IREB Certified Professional for Requirements Engineering

- Foundation Level -

Syllabus

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(based on the German Version 2.2)

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Preface

Purpose of the Document

This syllabus defines the foundation level of the certification "Certified Professional for Requirements Engineering” established by the International Requirements Engineering Board (IREB). IREB offers this syllabus and associated examinations in various languages. The syllabus provides training providers with the basis for creating their course materials. Students can use the syllabus to prepare themselves for the examination.

Contents of the Syllabus

The foundation level addresses the needs of all people involved in the topic of requirements engineering. This includes people in roles such as project or IT management, domain experts, system analysts and software developers.

Content Scope

The foundation level communicates fundamentals equally valid for all areas (e.g. embedded systems, safety critical systems, classical information systems). This does not mean that the suitability of approaches for the individual areas, considering their special characteristics, cannot be handled in a training course. It is not however the goal to present requirements engineering specific to a certain domain.

No specific procedure and associated process model is suggested that makes a statement for the planning, steering and sequence of application of the learned concepts in practice. It is not about emphasizing a certain process for requirements engineering or even software engineering overall.

What constitutes the knowledge of requirements engineers is defined, but not the exact interface to other disciplines and processes of software engineering.

Level of Detail

The level of detail of this syllabus allows internationally consistent teaching and examination. To reach this goal, the syllabus contains the following

- General educational objectives
- Contents with a description of the educational objectives and
- References to further literature (where necessary)

Educational Objectives / Cognitive Knowledge Levels

Each module of the syllabus is assigned a cognitive level. A higher level includes the lower levels. The formulations of the educational objectives are phrased using the verbs "knowing" for level L1 and "mastering and using" for level L2. These two verbs are placeholders for the following verbs:

- **L1 (knowing):** enumerate, characterize, recognize, name, reflect
- **L2 (mastering and using):** analyze, use, execute, justify, describe, judge, display, design, develop, complete, explain, exemplify, elicit, formulate, identify, interpret, conclude from, assign, differentiate, compare, understand, suggest, summarize

⚠ All terms defined in the glossary have to be known (L1), even if they are not explicitly mentioned in the educational objectives.

This syllabus uses the abbreviation "RE" for Requirements Engineering.

Structure of the Syllabus

The syllabus consists of 9 main chapters. One chapter covers one educational unit (EU). Each main chapter title contains the cognitive level of the chapter, which is the highest level of the sub-chapters. Furthermore, the teaching time is suggested that is the minimum a course should invest for that chapter. Important terms in the chapter, which are defined in the glossary, are listed at the beginning of the chapter.

Example:	EU 1 Introduction and Foundations (L1)
Duration:	1 ¼ hours
Terms:	Requirement, Stakeholder, Requirements Engineering, Functional Requirement, Quality Requirement, Constraint

This example shows that chapter 1 contains education objectives at level L1 and 75 minutes are intended for teaching the material in this chapter.

Each chapter can contain sub-chapters. Their titles also contain the cognitive level of their content.

Educational objectives (EO) are enumerated before the actual text. The numbering shows to which sub-chapter they belong.
Example: EO 3.1.2

This example shows that educational objective EO 3.1.2 is described in sub-chapter 3.1

The Examination

This syllabus is the basis for the examination for the foundation level certificate.

⚠ A question in the examination can cover material from several chapters of the syllabus. All chapters (EU 1 to EU 9) of the syllabus can be examined.

The format of the examination is a multiple-choice.

Examinations can be held immediately after a training course, but also independently from courses (e.g. in an examination center). A list of recognized examination providers can be found on the internet homepage, at http://www.ireb.org

Version History

Version	**Date**	**Comment**
2.1	November 2010	Initial version
2.1-1	March 1st 2011	Modified to reflect changes in the English translation
2.1-2	November 9th 2011	Minor changes (typos etc.), Synonyms for the categories in the Kano model added
2.1-5	June 15th 2012	Version number aligned for all languages (2.1-3 and 2.1-4 skipped) Minor changes (typos, US notation etc.) Term *context diagram* added to EU 6.6
2.1-5.1	December 20th 2012	Added footnote to term *Subject conflict* in EU 7.6, page 26.

