology Reuse

Localizing Ontologies

Ontology Design Patterns

Restructuring Ontologies

Ontology learning

Ontological Resource Reengineering

Classical

. . . . .

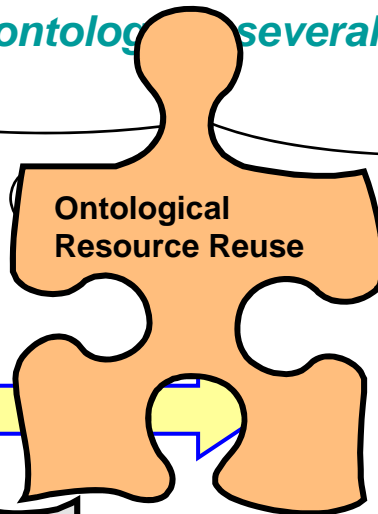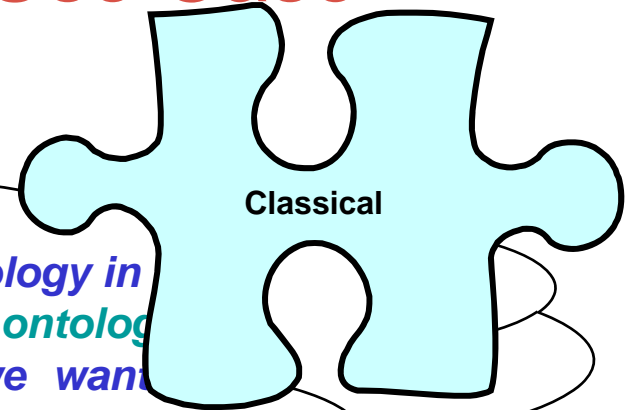Ontology Engineer ingGroup

Building Ontologies: Use Case

In our team, we want to build an OWL ontology in the pharmaceutical domain, but we want to use several pharmaceutical standards in XML and classification schemes in our own format.

Classical

Non Ontological Resource Reuse

Non Ontological Resource Reengineering

Key asssets in the NeOn methodology

- The NeOn Glossary of activities
- Table of Recommended and If-Applicable" Activities
- The NeOn scenarios
- All processes and activities are described with:
  - A filling card
  - A workflow
  - Examples

The NeOn Glossary of Activities

- The *NeOn Glossary of Activities* identifies and defines 55 activities that are carried out when ontology networks are collaboratively built

- Published in the NeOn website

- Consensuated by *all NeOn* partners

- On-going procedure for getting feed-back from the community

NeOn Glossary of Activities

- **Ontology Alignment / Aligning**
- **Ontology Articulation**
- **Ontology Assessment**
- **Ontology Combining**
- **Ontology Conceptualization**
- **Ontology Configuration Management**
- **Ontology Coordination**
- **Ontology Diagnosis**
- **Ontology Documentation**
- **Ontology Elicitation**
- **Ontology Enrichment**
- **Ontology Evaluation**
- **Ontology Evolution**
- **Ontology Extension**
- **Ontology Formalization**
- **Ontology Implementation**
- **Ontology Integration**
- **Knowledge Acquisition for Ontologies**
- **Ontology Learning**
- **Ontology Localization**
- **Ontology Mapping**
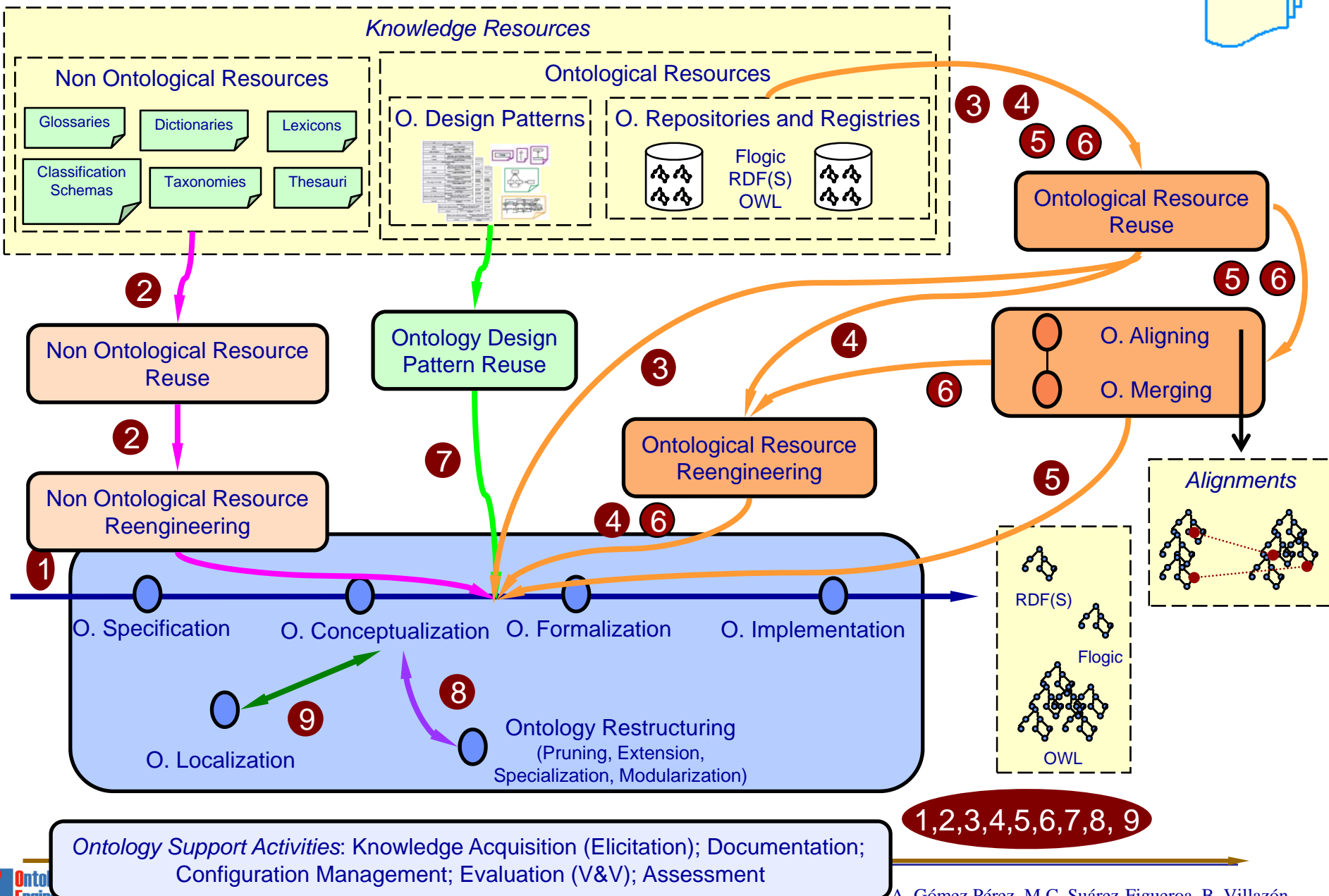- **Ontology Matching**
- **Ontology Mediation**

http://www.neon-project.org/

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"Recommended and If-Applicable" Activities

- For each activity included in the NeOn Glossary of Activities, the table identifies which activities are required and which activities are optional (can be carried out or not, depending on the case)during the ontology network building process.

	Required	If Applicable
Ontology Conceptualization	X	
Ontology Evaluation	X	
Ontology Integration	X	
Knowledge Acquisition for Ontologies	X	
Ontology Learning		X
Ontology Localization		X
Ontology Matching		X
Ontology Search	X	
Ontology Specification	X	

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NeOn Scenarios

D5.3.1

Knowledge Resources

Non Ontological Resources
- Glossaries
- Dictionaries
- Lexicons
- Classification Schemas
- Taxonomies
- Thesauri

Ontological Resources

O. Design Patterns

O. Repositories and Registries
- Flogic
- RDF(S)
- OWL

3 **4** **5** **6**

Ontological Resource Reuse

5 **6**

Non Ontological Resource Reuse

2

Ontology Design Pattern Reuse

O. Aligning

O. Merging

6

2

Non Ontological Resource Reengineering

7

Ontological Resource Reengineering

3

4 **6**

5

Alignments

1

O. Specification — O. Conceptualization — O. Formalization — O. Implementation

RDF(S)

Flogic

OWL

9

O. Localization

8

Ontology Restructuring
(Pruning, Extension, Specialization, Modularization)

Ontology Support Activities: Knowledge Acquisition (Elicitation); Documentation; Configuration Management; Evaluation (V&V); Assessment

1,2,3,4,5,6,7,8, 9

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Scenarios

1. Building ontology networks from scratch without reusing existing resources.
2. Building ontology networks by reusing and reengineering non ontological resources.
3. Building ontology networks by reusing ontologies or ontology modules.
4. Building ontology networks by reusing and reengineering ontologies or ontology modules.
5. Building ontology networks by reusing and merging ontology or ontology modules.
6. Building ontology networks by reusing, merging and reengineering ontologies or ontology modules.
7. Building ontology networks by reusing ontology design patterns.
8. Building ontology networks by restructuring ontologies or ontology modules.
9. Building ontology networks by localizing ontologies or ontology modules.

NeOn Methodology

Process and activities covered:

- ❑ Ontology Specification
- ❑ Scheduling
- ❑ Non Ontological Resource Reuse
- ❑ Non Ontological Resource Reengineering
- ❑ Reuse General Ontologies
- ❑ Reuse Domain Ontologies
- ❑ Reuse Ontology Statements
- ❑ Reuse Ontology Design Patterns

All processes and activities are described with:

- ❑ A filling card
- ❑ A workflow
- ❑ Examples

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❑ Introduction

❑ Scenarios in Ontology Building

❑ **Methodological Guidelines for Ontology Specification**

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❑ Methodological Guideliness for Ontology Reuse

❑ Creating the final Ontology Model

Ontology Specification

Definition

Ontology Specification refers to the activity of collecting the requirements that the ontology should fulfill, e.g. reasons to build the ontology, target group, intended uses, possibly reached through a consensus process.

Goal

The specification activity states why the ontology is being built, what its intended uses are, who the end-users are, and what the requirements the ontology should fulfill are.

Input

A set of ontological needs.

Output

Ontology Requirements Specification Document (ORSD).

Who

Software developers and ontology practitioners, who form the ontology development team (ODT), in collaboration with users and domain experts.

When

This activity must be carried out in parallel with the knowledge acquisition activity.

Competency Questions (CQs) are questions that the ontology to be built should be able to answer.

- ❑ CQs in natural language
- ❑ CQs in SPARQL
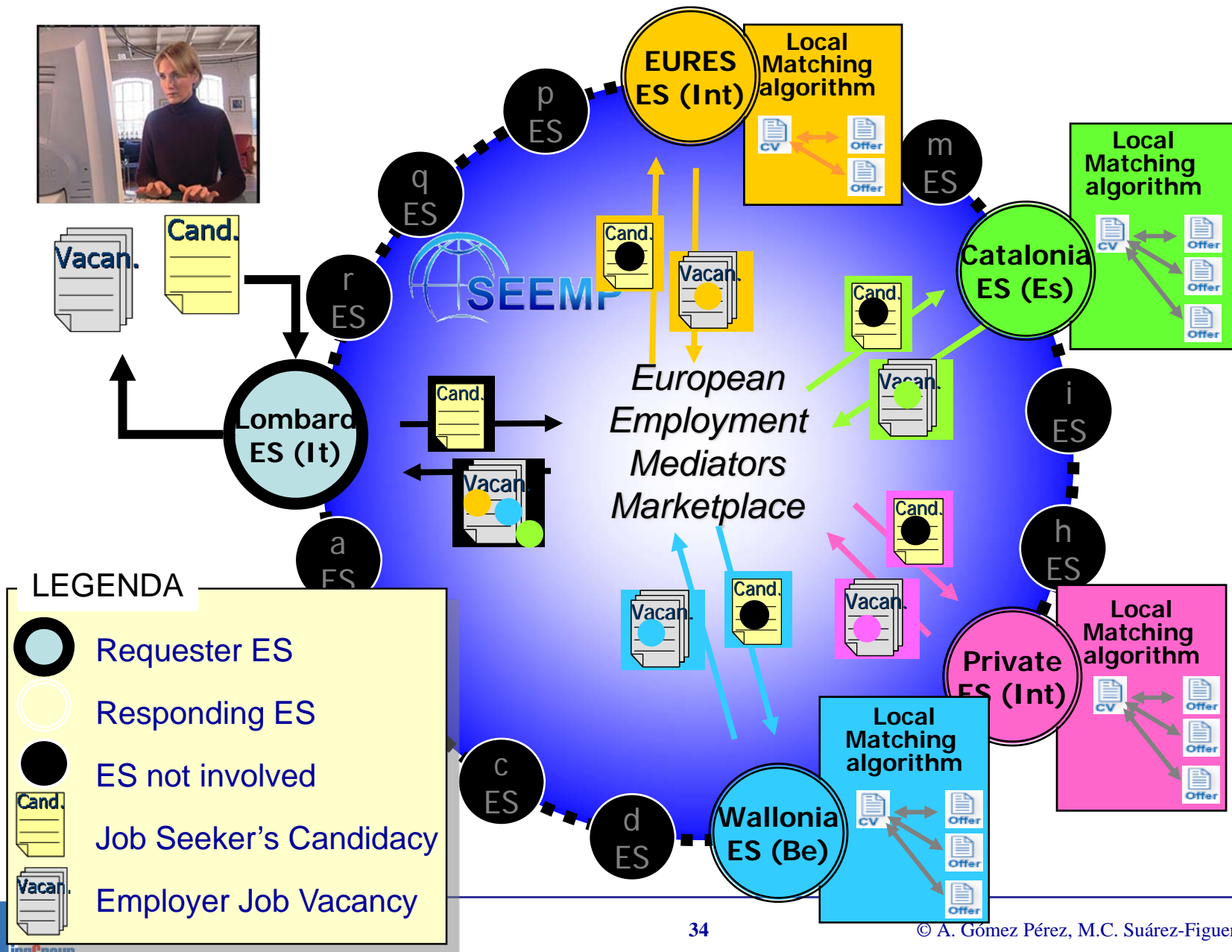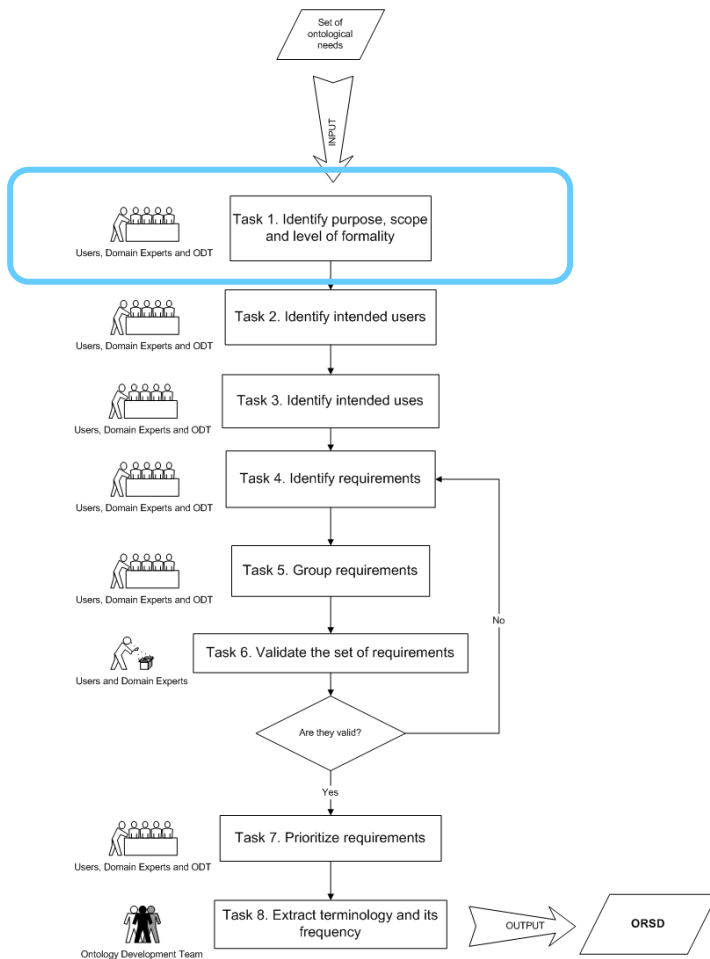
Ontology Requirements Specification Document Template	
1	**Purpose**
	"Software developers and ontology practitioners should include in this slot the purpose of the ontology"
2	**Scope**
	"Software developers and ontology practitioners should include in this slot the scope of the ontology"
3	**Level of Formality**
	"Software developers and ontology practitioners should include in this slot the level of formality of the ontology"
4	**Intended Users**
	"Software developers and ontology practitioners should include in this slot the intended users of the ontology"
5	**Intended Uses**
	"Software developers and ontology practitioners should include in this slot the intended uses of the ontology"
6	**Groups of Competency Questions**
	"Software developers and ontology practitioners should include in this slot the groups of competency questions and their answers, including priorities for each group"
7	**Pre-Glossary of Terms**
	Terms
	"Software developers and ontology practitioners should include in this slot the list of terms included in the CQs and their frequencies"
	Objects
	"Software developers and ontology practitioners should include in this slot a list of objects and their frequencies"

Ontology Specification. Sequence of Tasks

Gómez Pérez, M.C. Suárez-Figueroa, B. Villazón
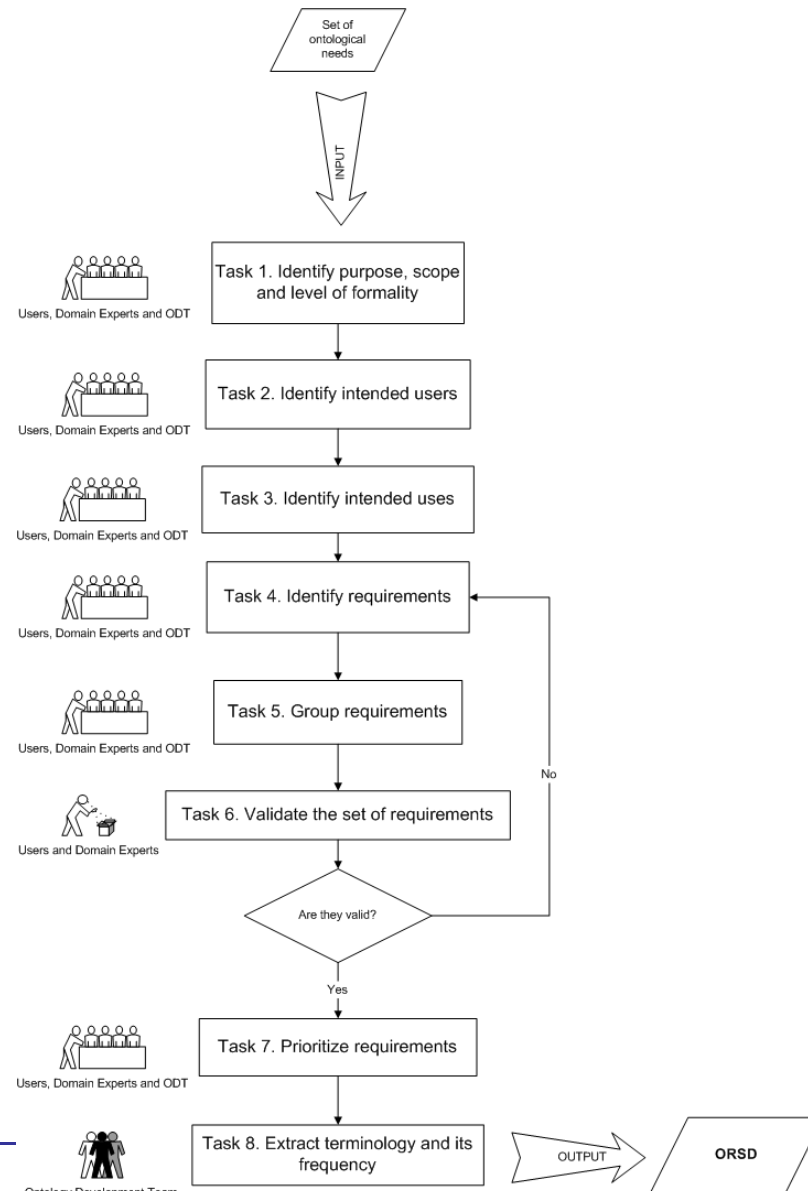
Helping Job Seekers on their way

© A. Gómez Pérez, M.C. Suárez-Figueroa, B. Villazón

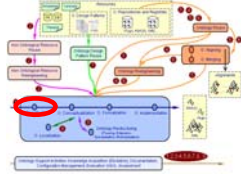# Ontology Specification: Purpose

- ❑ *Input*: a set of ontological needs

- ❑ *Objective*: obtaining the **purpose, scope and level of formality of the ontology**

- ❑ *Techniques*: physical or virtual interviewers

- ❑ *Output*: purpose, scope and level of formality of the ontology, which will be included in the corresponding slots of the OSRD template

1	Purpose
	The purpose of building the Reference Ontology is to provide a consensual knowledge model of the employment domain that could be used by public e-Employment services (PES).
2	Scope
	The ontology has to focus just on the ICT (Information and Communication Technology) domain. The level of granularity is directly related to the competency questions and terms identified.
3	Level of Formality
	The ontology has to be implemented in WSML language

Ontology Specification: Users
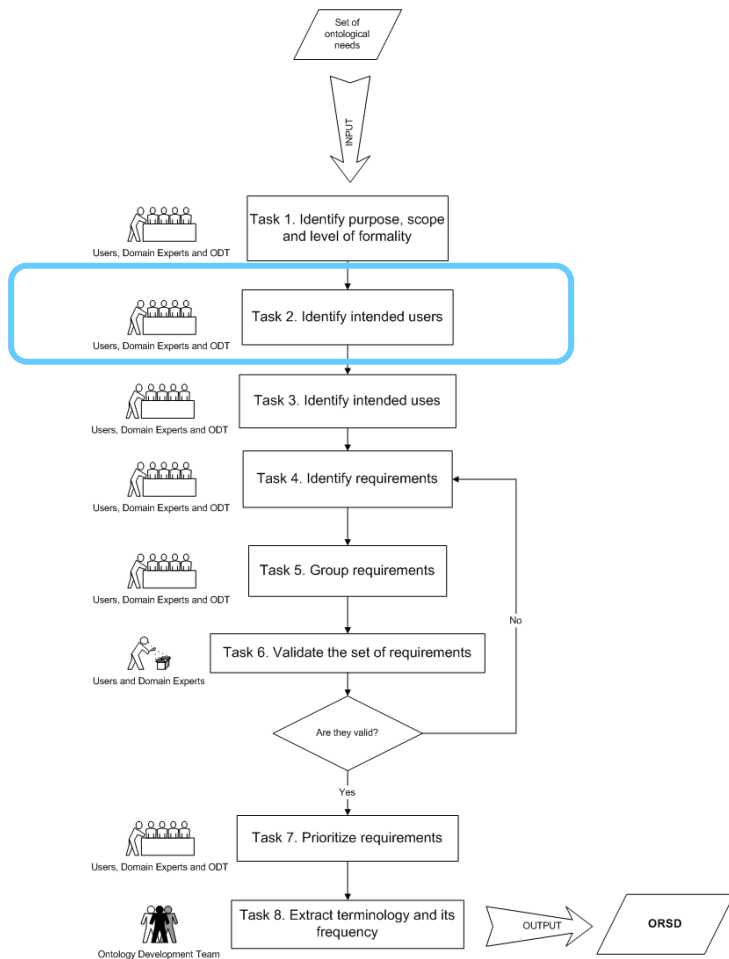
- ❑ *Input*: a set of ontological needs
- ❑ *Objective*: identifying the **intended users**
- ❑ *Techniques*: physical or virtual interviewers
- ❑ *Output*: a list with the intended users, which will be included in the corresponding slot of the OSRD template

4	Intended Users
	1. Candidate who is unemployed and searching for a job or searching another occupation for immediate or future purposes 2. Employer who needs more human resources. 3. Public or private employment search service which offers services to gather CVs or job postings and to prepare some data and statistics. 4. National and Local Governments which want to analyze the situation on the employment market in their countries and prepare documents on employment, social and educational policy. 5. European Commission and the governments of EU countries which want to analyze the statistics and prepare international agreements and documents on the employment, social and educational policy.