Version	Date	Comment
2.2	March 1st 2015	Fixed typos and grammar issues EU 1: Reference to ISO/IEC/IEEE 29148:2011 added EU 1: List of aspects for quality requirements modified and reference to ISO/IEC25010:2011 added EU 3.1: Term “legacy” replaced by “existing” EU 4.3: Reference to IEEE 830-1998 replaced by reference to ISO/IEC/IEEE 29148:2011 EU 4.6: List of quality criteria for requirements modified EU 5.2: Term “may” added to the verbs for fixing liability of a requirement EU 6.1: Hint added to the definition of the term “model” EU 6.5: Duplicate paragraph regarding cardinalities removed EU 7.1: examples “correctness” and “completeness” for quality criteria replaced by reference to EU 4.6 EU 7.3: List of criteria for quality aspect "documentation” modified EU 7.6: List of conflict types modified; detailed description added; “Subject conflict” replaced by “Data conflict” EU 8: New Educational objective 8.7.1 added EU 8.1: Attribute “criticality” replaced by “risk” EU 8.7: New Educational unit “Measurement for Requirements” added
2.2.1	July 24th 2017	Formatting issues and typos fixed
2.2.2	August 23, 2017	Wrong term “sentence template” removed

Contents

EU 1 Introduction and Foundations (L1)

Duration: 1 ¼ hours
Terms: Requirement, Stakeholder, Requirements Engineering, Functional Requirement, Quality Requirement, Constraint

Educational Objectives:

EO 1.1	Knowing symptoms of and reasons for inadequate RE
EO 1.2	Knowing the four major activities of RE
EO 1.3	Knowing the role of communication in RE
EO 1.4	Knowing skills of a requirements engineer
EO 1.5	Knowing the three kinds of requirements
EO 1.6	Knowing the role of quality requirements

Good RE is important since many errors arise already in this phase and can only be rectified later at high cost. Typical symptoms of inadequate RE are missing and unclear requirements. Typical reasons for inadequate RE are

- the wrong assumption of the stakeholders that much is self-evident and does not need to be stated explicitly
- communication problems due to differences in experience and knowledge
- the project pressure from the client to build a productive system rapidly.

The four main activities of RE are elicitation, documentation, validation/negotiation plus the management of requirements. The activities can be scheduled in specific processes such as recommended in the Standard ISO/IEC/IEEE 29148:2011. They often concern different levels of requirements such as stakeholder requirements and system or software requirements.

Natural language is the most important means to communicate requirements. At the same time it is particularly important to agree on a common terminology. Furthermore the communication medium (written or spoken) plays a big role. When communicating, all participants must deal consciously with focusing and simplification.

This is especially true for the most important role in RE: the requirements engineer. Besides communication skills he or she must especially have the following skills: analytical thinking, empathy, conflict resolution skills, moderation skills, self-confidence and the ability to convince.

Typically we differentiate between three kinds of requirements: functional requirements, quality requirements and constraints.

The umbrella term “non-functional requirement” is often used for quality requirements and constraints. Quality requirements must be documented explicitly. In particular the following aspects need to be considered

- Performance
- Security
- Reliability
- Usability
- Maintainability
- Portability

More comprehensive quality models can be found in the requirements engineering literature and in standards such as the Standard ISO/IEC25010:2011.

Even though quality requirements are mostly documented using natural language, their relation to other statements have to be traceable and their validation has to be ensured by quantitative assertions or made operational by transformation into additional functionality.

EU 2 System and System Context (L2)

Duration: 1 ¼ hours
Terms: System Context, System Boundary, Context Boundary

Educational Objectives:
EO 2.1 Knowing system context, system boundary and context boundary
EO 2.2 Mastering and using system boundary and context boundary

EU 2.1 System, System Context and Boundaries (L1)

The source and so the justifications of the requirements for a system lie in the system context of the planned system. The source consists of the set of all context aspects that initiated or influenced the definition of the requirements. Among the potential aspects in the system context are:

- People (stakeholder or groups of stakeholders)
- Systems in operation (technical systems, software and hardware)
- Processes (technical or physical processes, business processes)
- Events (technical or physical)
- Documents (e.g. laws, standards, system documentation)

It is the function of the system boundary to define which aspects will be covered by the planned system and which aspects are part of this system's environment. The context boundary identifies the part of the environment that has a connection to the system to be developed.

EU 2.2 Determining System and Context Boundaries (L2)

Often the system boundary is only precisely defined towards the end of the requirements process. Before that, the desired functions and qualities of the planned system are only incompletely known or not known at all. Therefore there will be a grey zone in which the possible system boundary lies. Besides a shifting of the system boundary within the grey zone, the grey zone itself can also shift during the RE process, e.g. when, through a shifting of the system boundary, further aspects of the environment become important.

Also the context boundary can change over time, e.g. when it turns out, contrary to expectations, that a legal requirement, previously classified as relevant, has absolutely no impact on the planned system, then the system context is reduced in this area.

The context boundary also has a grey zone. It comprises the identified aspects of the environment for which, at a particular time, it is unclear whether these aspects have a relation to the planned system or not.

Use case diagrams or data flow diagrams are often used for the documentation of the system contexts (especially the system and context boundaries). In context modeling, based on data flow diagrams, the sources and sinks in the system environment are modeled, showing respectively the source or destination of data flows between the system in consideration and the environment. The actors (i.e. for example people or other systems) in the system environment and their use relations with the system to be developed are modeled in use case diagrams.