Ontology Specification: Uses
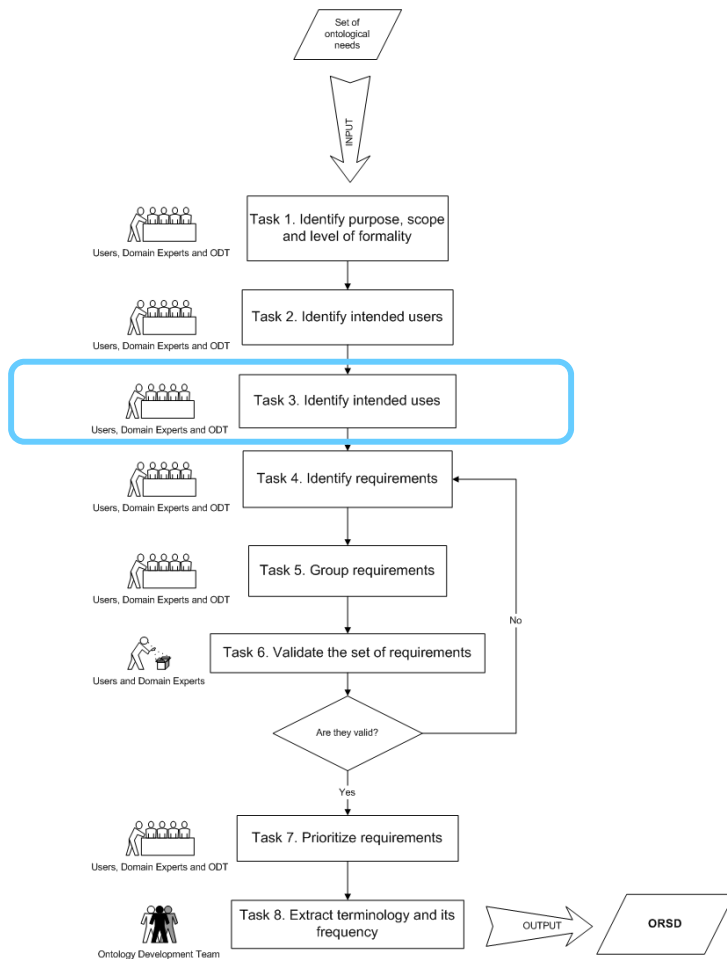
- ❑ *Input*: a set of ontological needs
- ❑ *Objective*: identifying the **intended uses**
- ❑ *Techniques*: physical or virtual interviewers between them
- ❑ *Output*: a list of intended uses in the form of scenarios. The scenarios can be described in natural language or expressed in UML as use cases. The list of scenarios will be included in the corresponding slot of the OSRD template.

5	Intended Uses
	1. Publish CV. Job seeker places his/her CV on the PES Portal. 2. Publish Job Offer. An Employer places a Job Offer on the PES Portal. 3. Search for Job Offers. The Employer looks for candidates for the Job Offer through PES Portal. 4. Search for Employment information. Job Seeker looks for of general information about employment in a given location at the PES Portal. 5. Provide Job Statistics. The PES Portal provides employment statistics to the Job Seeker and Employer.
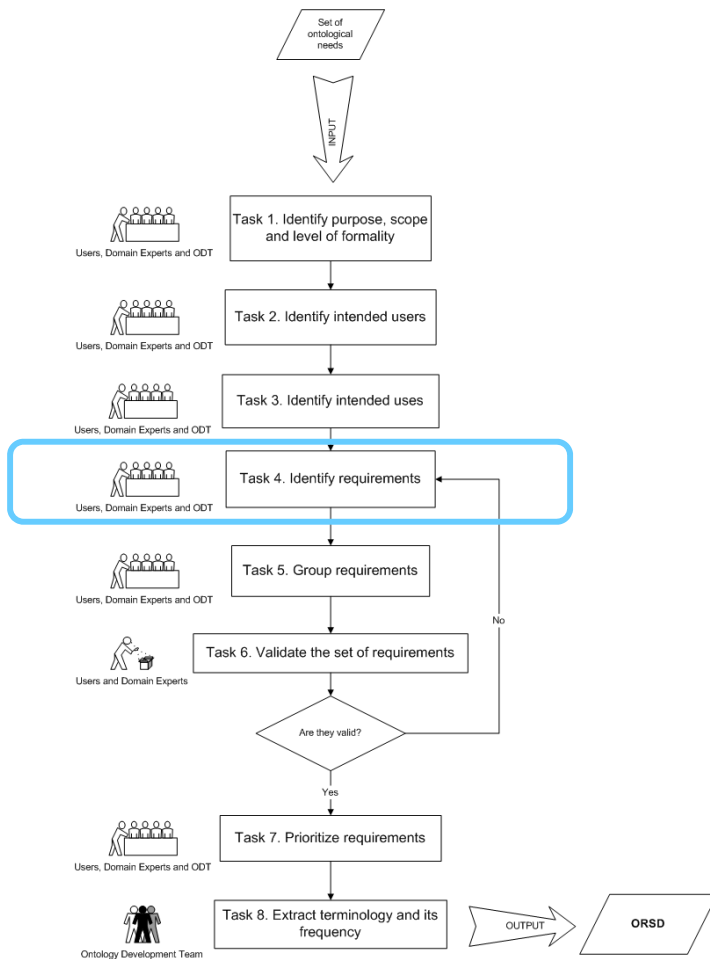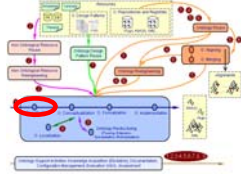
- ❑ *Input*: a set of ontological needs

- ❑ *Objective*: identifying the **ontology requirements**

- ❑ *Techniques*: writing the requirements in natural language in the form of the so-called competency questions (CQs)

- ❑ *Tools*: mind map tools, excel, and collaborative tools (e.g., Cicero)

- ❑ *Output*: a list of competency questions written in Natural Language and a set of answers for the CQs

- ❑ *Approaches*:

  - ▪ Top-Down: Complex questions are decomposed in simple ones.

  - ▪ Bottom-Up: Simple questions that are organised to form complex ones.

  - ▪ Middle out: Mix approach between top-down and bottom-up.

An example of Competency Questions

Find all the job offers demanding researchers working on semantic web projects

Each project has a property storing its type

- Taxonomy of Topics
- There exist a relation that connects projects and topics

Identify Queries:
Questions: Job offers, Researcher, Project,
            demand, type-of-Project
Answers: Job1, Job2, ...

Identify Queries:
Questions: Job offers, Researcher, Project,
            demand, type-of-Project
            Semantic Web Topics, main-topics
Answers: Job1, Job2, ...

Classes: Job Offer, Researcher, Person,
            Project,
Relations: demand, demanded-by
Attributes: Type of Project
Axioms: For all...
Instances: Job1, Job2, ...

Classes: Job Offer, Researcher, Person, Project,
            Topics, Ontologies, mark-up languages,
            semantic web services, annotations, ...
Relations: demand, main-topics, topic-of
Attributes: ---
Axioms: For all ....
Instances:job 1, job2, ...

Ontology Engineer ingGroup

Task 4. Identify requirements. SEEMP Example

SEEMP Reference Ontology Competency Questions

CQ1. What is the Job Seeker Name?

CQ2. What is the Job Seeker nationality?

CQ3. When is the Job Seeker birthdate?

CQ4. What is the Job Seeker contact information?

CQ5. What is the Job Seeker current job?

CQ6. What is the Job Seeker desired job?

CQ7. What are the Job Seeker desired working conditions?

CQ8. What kind of contract does the Job Seeker want?

CQ9. How much salary does the Job Seeker want to earn?

CQ10. What is the Job Seeker education level?

CQ11. What is the Job Seeker work experience?

CQ12. What is the Job Seeker knowledge?

CQ13. What is the Job Seeker expertise?

CQ14. What are the Job Seeker skills?

CQ15. What publications does the Job Seeker have?

CQ16. What hobbies does the Job Seeker have?

CQ17. What is the employer information?

CQ18. What kind of job does the employer offer?

CQ19. What kind of contract does the employer offer?

CQ20. How much salary does the employer offer?

CQ21. What is the economic activity of the employer?

CQ22. What is the description of the job offer?

CQ23. What is the work condition of the job offer?

CQ24. What is the required education level for the job offer?

CQ25. What is the required work experience for the job offer?

CQ26. What is the required knowledge for the job offer?

CQ27. What are the required skills for the job offer?

CQ28. When the Job Seeker completed his/her first degree?

CQ29. Is the Job Seeker older than 30 years?

CQ30. How much time did the Job Seeker spend completing his/her first degree?

CQ31. How long is the duration of the contract?

CQ32. Which job offers were posted in the last 24 hours?

CQ33. Which job offers were posted in the last 7 days?

CQ34. Which job offers were posted in the last month?

CQ35. Is the job offer's salary greater than 14000 zlotes?

CQ36. Is the job offer's salary lower than 25000 kroner?

CQ37. The offered salary is given in US dollars?

CQ38. The offered salary is given in Euros?

CQ39. Given the personal information (name, nationality, birth date, contact information) and the objectives (desired contract type, desired job, desired working conditions, desired salary) of the job seeker, what job offers are the most appropriate?

CQ40. Given the personal information (name, nationality, birth date, contact information) and the profile (current job, education level, work experience, knowledge, expertise, skill) of the job seeker what job offers are the most appropriate?

CQ41. Given the objectives (desired contract type, desired job, desired working conditions, desired salary) and the profile (current job, education level, work experience, knowledge, expertise, skills) of the job seeker, what job offers are the most appropriate?

CQ42. Given the personal information (name, nationality, birth date, contact information), the profile (current job, education level, work experience, knowledge, expertise, skill) and the objectives (desired contract type, desired job, desired working conditions, desired salary) of the job seeker, what job offers are the most appropriate?

CQ43. Given the employer information, economic activity of the employer and the job offer profile (job, contract type, salary, work condition), what job seekers are the most appropriate?

CQ44. Given the employer information, economic activity of the employer and the required profile to seek (required education level, required work experience, required knowledge, required skills), what job seekers are the most appropriate?

CQ45. Given the job offer profile (job, contract type, salary, work condition) and the required profile to seek (required education level, required work experience, required knowledge, required skills), what job seekers are the most appropriate?

CQ46. Given the employer information, economic activity of the employer, job offer profile (job, contract type, salary, work condition) and the required profile to seek (required education level, required work experience, required knowledge, required skills), what job seekers are the most appropriate?