EU 3 Requirements Elicitation (L2)

Duration: 1 ½ hours
Terms: none

Educational Objectives:

EO 3.1.1	Knowing various types of requirements sources
EO 3.1.2	Knowing the significance of requirements sources and the consequences of disregarded requirements sources
EO 3.1.3	Knowing the most important information of the stakeholder documentation
EO 3.1.4	Knowing important principles in dealing with stakeholders (stakeholder rights and duties)
EO 3.2.1	Mastering and using the content and significance of the Kano model
EO 3.3.1	Knowing influencing factors for the choice of elicitation techniques
EO 3.3.2	Knowing advantages and disadvantages of elicitation techniques
EO 3.3.3	Mastering and using the following types of elicitation techniques and examples for each: survey techniques, creativity techniques, document-centered techniques, observation techniques and supporting techniques

EU 3.1 Requirements Sources (L1)

An important activity in RE activity is the elicitation of requirements for the system to be developed. The foundations for the requirements elicitation comprise on the one hand the system context and on the other hand the requirements sources. Various types of requirements sources are differentiated. Possible requirements sources are, for example, stakeholders, documents or existing systems.

It is the task of RE to collect the goals and requirements from the various requirements sources. If sources are disregarded, this can have significant negative consequences on the entire course of the project. The documentation of the requirements sources should, with respect to the stakeholders, contain at least the following information:

- name
- function (role)
- additional personal and contact data
- temporal and spatial availability during the project progress
- relevance of the stakeholder
- their area and extent of expertise
- their goals and interests regarding the project

Depending on the company culture it is appropriate, in agreement with the stakeholders, to define verbally or by means of written documentation the tasks, responsibilities, authority, etc. From the stakeholder agreements arise rights and duties for each stakeholder. Dealing with stakeholders effectively guards against lack of motivation and conflicts. Stakeholders should be involved in the project and not only affected by the project.

EU 3.2 Requirements Categorization according to the Kano Model (L2)

For the elicitation of requirements, it is crucial to know what importance the requirements have for the satisfaction of the stakeholders. According to the model of Dr. Kano, this satisfaction can be classified into three categories:

- Basic factors (synonym: Dissatisfiers)
- Performance factors (synonym: Satisfiers)
- Excitement factors (synonym: Delighters)

EU 3.3 Elicitation Techniques (L2)

Elicitation techniques fulfill the purpose of finding out the conscious, unconscious and subconscious requirements of stakeholders. Important factors influencing the choice of elicitation technique are risk factors, human influences, organizational influences, function-content influences and the intended level of detail of the requirements. Various techniques are needed for the various RE products:

- Survey techniques (e.g. interviews, questionnaires)
- Creativity techniques (e.g. brainstorming, brainstorming paradox, change of perspective, analogy technique)
- Document-centric techniques (e.g. system archaeology, perspective-based reading, requirements reuse)
- Observation techniques (e.g. field observation, apprenticing)
- Support techniques (e.g. mind mapping, workshops, CRC cards, audio and video recordings, use case modeling, prototypes)

The application of appropriate elicitation techniques is a project-critical key competence. The best results are achieved with a combination of various elicitation techniques.

EU 4 Requirements Documentation (L2)

Duration: 2 hours
Terms: Requirements Document, Requirements Specification

Educational Objectives:

EO 4.1.1	Knowing key reasons for requirements documentation
EO 4.2.1	Knowing the three perspectives of functional requirements
EO 4.2.2	Knowing advantages and disadvantages of natural language requirements documentation
EO 4.2.3	Knowing the most important model-based requirements documentation form
EO 4.2.4	Knowing the advantages of mixed form of requirements documentation
EO 4.3.1	Knowing the advantages of standardized document structures
EO 4.3.2	Knowing one widespread document structures
EO 4.3.3	Knowing important points for a tailored standard structure
EO 4.4.1	Knowing activities building on requirements documents
EO 4.5.1	Mastering and using quality criteria for requirements documents
EO 4.6.1	Mastering and using quality criteria for requirements
EO 4.6.2	Knowing the two most important style rules for requirements
EO 4.7.1	Mastering and using contents and importance of a glossary
EO 4.7.2	Mastering and using rules for handling the glossary

EU 4.1 Document Design (L1)

In RE it is necessary to document all important information. All forms of more or less formal representation of requirements, from the description in prose up to diagrams with formal semantics, are called documentation techniques. Many people are involved in the documentation in the lifecycle of a requirements document. Documentation plays a goal-orientated supporting function in communication. The following factors make this support necessary. Requirements are long-lasting, legally relevant and should be accessible to all. Requirements documents are complex.

EU 4.2 Documentation Types (L1)

Requirements documents include, amongst other things, functional requirements that normally represent the following three different perspectives of a system.