CQ47. When the job seeker completed his/her first degree and how much time did he/she spend completing his/her first degree?

CQ48. When the job seeker completed his/her first degree and is he/she older than 30 years?

CQ49. Is the job seeker older than 30 years and how much time did he/she spend completing his/her first degree?

CQ50. Which job offers were posted in last 24 hours and how long is the duration of their contracts?

CQ51. Which job offers were posted in last 7 days and how long is the duration of their contracts?

CQ52. Which job offers were posted in last month and how long is the duration of their contracts?

CQ53. Is the job offer's salary greater than 14000 zlotes and could it be given in US dollars?

CQ54. Is the job offer's salary lower than 25000 kroner and could it be given in Euros?

CQ55. Given the age (30 years old) and the desired salary (equal or greater than 14000 €) of the job seeker, what job offers are the most appropriate?

CQ56. Given the employer information, economic activity of the employer and the job offer profile (job, contract type, salary, work condition, contract duration), what job seekers are the most appropriate?

CQ57. Given the age (20 years old) and the desired salary (equal or greater than 14000 zlotes) of the job seeker, what job offers posted in last month are the most appropriate?

CQ58. Given the employer information, economic activity of the employer and the job offer profile (job, contract type, salary of 3400 €, work condition, contract duration), what job seekers are the most appropriate?

CQ59. Given the time spend for his/her degree (8 years) and the desired salary (equal or greater than 14000 €) of the job seeker, what job offers posted in last 7 days are the most appropriate?

CQ60. Given the time spend for his/her degree (8 years) and the desired salary (equal or greater than 14000 €) of the job seeker, what job offers posted in last 24 hours are the most appropriate?

N	Competency Questions	Answers
CQ1	What is the Job Seeker Name?	Lewis Hamilton
CQ2	What is the Job Seeker nationality?	British; Spanish; Italian; French; German
CQ3	When is the Job Seeker birthdate?	13/09/1984; 30/03/1970; 15/04/1978
CQ4	What is the Job Seeker contact information?	
CQ5	What is the Job Seeker current job?	Programmer; Computer Engineer; Computer Assistant
CQ6	What is the Job Seeker desired job?	Radio engineer; Hardware designer; Software Engineer
CQ7	What are the Job Seeker desired working conditions?	Autonomous; Seasonal Job; Traineeship;Consultant
CQ8	What kind of contract does the Job Seeker want?	
CQ9	How much salary does the Job Seeker want to earn?	
CQ10	What is the Job Seeker education level?	Basic education; Higher education/University
CQ11	What is the Job Seeker work experience?	3 months, 6 months, 1 year, 2, years, 3 years
CQ12	What is the Job Seeker knowledge?	
CQ13	What is the Job Seeker expertise?	
CQ14	What are the Job Seeker skills?	SQL programming, network administration
CQ15	What publications does the Job Seeker have?	
CQ16	What hobbies does the Job Seeker have?	
CQ17	What is the employer information?	CEFRIEL Research Company, Milano, Italy
CQ18	What kind of job does the employer offer?	Java Programmer; C Programmer, Database administration
CQ19	What kind of contract does the employer offer?	
CQ20	How much salary does the employer offer?	3500 euros, 3000 USD, 2000 euros
CQ21	What is the economic activity of the employer?	Research; Financial; Education; Industrial
CQ22	What is the description of the job offer?	Sun Certified Java Programmer
CQ23	What is the work condition of the job offer?	Full time; Partial time; Autonomous; Seasonal Job;
CQ24	What is the required education level for the job offer?	Basic education; Higher education/University
CQ25	What is the required work experience for the job offer?	1 year, 2 years, 3 years, 4 yerars, 5 or more years
CQ26	What is the required knowledge for the job offer?	Java, Object oriented design, Haskell, Windows
CQ27	What are the required skills for the job offer?	ASP Programmer, Data warehouse, Hardware programming
CQ28	When the Job Seeker completed his/her first degree?	2001; March 1999; 23/10/1970
CQ29	Is the Job Seeker older than 30 years?	
CQ30	How much time did the Job Seeker spend completing his/her first degree?	4 years, 6 years, 7 years and 6 months
CQ31	How long is the duration of the contract?	1 month, 6 months, 1 year, 2 years, 3 years
CQ32	Which job offers were posted in the last 24 hours?	
CQ33	Which job offers were posted in the last 7 days?	
CQ34	Which job offers were posted in the last month?	

Competency Questions
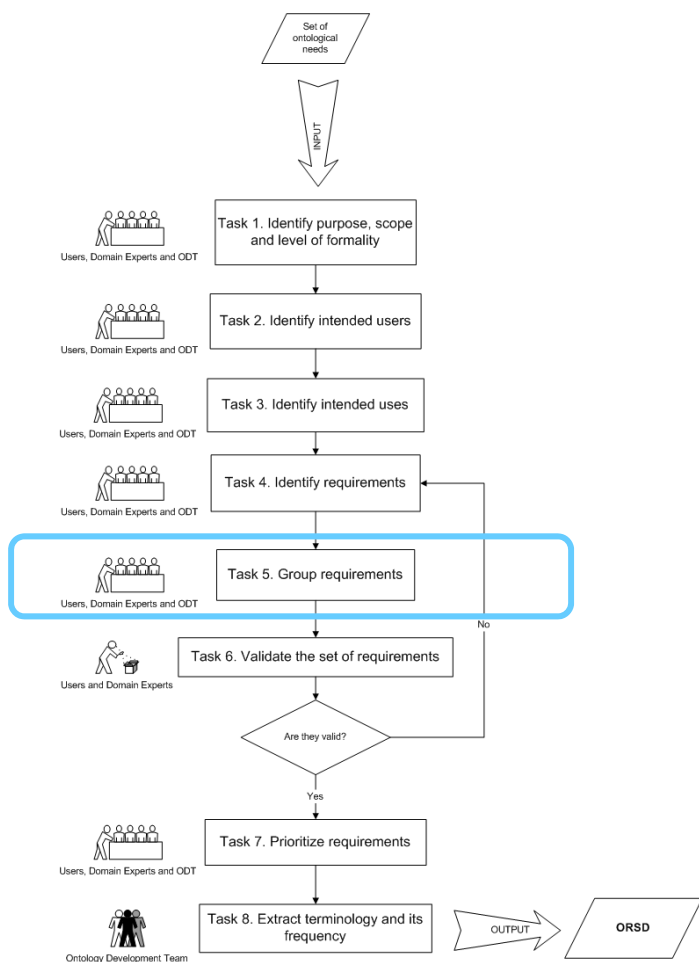
❑ *Input*: the list of CQs

❑ *Objective*: obtaining different **groups of CQs**

❑ *Techniques*: Card Sorting, when the grouping is done manually, and Clustering NL sentences or Information Extraction when the grouping is done automatically

❑ *Tools*: MindMap Tools or Cicero Tool (for distributed teams)

❑ *Output*: a set of groups including CQs

❑ *Hybrid approach*:

- The analysis of the frequency of terms and the grouping of CQs based on those terms that have a higher frequency.

- The use of pre-established categories, such as time and date, units of measure, currencies, location, languages, etc.

Job Offer (10 CQ)

General (24 CQ)

SEEMP Reference Ontology Competency Questions

Job Seeker (16 CQ)

Time and date (6 CQ)

Currencies (4 CQ)

CQ17.What is the employer information?

CQ18. What kind of job does the employer offer?

CQ19. What kind of contract does the employer offer?

CQ20.How much salary does the employer offer?

CQ21.What is the economic activity of the employer?

CQ22.What is the description of the job offer?

Job Offer

CQ23. What is the work condition of the job offer?

CQ24. What is the required education level for the job offer?

CQ25.What is the required work experience for the job offer?

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CQ44. Given the employer information, economic activity of the employer and the required profile to seek (required education level, required work experience, required knowledge, required skills), what job seekers are the most appropriate?

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CQ47. When the job seeker completed his/her first degree and how much time did he/she spend completing his/her first degree?

General

CQ48.When the job seeker completed his/her first degree and is he/she older than 30 years?

CQ49. Is the job seeker older than 30 years and how much time did he/she spend completing his/her first degree?

CQ50.Which job offers were posted in last 24 hours and how long is the duration of their contracts?

CQ51.Which job offers were posted in last 7 days and how long is the duration of their contracts?

CQ52.Which job offers were posted in last month and how long is the duration of their contracts?

CQ53.Is the job offer's salary greater than 14000 zlotes and could it be given in US dollars?

CQ54.Is the job offer's salary lower than 25000 kroner and could it be given in Euros?

CQ55. Given the age (30 years old) and the desired salary (equal or greater than 14000 €) of the job seeker, what job offers are the most appropriate?

CQ56. Given the employer information, economic activity of the employer and the job offer profile (job, contract type, salary, work condition, contract duration), what job seekers are the most appropriate?
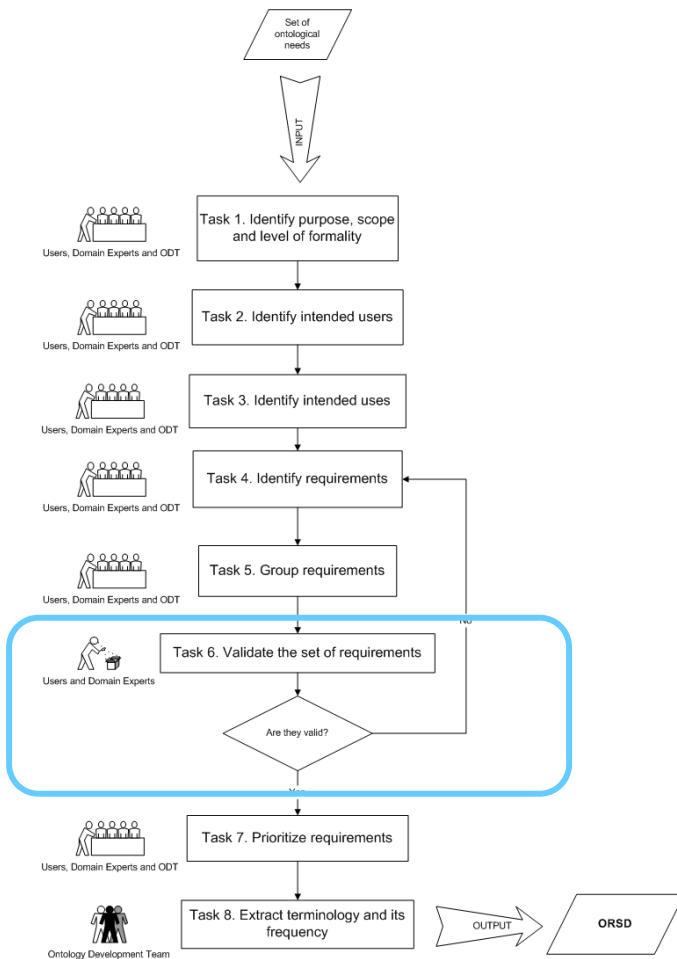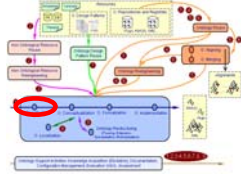
CQ57. Given the age (20 years old) and the desired salary (equal or greater than 14000 zlotes) of the job seeker, what job offers posted in last month are the most appropriate?

CQ58. Given the employer information, economic activity of the employer and the job offer profile (job, contract type, salary of 3400 €, work condition, contract duration), what job seekers are the most appropriate?

CQ59. Given the time spend for his/her degree (8 years) and the desired salary (equal or greater than 14000 €) of the job seeker, what job offers posted in last 7 days are the most appropriate?