- Data perspective
- Behavioral perspective
- Functional perspective

All three perspectives can be documented by means of natural language requirements, whilst conceptual model types are specialized for one of these perspectives. Effectively applicable forms of the documentation are:

- Natural language requirements documentation
- Conceptual requirements models such as, for example use case diagrams, class diagrams, activity diagrams or state diagrams (see also EU 6)
- Combined forms of requirements documentation

EU 4.3 Document Structures (L1)

Central components of a requirements document are the requirements for the system being considered. Besides the requirements, depending on the purpose of the document, the requirements documents also contain information about the system context, acceptance conditions or, for instance, characteristics of the technical implementation. In order to ensure the manageability of requirements documents, such documents must be structured most appropriately.

Reference structures for requirements documents propose a more or less complete and a more or less flexible field-tested content structure. Common reference structures for requirements documents are described amongst others in the Standard ISO/IEC/IEEE 29148:2011.

In practice it turns out that there are a lot of positive effects from using reference structures for requirements documents. For instance, the use of reference structures simplifies the usage of the requirements documents in subsequent development activities (e.g. in the definition of test cases). Generally reference structures cannot be adopted one-to-one for a requirements document, as the content structure frequently has to be adapted in detail for domain-, company- or project-specific circumstances.

EU 4.4 Use of Requirements Documents (L1)

Requirements documents serve as the basis for many activities during the project lifespan, such as, for example

- Planning
- Architectural design
- Implementation
- Test
- Change management
- System usage and system maintenance
- Contract management

EU 4.5 Quality Criteria for the Requirements Document (L2)

In order to serve as a basis the subsequent development processes, the requirements document must meet certain quality criteria. In particular this includes:

- Unambiguity and consistency
- Clear structure
- Modifiability and extensibility
- Completeness
- Traceability

EU 4.6 Quality Criteria for Requirements (L2)

In addition, the individual requirement must satisfy certain quality criteria, in particular:

- agreed
- unambiguous
- necessary
- consistent
- verifiable
- feasible
- traceable
- complete
- understandable

Besides the quality criteria for requirements there are two basic style rules for requirements in natural language, which promote readability:

- short sentences and paragraphs
- formulate only one requirement per sentence

EU 4.7 Glossary (L2)

A frequent cause of conflicts, arising in RE, lies in the different understanding of terminology among the involved people. To prevent this problem, it is necessary that all relevant terms are defined in a glossary. A glossary is a collection of term definitions for:

- context-specific technical terms
- abbreviations and acronyms
- everyday concepts that have a special meaning in the given context
- synonyms
- homonyms

The following rules should be observed when working with a glossary:

- The glossary must be managed centrally
- The responsibilities for maintaining the glossary must be defined
- The glossary must be maintained over the course of the project
- The glossary must be commonly accessible
- Use of the glossary must be obligatory
- The glossary should contain the sources of the terms
- The stakeholders should agree upon the glossary
- The entries in the glossary should have a consistent structure

It is beneficial to begin the development of the glossary as early as possible, in order to reduce the alignment work later on.

EU 5 Documentation of Requirements using Natural Language (L2)

Duration: 1 hour
Terms: Requirements Template

Educational Objectives:
EO 5.1 Mastering and using the five transformational processes in the perception and writing of natural language and their consequences on the formulation of requirements
EO 5.2 Mastering and using the five steps for formulating requirements using a requirements template

EU 5.1 Language Effects (L2)

As natural language is often ambiguous and interpretable, it is necessary to pay special attention to precisely this aspect when using language. During the processes of perception and writing, so-called “transformational processes” occur. The fact that these transformational processes follow certain rules can be used by the requirements engineer to elicit exactly what the author of the requirement really did mean. The five most relevant transformational processes for RE are:

- Nominalization
- Nouns without reference index
- Universal quantifiers
- Incompletely specified conditions
- Incompletely specified process words

EU 5.2 Requirements Construction using Templates (L2)

Requirements templates are an easily learnable and applicable approach to reducing language effects in the formulation of requirements. The requirements template effectively supports the author of a requirement in creating high quality requirements.

The five steps to formulating requirements through a requirements template are:

- Determine legal obligation
- Determine the core of the requirement
- Characterizes the activity of the system
- Insert objects
- Determine logical and temporal conditions

The fixing of liability by using the verbs "shall", "should", "will", “may” can be made in the text of the requirement. If the liabilities change, then the requirements change too. The use of attributes is another possibility for documenting the liabilities of requirements.

The best results cannot be achieved by making the use of requirements templates compulsory, but rather by offering training on the method and by treating requirements templates as a supplemental tool.