CQ60. Given the time spend for his/her degree (8 years) and the desired salary (equal or greater than 14000 €) of the job seeker, what job offers posted in last 24 hours are the most appropriate?

❑ *Input*: the set of grouped CQs

❑ *Objective*: to identify possible conflicts between CQs, missing CQs, and contradictions in CQs. To decide **if such CQs are valid or not**

❑ *Output*: a confirmation about the validity of the set of CQs

❑ *Criteria*:

Correctness.	*Completeness.*
Consistent.	*Verificable.*
Understandable.	*No Ambiguity.*
Conciseness.	*Realism.*
Modifiable.	
Traceable.	

Correctness. Domain experts checked the correctness of each competency question, verifying that its formulation and answers were correct.

Consistent. Domain experts also verified that the competency questions did not have any possible inconsistency.
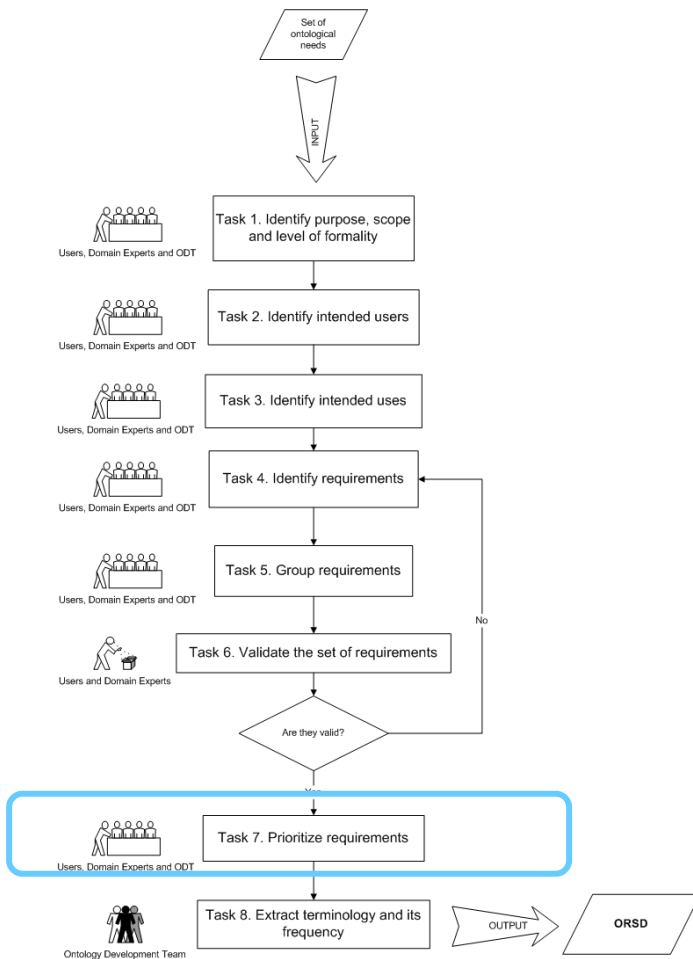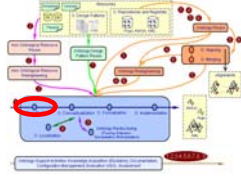
☐ *Input*: the groups of CQs written in natural language (obtained in task 5)

☐ *Objective*: to give **different levels of priority** to the different groups of CQs, and within each group to the identified requirements (in the form of CQs)

☐ *Output*: a set of priorities attached to each group of CQs and to each CQ in a group

Within the SEEMP Reference Ontology specification we did not carry out this step. This means the first version of the ontology must be able to represent the knowledge contained in all the competency questions.

Ontology Specification.
Extract Frequencies
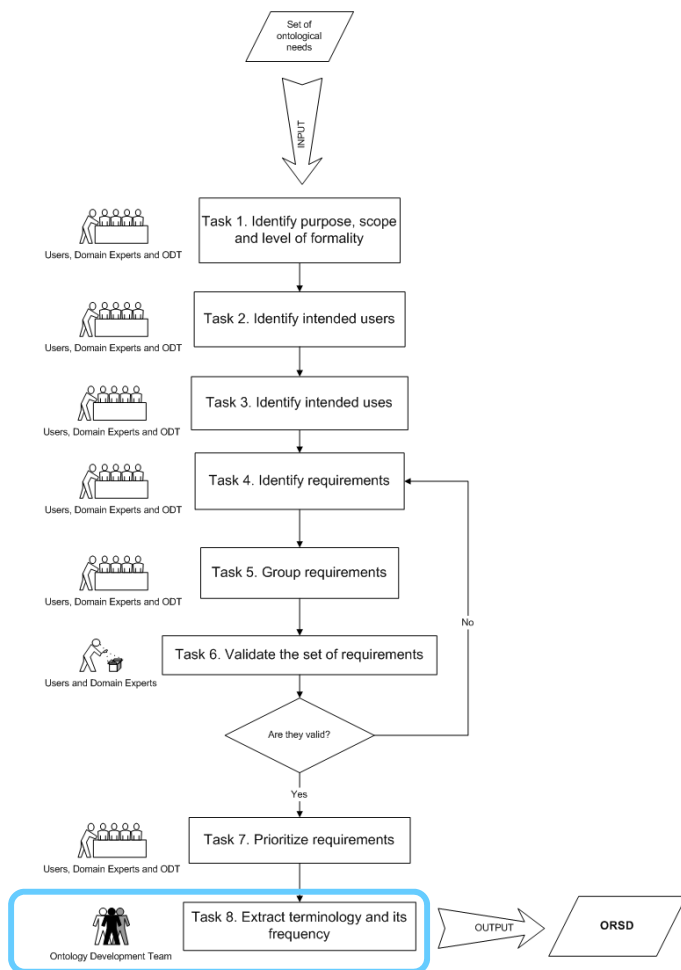
- ❑ *Input*: the list of identified CQs and their answers

- ❑ *Objective*: to extract from the list of CQs a pre-glossary to be used in the conceptualization activity. Obtaining a list of the **most used terms**

- ❑ *Techniques*: terminology extraction techniques and tools supporting such techniques

From the requirements in form of competency questions, we extract the terminology (names, adjectives and verbs) that will be formally represented in the ontology by means of concepts, attributes and relations.

From the answers to the CQs we extract the objects in the universe of discourse that will be represented as instances.

Term	Frequency
Job Seeker	27
• CV	2
• Personal Information	3
Name	4
Gender	1
Birth Date	1
Address	1
Nationality	1
Contact (phone, fax, mail)	3
• Objective	3
Job Category	3
Activity Sector	3
Location	3
Work Condition	2
Contract type	2
Salary	3
• Education and training	3
• Work Experience	3
• Competencies	3
Knowledge	3
Abilities	3
Skills	3
• Publication	1
• Hobbies	1
• References	1

Term	Frequency
Job Offer	27
• Employer information	1
Name	1
Address	1
Contact	1
• Vacancy	1
Job category	3
Activity sector	1
Location	3
Work condition	3
Contract type	3
Salary	3
Education	3
Work experience	2
Skills	2
Languages	1

Nationality	Job Category	Education	Currency	Languages	Activity Sector
Austrian	Computer System Designer	Life Science	Euro	Austrian	Telecommunication
Belgian	Computer System Analyst	Mathematics	Krone	Belgian	Justice and Judicial
Cypriot	Programmer	Computer Science	Great British Pound	Cypriot	Public Security and law
Czech	Computer Engineer	Computer Use	Zlote	Czech	Manufacture of machine tools
Danish	Computer Assistant	Statistics	US Dollar	Danish	Research and Development
Estonian	Computer Equipment Operator	Physics	Franc	Estonian	Hardware Consultancy
Finnish	Industrial Robot Controller	Chemistry	Peso	Finnish	Software Consultancy and Supply
French	Telecommunication Equipment Operator	Earth Science		French	Data processing
German	Medical Equipment Operator	Network Administration		German	Database
Greek	Electronic Equipment Operator	Operating Systems		Greek	Publishing of Software
Hungarian	Image Equipment Operator	Informatics		Hungarian	Maintenance of computing machinery
Irish	Software Engineer	Programming Language		Irish	Government
Italian	Computer code recorder	Sports		Italian	Culture, Media, Design

Ontology Specification.
SEEMP Ontology Requirement Specification Document

SEEMP Reference Ontology Requirements Specification	
1	**Purpose**
	The purpose of building the Reference Ontology is to provide a consensual knowledge model of the employment domain that could be used by public e-Employment services (PES).
2	**Scope**
	The ontology has to focus just on the ICT (Information and Communication Technology) domain. The level of granularity is directly related to the competency questions and terms identified.
3	**Level of Formality**
	The ontology has to be implemented in WSML language
4	**Intended Users**
	User 1. Candidate who is unemployed and searching for a job or searching another occupation for immediate or future purposes
	User 2.
	User 3.
	User 4.
	User 5.
5	**Intend**
	Use 1.
	Use 2.
	Use 3.
	Use 4.
	Use 5.

6 Groups of Competency Questions

CQG1. Job Seeker (16 CQ)
- CQ1. What is the Job Seeker Name?
- CQ2. What is the Job Seeker nationality?
- CQ3. When is the Job Seeker birthdate?
- CQ4. What is the Job Seeker contact information?
- CQ5. What is the Job Seeker current job?
- CQ6. What is the Job Seeker desired job?
- CQ7. What are the Job Seeker desired working conditions?
- CQ8. What kind of contract does the Job Seeker want?
- CQ9. How much salary does the Job Seeker want to earn?
- CQ10. What is the Job Seeker education level?
- CQ11. What is the Job Seeker work experience?
- CQ12. What is the Job Seeker knowledge?
- CQ13. What is the Job Seeker expertise?
- CQ14. What are the Job Seeker skills?
- CQ15. What publications does the Job Seeker have?
- CQ16. What hobbies does the Job Seeker have?

CQG2. Job Offer (10 CQ)
- CQ17. What is the employer information?
- CQ18. What kind of job does the employer offer?
- CQ19. What kind of contract does the employer offer?
- CQ20. How much salary does the employer offer?
- CQ21. What is the economic activity of the employer?
- CQ23. What is the work condition of the job offer?
- CQ24. What is the required education level for the job offer?
- CQ25. What is the required work experience for the job offer?
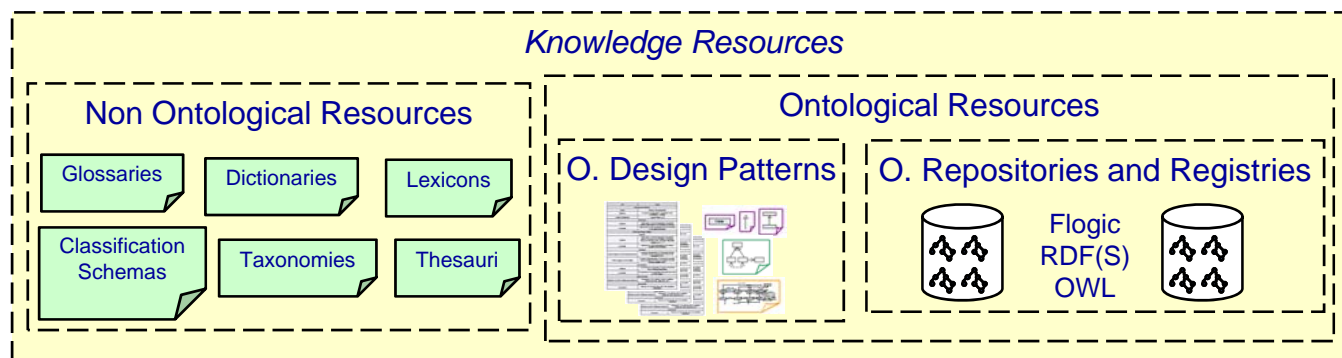- CQ26. What is the required knowledge for the job offer?

CQG3 (CQ)

Objects

Objects in the universe of discourse, which are instances of:

- Job Category
  - O1. Computer System Designer
  - O2. Computer System Analyst
  - O3. Programmer
  - O4. Computer Engineer
  - O5. Computer Assistant
  - O6. Computer Equipment Operator
  - O7. Industrial Robot Controller
  - O8. Telecommunication Equipment Operator
  - O9. Medical Equipment Operator
  - O10. Electronic Equipment Operator
  - O11. Image Equipment Operator

- Nationality
  - O12. Austrian
  - O13. Belgian
  - O14. Danish
  - O15. Estonian
  - O16. Finnish
  - O17. French
  - O18. German
  - O19. Greek
  - O20. Italian

- Activity Sector
  - O21. Telecommunication
  - O22. Justice and Judicial
  - O23. Public Security and law
  - O24. Manufacture of machine tools
  - O25. Research and Development
  - O26. Hardware Consultancy
  - O27. Software Consultancy and Supply
  - O28. Data processing

- Education
  - O29. Life Science
  - O30. Mathematics
  - O31. Computer Science
  - O32. Computer Use
  - O33. Statistics
  - O34. Physics
  - O35. Network Administration

- Languages
  - O36. Swedish
  - O37. Spanish
  - O38. Slovenian
  - O39. Portuguese
  - O40. English
  - O41. French
  - O42. German

- Currency
  - O43. Euro
  - O44. Krone
  - O45. Great British Pound
  - O46. Zlote
  - O47. US Dollar
  - O48. Franc

- Location
  - O49. Austria
  - O50. Belgium
  - O51. Danmark
  - O52. Estonia
  - O53. Finland
  - O54. France
  - O55. Germany
  - O55. Greece

7 Pre-Glossary of Terms

Terms		Frequency
a.	Job Seeker	27
b.	CV	2
c.	Personal Information	3
d.	Name	5
e.	Gender	1
f.	Birth date	1
g.	Address	2
h.	Nationality	1
i.	Contact (phone, fax, mail)	4
j.	Objective	3
k.	Job Category	6
l.	Job Offer	27
m.	Employer Information	1
n.	Vacancy	1
o.	Activity Sector	1
p.	Location	3
q.	Work Condition	3
r.	Contract Type	3
s.	Salary	3
t.	Education	3
u.	Work Experience	3

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- ❑ Scenarios in Ontology Building

- ❑ Methodological Guidelines for Ontology Specification

- ❑ **Quick Search and Selection of Existing Knowledge Resources**

- ❑ Guidelines for Ontology development project Planning

- ❑ Methodological Guidelines for Non Ontological Resource Reuse and Reengineering

- ❑ Methodological Guideliness for Ontology Reuse

- ❑ Creating the final Ontology Model

Searching Resources

- Use the terminology from the ORSD

- Find resources covering the terminology

Knowledge Resources

Non Ontological Resources
- Glossaries
- Dictionaries
- Lexicons
- Classification Schemas
- Taxonomies
- Thesauri

Ontological Resources
- O. Design Patterns
- O. Repositories and Registries
  - Flogic RDF(S) OWL

Objects

Objects in the universe of discourse, which are instances of:

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  - O9. Medical Equipment Operator
  - O10. Electronic Equipment Operator
  - O11. Image Equipment Operator

- Nationality
  - O12. Austrian
  - O13. Belgian
  - O14. Danish
  - O15. Estonian
  - O16. Finnish
  - O17. French
  - O18. German
  - O19. Greek
  - O20. Italian

- Where:
  - Internet
  - Standardization bodies (ISO,…)
  - Intranet of the organization
  - Ontology Registries

Searching
non ontological resources

- *We select the most appropriate standards and taxonomies for:*
  - Occupation Classification
    ISCO-88 (COM), SOC, ISCO-88, ONET, Eures Taxonomy.
  - Classification of Economic Activities
    ISIC Rev. 3.1, NACE Rev. 1.1, NAICS
  - Apprenticeship classifications
    ISCED 97, FOET
  - Currency Classification
    ISO 4217
  - Geography Classification
    ISO 3166, Eures Taxonomy

Language Classification
ISO 6392, CEF

Driving License Classification
European Legislation

Skill Classification
Eures Taxonomy

Contract Types Classification
LE FOREM, Eures and BLL Classification

Work Condition Classification
LE FOREM, Eures and BLL Classification

**Is the terminology included in
the Ontology Requirements Specification Document
covered by the resources?**

Selection of Ontologies

- Search ontologies
- Compare ontologies in the same domain using a set of criteria
- Assess if the ontologies cover the set of competency questions
- Select the best ontology based on
  - Coverage of the domain
  - Expressivity of the Implementation language

Searching Ontologies in Watson

Watson NeOn Toolkit plugin

- While building an ontology with the Neon toolkit

- Find descriptions of existing entities in Web ontologies

- Integrate these descriptions into the edited ontology

- Thus allowing knowledge reuse at the scale of the Semantic Web

- In one simple, integrated, and interactive tool
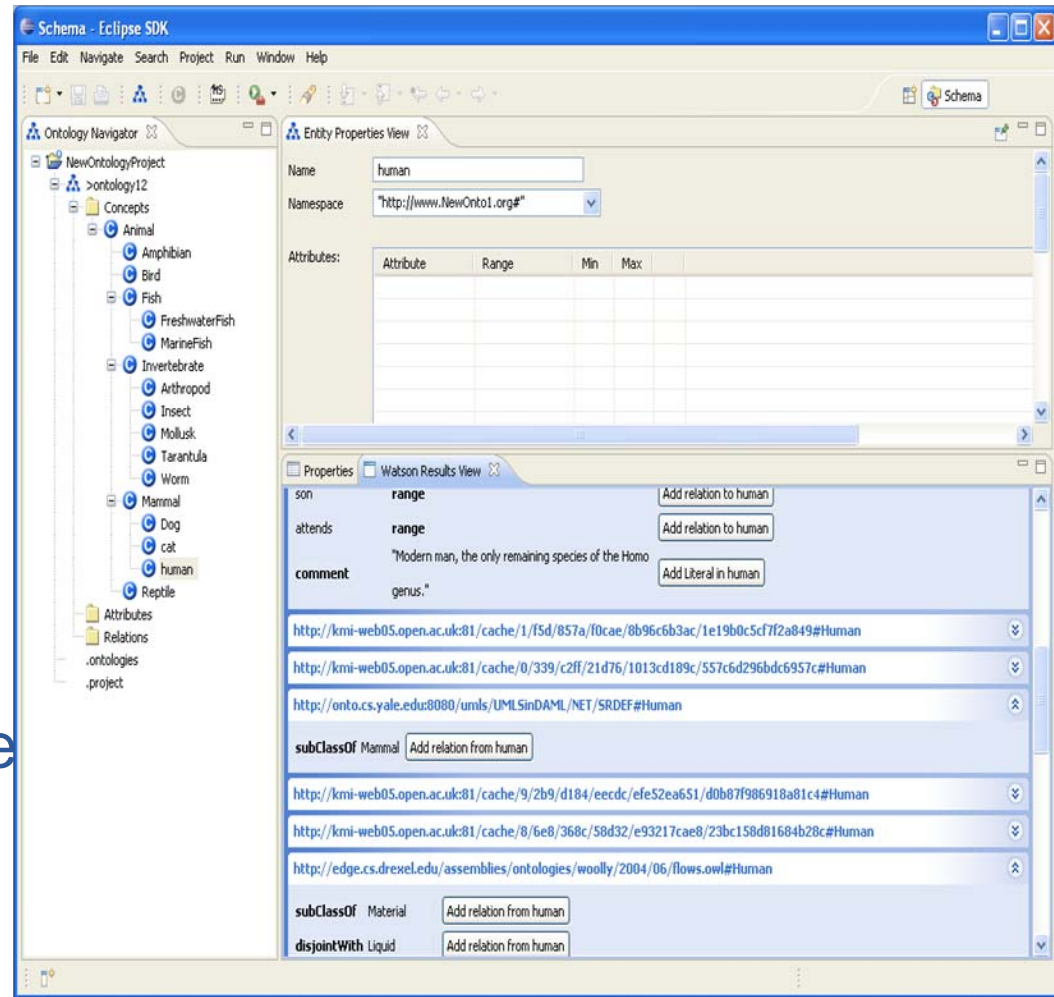
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# Life Cycle Models and Life Cycles in Ontological Engineering

❑ An **ontology life cycle model** is the framework (waterfall, incremental, etc.), selected by each using organization, on which to map the activities identified in the ontology development process.

❑ The **ontology life cycle** is the specific sequence of activities that the ontology practitioners carry out for developing an ontology.

Example: three ontology life cycles based on the waterfall model
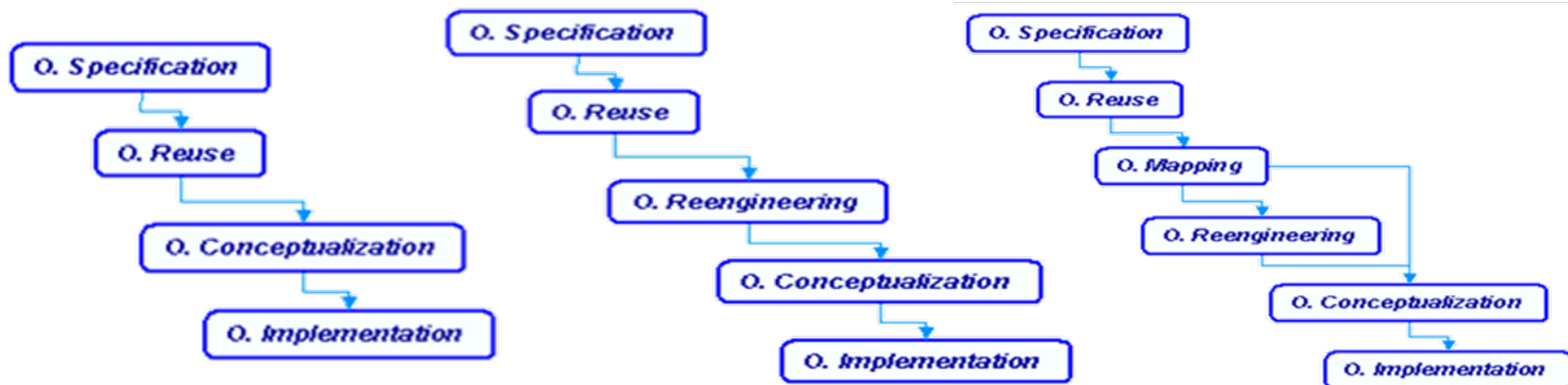
Several Ontology Life Cycle Models could be possible

- **Assumption: Ontology requirements are known at the begining of the ontology development project.**

Waterfall

Incremental

Iterative
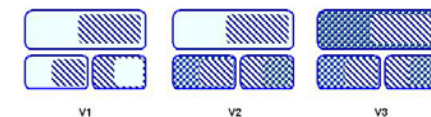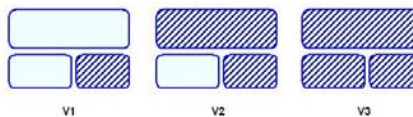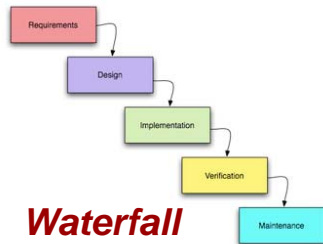
- **Assumption: Ontology requirements can be not known at the begining of the ontology development project and can change during the project.**