EU 6 Model-based Documentation of Requirements (L2)

Duration: 5 hours
Terms: Model

Educational Objectives

EO 6.1.1	Knowing the term “model” and the properties of models
EO 6.1.2	Knowing definition elements of a conceptual modeling language
EO 6.1.3	Knowing the advantages of requirements models
EO 6.2.1	Knowing the importance of goals in requirements engineering
EO 6.2.2	Knowing the two types of goal decomposition
EO 6.2.3	Mastering the modeling and using of goal relationships as and/or trees
EO 6.3.1	Mastering the modeling of and using use case diagrams
EO 6.3.2	Mastering the specification of and using use case specifications
EO 6.4.1	Knowing the three perspectives on requirements
EO 6.5.1	Knowing the focus of the data perspective on requirements
EO 6.5.2	Mastering and using entity relationship diagrams and UML class diagrams
EO 6.6.1	Knowing the focus of the functional perspective on requirements
EO 6.6.2	Mastering and using data flow diagrams and UML activity diagrams
EO 6.7.1	Knowing the focus of the behavioral perspective on requirements
EO 6.7.2	Mastering and using UML statecharts

⚠ Note: In this chapter the cognitive level L2 ("mastering and using”) does not contain the verbs "create”, "design”, "develop”, "formulate”. Students should be able to understand the models. Creating such models is part of the IREB advanced level module on "requirements modeling”.

EU 6.1 The term “Model” (L1)

Using models makes it easier to understand information selectively about the facts and their connections, to record them more quickly and document them unambiguously. A model is an abstraction of an existing reality or a reality to be created (note that this definition covers the most frequent case in requirements engineering, but is a bit narrow. More generally speaking, a model is an abstract representation of an existing entity or an entity to be created, where entity denotes any part of reality or any other conceivable set of elements or phenomena, including other models. With respect to a model, the entity is called the original.).

Models have three important properties:

- Representation property: models map reality
- Reduction property: models reduce the represented reality
- Pragmatic property: models are constructed for a special purpose

In RE conceptual models are used frequently. They typically model reality through a set of graphical elements. Conceptual modeling languages are used for the modeling of conceptual models, which are defined by their syntax (modeling elements and their valid combinations) and semantics (meaning of the modeling elements). Requirements models are conceptual models that define the requirements for the system to be developed. The documentation of requirements in the form of conceptual models offers, in contrast to natural language requirements documentation, among other things the following advantages:

- Information presented in pictures is quicker to understand and memorize
- Requirements models allow the targeted modeling of one perspective on the requirements
- By defining the modeling language for the particular purpose, an appropriate abstraction of reality can already be specified

The combination of natural language and requirements models provides the advantages of both documentation types.

EU 6.2 Goal Models (L2)

A goal describes an intention of a stakeholder. Such intentions typically concern characteristic features of the system to be developed or of the associated development project. Goals can be documented both in natural language and in the form of models. An integral part of the documentation of goals is the description of refinement relationships (decomposition relationships) between higher and subordinate goals. In this regard two types of decomposition are distinguished:

- "AND decomposition" (all sub-goals must be fulfilled in order to fulfill the higher goal (super-goal)
- "OR decomposition" (at least one sub- goal must be fulfilled in order to fulfill the higher goal (super-goal)

Such decomposition relationships between goals are frequently documented in the form of and/or trees.

EU 6.3 Use Cases (L2)

Use cases help to examine and document a planned or existing system, from users perspective. The use case approach is based on two complementary documentation techniques:

- Use case diagrams
- Use case specifications

Use case diagrams are simple models to document the functions of a system from a user's perspective and to document the interrelations of the functions of a system and the relations between these functions and the systems context. Typical modeling elements for use case diagrams are:

- Actors (people or other systems) in the system context
- The system boundary
- Use cases
- Various types of relationships between these modeling elements

Use case specifications complement the overview-like use case diagrams through a more precise specification of the essential characteristic of individual use cases. For this purpose, a predefined template is generally filled in for each relevant use case separately. Typical sections of such a template include:

- Unique designation of the use case
- Name of the use case
- Description of the use case
- Triggering event
- Actors
- Result
- Pre- and post-conditions
- Various kinds of scenarios. Scenarios describe typical event sequences which lead to the successful execution of the use case (main scenarios, alternative scenarios) or explicitly describe how, during the execution of the use case, exceptional situations should be handled (exception scenarios).

EU 6.4 Three Perspectives on Requirements (L1)

Within the scope of model-based documentation, requirements for the system to be developed are modeled in three overlapping modeling perspectives:

- Data perspective
- Functional perspective
- Behavioral perspective

For the data perspective, typical examples in conceptual modeling languages are entity relationship models and UML class diagrams. For the functional perspective, data flow diagrams or UML activity diagrams (with object flows between actions) are frequently used. For the behavioral perspective, typical examples in conceptual modeling languages are finite state automata or statecharts.

EU 6.5 Requirements Modeling in the Data Perspective (L2)

In the data perspective, for example, the structure of data is documented as well as usage and dependency relationships in the system context. Traditionally the data perspective is modeled using entity relationship diagrams, which document the structure of the reality to be modeled using three modeling elements:

- Entity types
- Relationship types
- Attributes

Furthermore, the frequency by which an instance (entity) of an entity type participates in a relationship of a specific relationship type can be documented using cardinalities.

UML class diagrams are a common approach to modeling the data perspective of requirements. A class diagram consists of a set of classes and associations between these classes. In this context, frequently used modeling elements of UML class diagrams are:

- Classes
- Associations (with multiplicities and roles)
- Aggregation and composition relationships
- Generalization relationships

EU 6.6 Requirements Modeling in the Functional Perspective (L2)

The functional perspective of requirements deals with the transformation of input data received from the environment into output data released into the environment of the system. Approaches to modeling the functional perspective include function models. Frequently, as for example in Tom DeMarco's "Structured Analysis", data flow diagrams are used as function models. The graphical representation of a system with its system context is called context diagram; in particular data flow diagrams are also called context diagrams if they are used to define the system boundary.

The modeling elements of data flow diagrams are:

- Processes
- Data flows
- Data stores
- Sources/sinks

Since in data flow diagrams no control flow, for example, or the internal workings of processes are shown, so data flow diagrams are supplemented with additional, structured forms of description. For example, in a mini-specification from structured analysis, the internal behaviors of processes are defined.

In UML 2.0 data flows are represented by the explicit modeling of object flows in activity diagrams and so these correspond best to the data flow diagrams. Among other things, activity diagrams model activity nodes and control flows between activity nodes. Object flows represent a special form of control flow. Synchronization bars in activity diagrams allow the modeling of concurrent control and object flows. Alternative control and object flows can be described using decision nodes.

The essential modeling elements in UML 2.0 activity diagrams are:

- Actions
- Start and end nodes
- Control flow
- Object flow
- Decision nodes
- Merge of alternative control flows
- Fork (concurrency)
- Join (concurrency)
- Hierarchization elements

EU 6.7 Requirements Modeling in the Behavioral Perspective (L2)

In requirements modeling, the dynamic behavior of a system is modeled in the behavioral perspective. In this perspective the focus lies on the various states in which a system can be found and on the events that are responsible for a change of state. In UML state diagrams, which are based on the principles of finite state machines, the following modeling elements are used:

- State
- Start and end states
- State transition
- Concurrency

EU 7 Requirements validation and negotiation (L2)

Duration: 2 ½ hours
Terms: none

Educational Objectives

EO 7.1.1	Knowing the significance of validating requirements
EO 7.2.1	Knowing the significance of conflicts with regard to requirements
EO 7.3.1	Knowing the three quality aspects of requirements
EO 7.3.2	Mastering and using validation criteria for the quality aspects "content", "documentation" and "agreement"
EO 7.4.1	Knowing the six principles for requirements validation
EO 7.4.2	Mastering and using the principles of requirements validation
EO 7.5.1	Knowing techniques for requirements validation
EO 7.5.2	Mastering and using the validation techniques: commenting (expert opinion), inspection, walkthrough, perspective-based reading, validation via prototypes and use of checklists
EO 7.6.1	Knowing activities for requirements negotiation
EO 7.6.2	Knowing the types of requirements conflicts
EO 7.6.3	Knowing the various conflict resolution techniques
EO 7.6.4	Knowing the documentation for conflict resolution

EU 7.1 Fundamentals of Requirements Validation (L1)

The objective of requirements validation is to validate whether requirements satisfy the defined quality criteria (see EU 4.6) in order to detect and correct any errors in the requirements as early as possible in RE. Since requirements documents are the basis for the further development activities, errors in the requirements affect all further development activities so much that the effort to correct an undetected requirements error increases significantly in the course of development. The reason for this is that not only the actual error in the requirements must be corrected, but also that all artifacts based on this must be reworked, e.g. architecture design, implementation, test cases.

EU 7.2 Fundamentals of Requirements Negotiation (L1)

Unresolved conflicts in a system's requirements mean, for example, that one group of stakeholders' requirements cannot be implemented or that the operational system is either not accepted or not sufficiently used. The goal of negotiating requirements is to develop, among the relevant stakeholders, a common and agreed understanding with respect to the requirements for the system to be developed.

EU 7.3 Quality Aspects for Requirements (L2)

A distinction is drawn between three quality aspects for requirements (content, documentation and agreement), whereby the quality of a requirement or set of requirements, in respect of the individual quality aspects, can each be assessed by means of a series of validation criteria.

For the quality aspect "content”, the eight validation criteria are:

- Completeness of the requirements document
- Completeness of the individual requirements
- Traceability
- Correctness and adequacy
- Consistency
- No premature design decisions
- Verifiability
- Necessity

For the quality aspect "documentation”, the four validation criteria are:

- Conformity to document format and document structures
- Understandability
- Unambiguity
- Conformity to documentation rules

For the quality aspect "agreement”, the three validation criteria are:

- Agreed
- Agreed after changes
- Conflicts resolved

EU 7.4 Principles of Requirements Validation (L2)

The validation of requirements is based on various principles. These principles ensure that during validation as many errors as possible can be identified in the requirements. The six principles for requirements validation are:

- Involvement of the correct stakeholders
- Separating the diagnosis and the correction of errors
- Validation from different views
- Adequate change of documentation type
- Construction of development artifacts that are based on requirements
- Repeated validation

EU 7.5 Techniques for Requirements Validation (L2)

There are several techniques for systematic validation of requirements, which are also partly used in addition to each other, in order to verify requirements against defined validation criteria as comprehensively as possible. Techniques for requirements validation are:

- Commenting (expert opinion)
- Inspections
- Walkthroughs

The following additional techniques are used:

- Perspective-based reading
- Validation through prototypes
- Usage of checklists

EU 7.6 Requirements Negotiation (L1)

Negotiating requirements aims at establishing a common understanding of the requirements for the system to be developed among all relevant stakeholders. The tasks in the negotiation of requirements are:

- Conflict identification
- Conflict analysis
- Conflict resolution
- Documentation of conflict resolutions

During the conflict analysis various conflict types are distinguished, in respect to the requirements, which require various strategies for conflict resolution. The various conflict types are:

- Interest conflict – Stakeholders have factually different needs or divergent personal interests (note that this conflict type includes conflicts of both objective and subjective nature. Objective interest conflicts root in factually different stakeholder needs, while subjective ones are caused by divergent personal interests of involved people.)
- Data conflict– Stakeholders interpret given information differently or have information deficits.
- Value conflict – Stakeholders have divergent values and preferences
- Relationship conflicts – There are emotional problems in personal relationships between stakeholders
- Structural conflict – Conflict roots in stakeholders being on different hierarchy and decision power levels in an organization

In practice, the causes of conflict are frequently mixed. In the resolution of a conflict, all relevant stakeholders should be considered. For conflict resolution there exist a number of conflict resolution techniques, namely:

- Agreement
- Compromise
- Voting
- Definition of variants
- Overruling
- Consider-all-facts
- Plus-minus-interesting
- Decision matrix

After resolving the conflict, the conflict should be suitably documented. This should record, in particular, the cause of the conflict, the involved stakeholders, the opinions of the various stakeholders, the means of resolving the conflict, potential alternatives, the decisions and the reasons for the decisions.

EU 8 Requirements Management (L2)

Duration: 2 ½ hours
Terms: none

Educational Objectives

EO 8.1.1 Knowing the purpose and definition of attribute schemes
EO 8.1.2 Knowing important attribute types for requirements
EO 8.2.1 Mastering and using views on requirements
EO 8.3.1 Knowing methods for prioritizing requirements
EO 8.3.2 Mastering and using techniques for prioritizing requirements
EO 8.4.1 Knowing the benefits of requirements traceability
EO 8.4.2 Mastering and using classes of traceability relationships
EO 8.4.3 Mastering and using forms of representation for traceability relationships
EO 8.5.1 Mastering and using versioning of requirements
EO 8.5.2 Mastering and using the formation of requirements configurations
EO 8.5.3 Mastering and using the formation requirements baselines
EO 8.6.1 Knowing the importance of requirements changes
EO 8.6.2 Knowing the functions and members of a Change Control Board
EO 8.6.3 Mastering and using the elements of a requirements change request
EO 8.6.4 Mastering and using different classes of change requests
EO 8.6.5 Mastering and using a process to handle change requests

EO 8.7.1 Knowing the importance of requirements measurements

EU 8.1 Assigning Attributes to Requirements (L1)

To manage the system’s requirements over the whole lifecycle of the system, it is necessary to collect requirements’ information as attributes in as structured a way as possible. The definition of the attribute structure for requirements is done through an attribute scheme, which can be defined either in tabular form or in the form of an information model.

Typical attributes are:

- Identifier
- Name
- Description
- Source
- Stability
- Risk
- Priority

The "legal obligation" can also be saved as additional requirement’s information in the form of an attribute.

Attribute schemes are frequently defined and adapted for a specific project on the basis of specific conditions. This includes:

- Specific properties of the project
- Constraints of the organization
- Domain rules
- Constraints of the development process

EU 8.2 Views on Requirements (L2)

In practice, the amounts of requirements in a project and the number of dependencies among these requirements are evermore increasing. In order to keep the complexity of the requirements manageable for the project staff, it is necessary to selectively access and thereby filter the requirements depending on the current task. Two kinds of view formation are distinguished:

- Selective views: showing a subset of the attribute values from requirements selected by defined selection criteria
- Condensed views: showing condensed information about requirements selected by defined selection criteria

EU 8.3 Prioritizing Requirements (L2)

Requirements are prioritized, at various times and during various activities, according to various criteria. Preparing prioritization of requirements is based on a simple system:

- Determining the goals and constraints for the prioritization
- Determining the prioritization criteria
- Determining the relevant stakeholders
- Selection of the artifacts to be prioritized

Based on the results of these activities, one or more techniques for prioritization are selected and the prioritization itself carried out. Among the prioritization techniques are:

- Ranking and top-ten technique
- Single-criterion classification
- Kano classification
- Prioritization Matrix According to Wiegers

EU 8.4 Requirements Traceability (L2)

Within the management of requirements, the requirements' traceability information is recorded, organized and maintained.