Evolving Prototyping

- **Assumption: Uncertainties in the ontology requirements can derive into risks in the project.**

Spiral
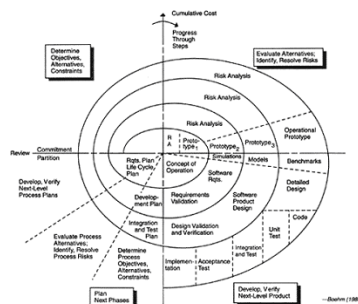
Risks can be:

- **Properties became classes**
- **Move from frames to DL**
- **Reuse new existing resources**

Waterfall: 5 different versions

D5.3.2
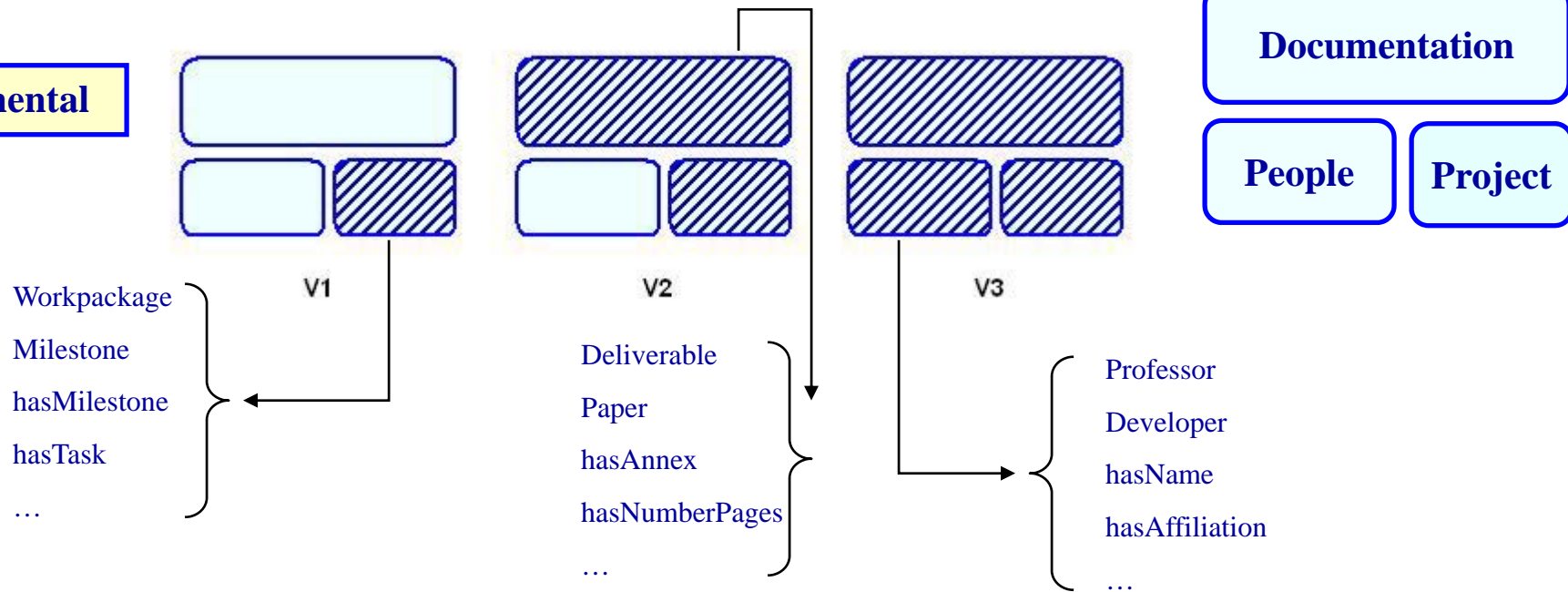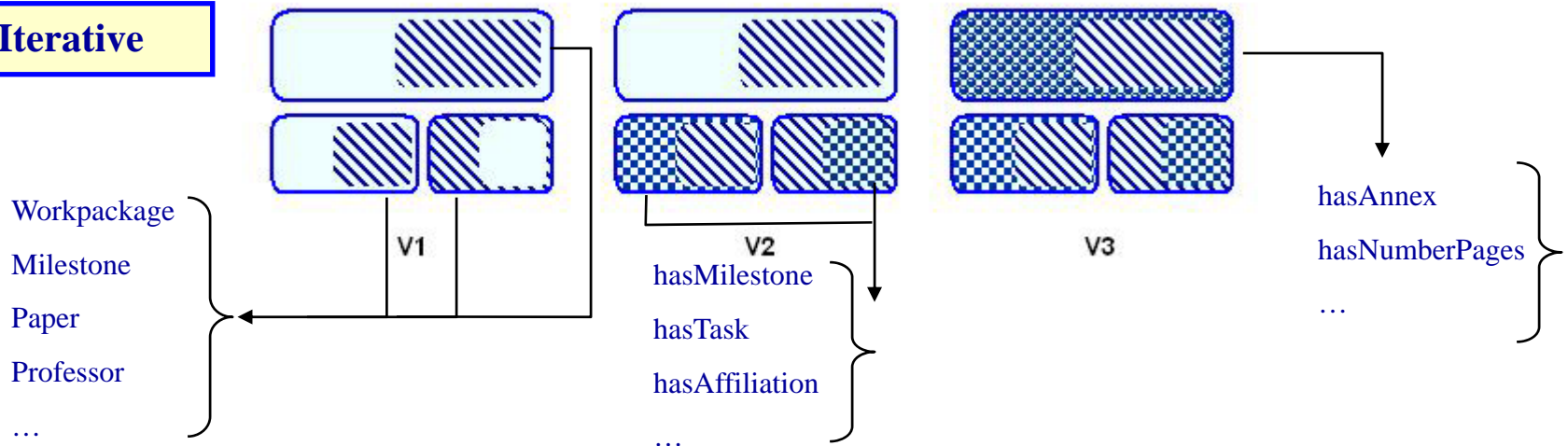
Four-Phase Waterfall

Five-Phase + Merging Phase Waterfall
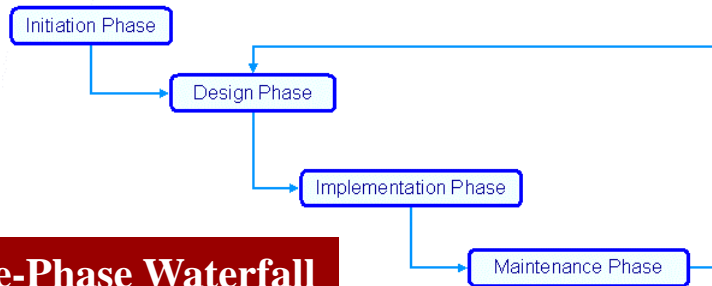
Five-Phase Waterfall

Six-Phase Waterfall
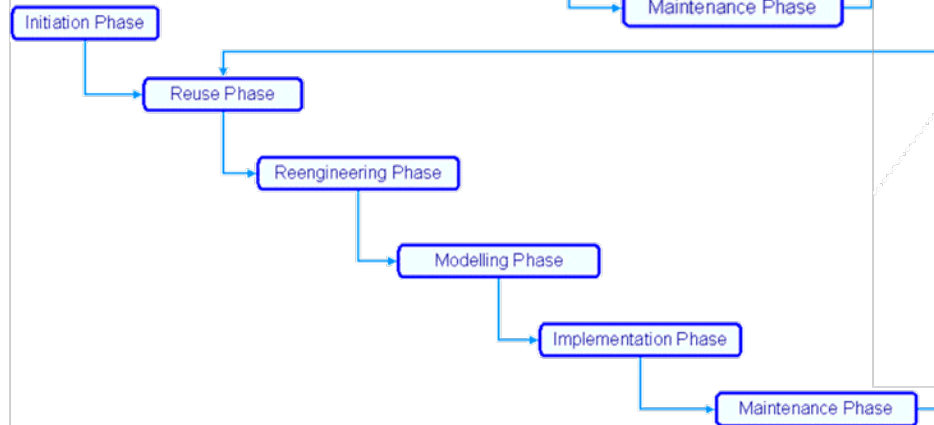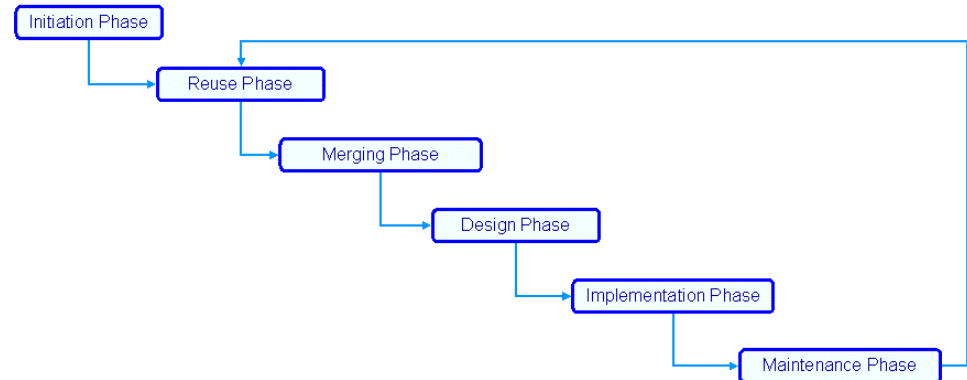
Six-Phase + Merging Phase Waterfall

Scheduling	
Definition	
Scheduling refers to the activity of identifying the different activities and processes to be performed during the ontology development, their arrangement, and the time and resources needed for their completion.	
Goal	
The scheduling activity states a concrete programming or scheduling to guide the ontology network development, including processes and activities, their order, and time and human resources restrictions and assignments.	

Input	Output
Ontology Requirements Specification Document (ORSD).	Schedule for the ontology network development.

Who
Software developers and ontology practitioners, who form the ontology development team (ODT), in collaboration with users and domain experts.

When
This activity must be carried out after the ontology requirements specification activity.

ORSD

INPUT

Users, Domain Experts and ODT — Task 1. Select the ontology network life cycle model

Users, Domain Experts and ODT — Task 2. Select processes and activities

Users, Domain Experts and ODT — Task 3. Map processes and activities into the ontology network life cycle model

Users, Domain Experts and ODT — Task 4. Set the order of processes and activities — OUTPUT — Ontology Network Life Cycle

Users, Domain Experts and ODT — Task 5. Establish resource restrictions and assignments — OUTPUT — Scheduling for the Ontology Network Development

How software developers and ontology practitioners select the *ontology life cycle model* and the *particular ontology life cycle* for developing his/her ontology?

1) Which **ontology network life cycle model** is the most appropriate for the ontology network development?

2) Which particular **processes and activities** should be carried out in the ontology network development?

3) How much **resources (human and time)** are needed for the development of the ontology network?