The benefits of requirements traceability involves:

- Simplification of verifiability
- Identification of unneeded properties in the system
- Identification of unneeded requirements
- Support of impact analysis
- Support of reusability
- Support of determination of accountability
- Support for maintenance and administration

With respect to the requirements' traceability relationships, three classes of traceability relationships are distinguished:

- Pre-requirements-specification traceability
- Post-requirements-specification traceability
- Traceability between requirements

Only such information should be recorded for which there exists a clear use. The traceability of requirements can be represented in various ways. Typical representation forms are:

- Text-based references and hyperlinks
- Trace matrices
- Trace graphs

EU 8.5 Versioning of requirements (L2)

Requirements' versioning and configuration makes it possible, over the lifecycle of a system or product, to have specific development states of requirements and requirements documents available. The version number of a requirement has at least two components:

- Version
- Increment

A requirements configuration comprises a defined set of logically related requirements, whereby at most one version of each requirement is contained in the requirements configuration. The formation of requirements configurations are defined in two dimensions:

- Product dimension: the individual requirements of the requirements foundation
- Version dimension: the various change states of a requirement

Requirements configurations have several typical properties:

- Logical connection of the requirements in a configuration
- Consistency of the requirements within a requirements configuration
- Unique identifier of the requirements configuration
- Immutability of the requirements within the requirements configuration
- Basis for rollbacks to earlier versions of the requirements base

Requirements baselines are specific requirements configurations, which comprise stable versions of requirements and often define the delivery increments of the system (system releases) as well.

EU 8.6 Management of Requirements Changes (L2)

Requirements change over the entire lifecycle of a system. The changes to the requirements are managed and processed in a systematic change management process. In this change management process, the Change Control Board is responsible for processing the incoming change requests. The tasks of the Change Control Board are:

- Classification of incoming change requests
- Determination of the effort for performing the change
- Assessment of the change requests in respect to effort-benefit
- Definition of new requirements based on incoming change requests
- Deciding whether to accept or reject a change request
- Prioritization of the accepted change requests
- Assign accepted change requests to change projects

Typical member of the Change Control Board are the change manager, contractor, architect, user representative, quality manager and requirements engineer.

If changes to requirements are deemed necessary, these are documented in the form of change requests and submitted to the Change Control Board. A change request contains at least the following information:

- Identifier of the change request
- Title of the change request
- Description of the necessary change
- Justification of the need for the change
- Date filed
- Applicant
- Priority of the change as seen by the applicant.

There are three types of change requests:

- Corrective changes
- Adaptive changes
- Exceptional changes

The process of change management provides the following steps:

- Impact analysis and assessment of the change
- Prioritization of the change request
- Assignment of the change to a change project
- Communication of the acceptance/rejection of the change request

EU 8.7 Measurement for Requirements (L1)

Based on the requirements validation and management information such as errors, attributes, traces or changes, the quality of the requirements documents and processes can be analyzed. This enables the identification of improvement possibilities. Typical measurements include

- Requirements change rates
- Requirements errors

EU 9 Tool Support (L1)

Duration: 1 hour
Terms: none

Educational Objectives

EO 9.1	Knowing the eight features of a requirements management tool
EO 9.2	Knowing the five aspects in the introduction of requirements engineering tools
EO 9.3	Knowing the seven views of requirements engineering tools

EU 9.1 Types of Tools (L1)

Many system development tools can also support RE, e.g. test management or configuration management tools, Wikis, office software or visualization software. Also modeling tools are important for RE in order to create and analyze information as models. Requirements management tools are intended only for RE. They should feature the following characteristics:

- manage various information
- manage logical relationships between information
- identify artifacts uniquely
- make information accessible flexibly and securely, e.g. through access control
- support views over the data
- organize the information, e.g. through assignment of attributes and formation of hierarchies
- generate reports over the information
- generate documents out of the information

Standard office tools support these features only to a limited extent, specialized tools refine these, e.g. through traceability management.

EU 9.2 Introducing Tools (L1)

Only after the introduction of RE procedures and techniques can an appropriate tool be sought. The tool introduction requires clear RE responsibilities and procedures. In the process, the following aspects are to be considered:

- Consider necessary resources
- Avoid risks by means of pilot projects
- Evaluation according to defined criteria
- Take into account costs beyond license costs
- Instruct employees

EU 9.3 Evaluating Tools (L1)

The variety of aspects to be considered when evaluating RE-tools can be structured using the following seven views:

- Project view (e.g. support for project planning)
- User view (especially usability)
- Product view (functionality)
- Process view (methodological support)
- Provider view (e.g. vendor services)
- Technical view (e.g. interoperability, scalability)
- Economic view (costs)

Clear criteria are to be defined for each view.