Schedule

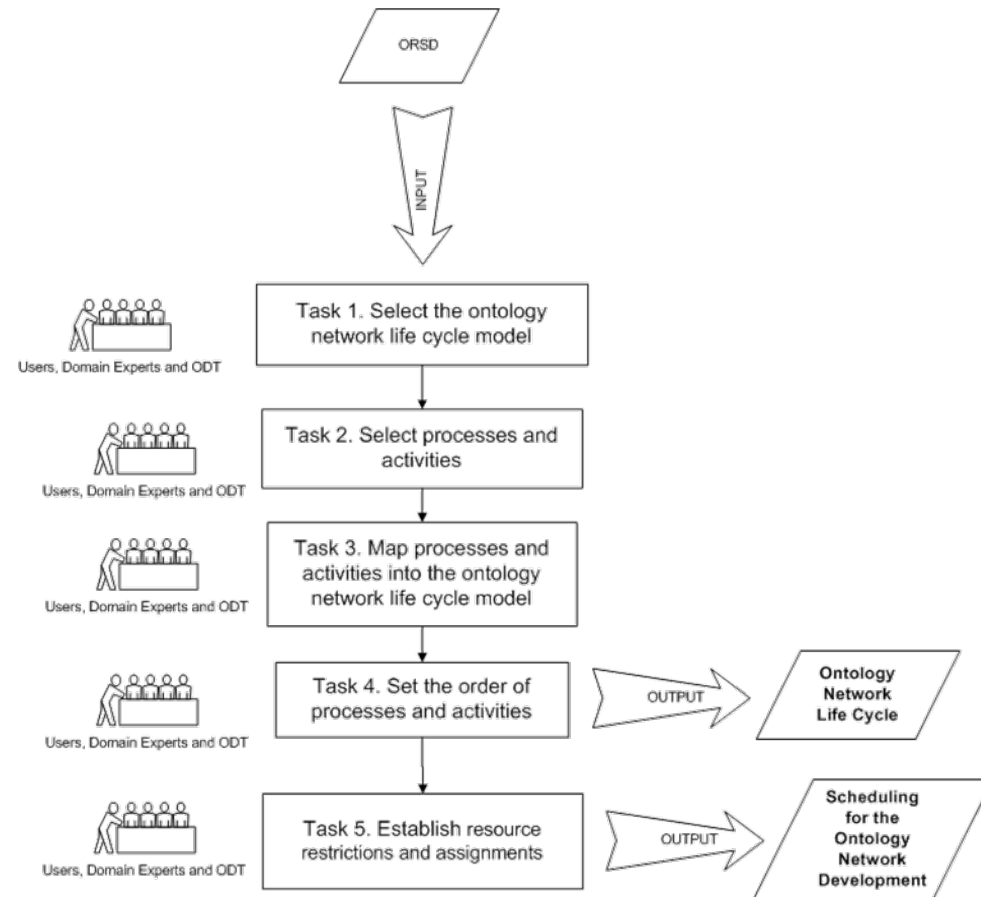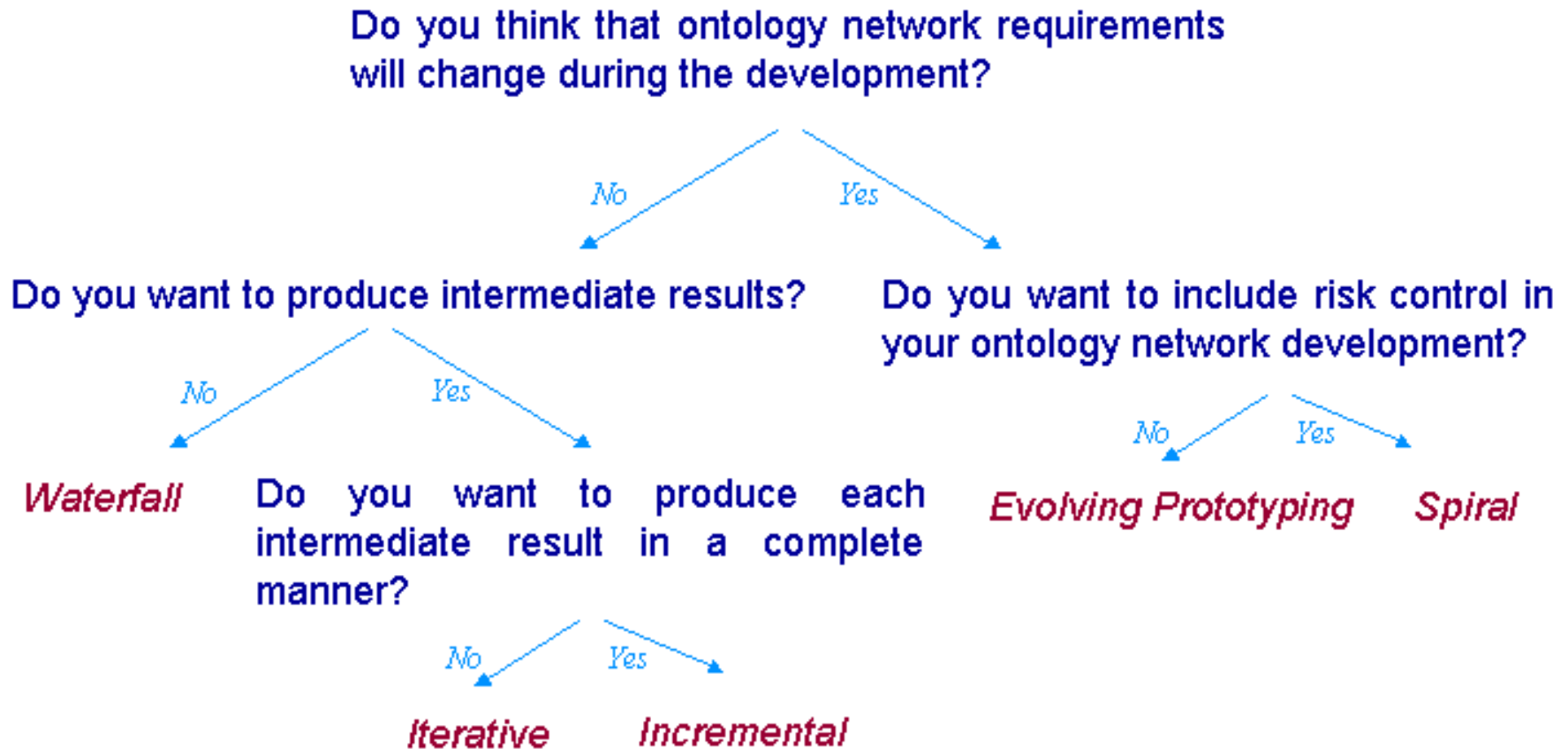| Scheduling	
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Input	**Output**
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ORSD

INPUT

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Users, Domain Experts and ODT — Task 4. Set the order of processes and activities — OUTPUT → Ontology Network Life Cycle

Users, Domain Experts and ODT — Task 5. Establish resource restrictions and assignments — OUTPUT → Scheduling for the Ontology Network Development

Decission tree for selecting your Ontology Life Cycle Model

Do you think that ontology network requirements will change during the development?

No → Do you want to produce intermediate results?

Yes → Do you want to include risk control in your ontology network development?

Do you want to produce intermediate results?
- No → **Waterfall**
- Yes → Do you want to produce each intermediate result in a complete manner?
  - No → **Iterative**
  - Yes → **Incremental**

Do you want to include risk control in your ontology network development?
- No → **Evolving Prototyping**
- Yes → **Spiral**

Decission Tree for Selecting Activities

Have you developed more than 5 ontologies?

No

Yes

Set of "yes/no" natural language questions for identifying the 'if-applicable' activities to be carried out.

➤ Do you want to have your ontology network in different natural languages, as for example, in English, Spanish and French? YES → *O. Localization*.

➤ Do you want to take an existing and implemented ontology, in order to enhance it and implement it again? NO → *O. Reengineering is not selected*.

Software developers and ontology practicioners select the activities to be carried out from the "Required-If Applicable" table

	If Applicable	Selected
Ontology Aligning	X	x
Ontology Customization	X	
Ontology Learning	X	
Ontology Localization	X	x
Ontology Matching	X	x
Ontology Modification	X	
Ontology Reengineering	X	
Ontology Restructuring	X	x

Automatically

Classical + Waterfall
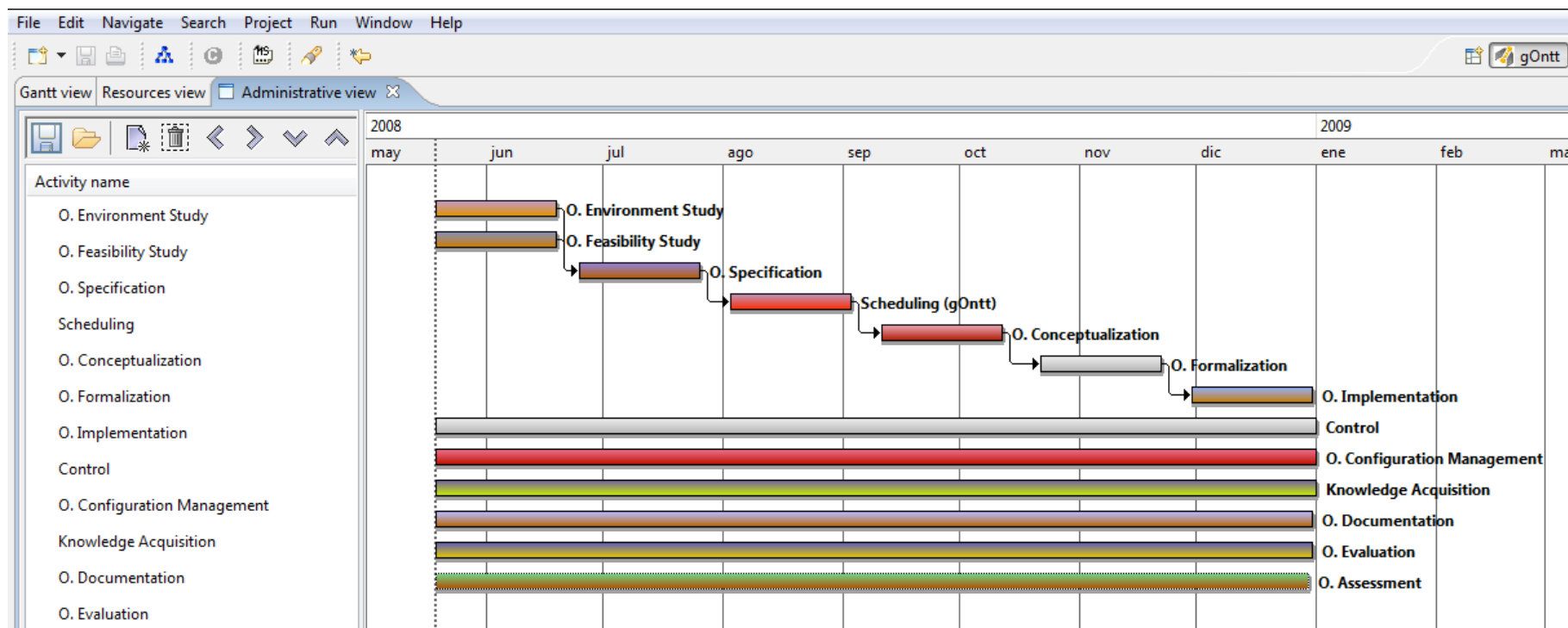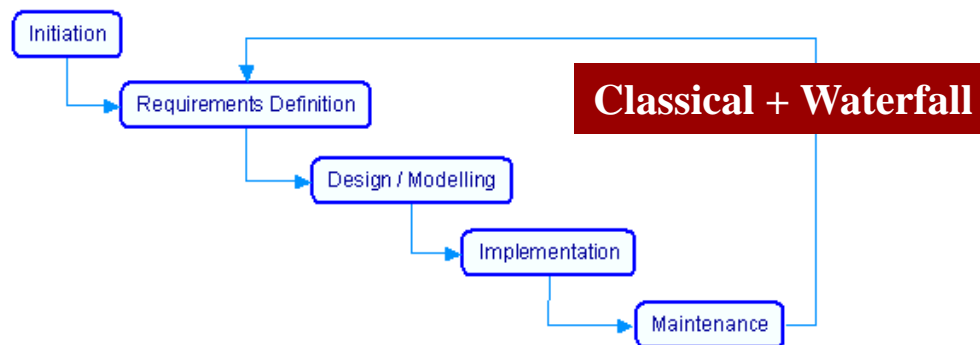
Reuse and Reengineering + Waterfall