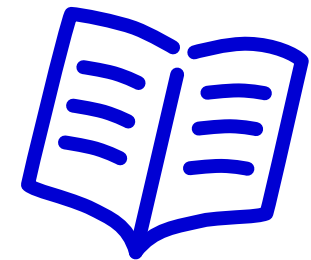


Requirements Engineering I

Chapter 3

Documenting Requirements





Chapter roadmap

Work products

3.1

The results of RE work

Classic specs

3.2

Classic requirements
documentation

RE in agile

3.3

Agile work products

Glossary

3.4

Why terminology matters

Prototypes

3.5

What you see is what you get

Aspects to be documented

3.6

More than just functionality

How to document

3.7

Standards, templates, formality,
precision, detail, depth

Quality

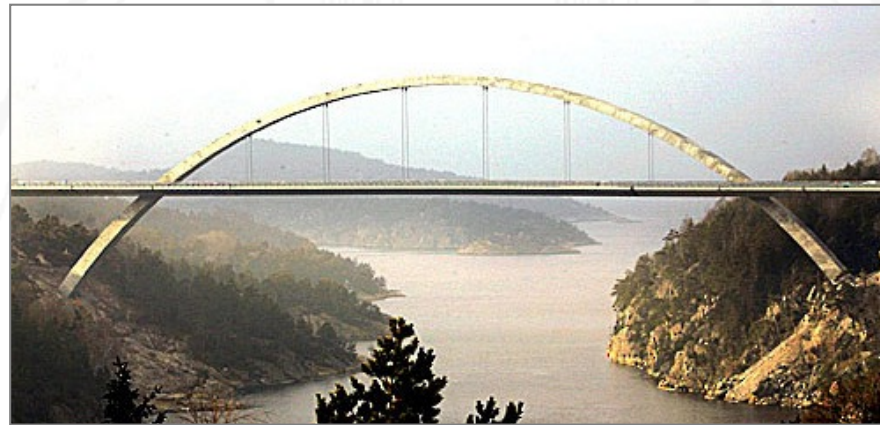
3.8

of requirements and work products

Motivation

Bridging the gap:

Stakeholders



System builders

Photo © Lise Aserud / DPA

The need:

- Communicating requirements
- Having a basis for contracts and acceptance decisions

The means: Documented requirements

3.1 Requirements Engineering work products

DEFINITION. **Work product** – A recorded, intermediate or final result of information generated in a work process.

Synonym: **artifact**

Work products are characterized by their

- **Purpose**
- **Representation** (free text, structured text, lists, graphics, drawings,...)
- **Size** (single requirements, sets of requirements, documents (or document-like structures))
- **Lifespan** (temporary, evolving, durable)

Note that a work product may contain other work products

Work products and their purposes

Single requirements

- **Sentence** in natural language – expressing an individual requirement

The control system shall prevent engine overspeed.

- **User story** – specifying a function or behavior from a stakeholder's perspective

As a skier, I want to pass the chairlift gate so that I get access without presenting, scanning or inserting a ticket at the gate.

Work products and their purposes – 2

Sets of requirements

- **Use case** – specifying a system function from a stakeholder’s perspective

- **Graphic model** – specifying various aspects, e.g., context, activity, behavior

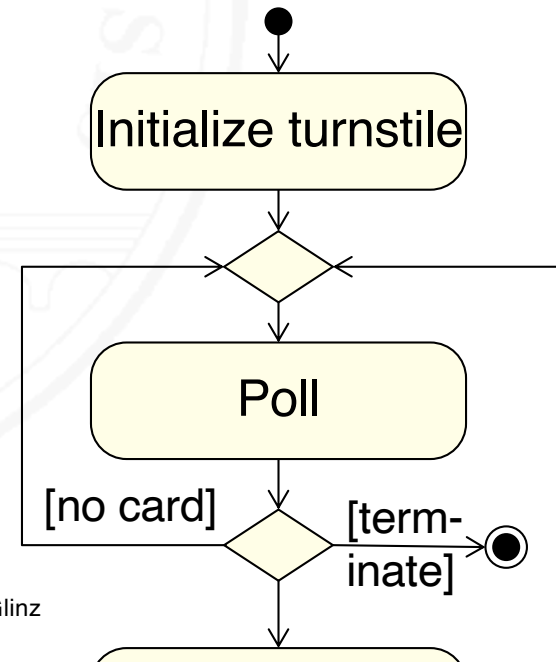
USE CASE SetTurnstiles

Actor: Service Employee

Precondition: none

Normal flow:

- 1 Service Employee chooses turnstile setup. System displays controllable turnstiles: locked in red, normal in green, open in yellow
- 2 Service Employee selects turnstiles s/he wants to modify. (...)



Work products and their purposes – 3

Sets of requirements

[Lauesen 2002]

- **Task description** – specifying a task to perform

Task:	2.1 Record time actually worked
Goal:	Provide basis for calculation and flex time
Frequency:	Most work is done according to the official plan. Deviations from the plan may happen very two weeks for each person.
Critical:	Nothing really.
Sub-tasks:	Example of solution:
1 Record work time (...)	Staff record deviating work time in the online roster. Alternatively, (...)

- **External interface** – specifying the information exchanged between a system and an actor in the system context

Desired_speed	IN	Integer (16 Bit)
Pedal_override	IN	Flag
Cruise_on	OUT	Flag

Work products and their purposes – 4

- **Epic** – providing a high-level view of a stakeholder need

Let users create and manage their profile themselves.

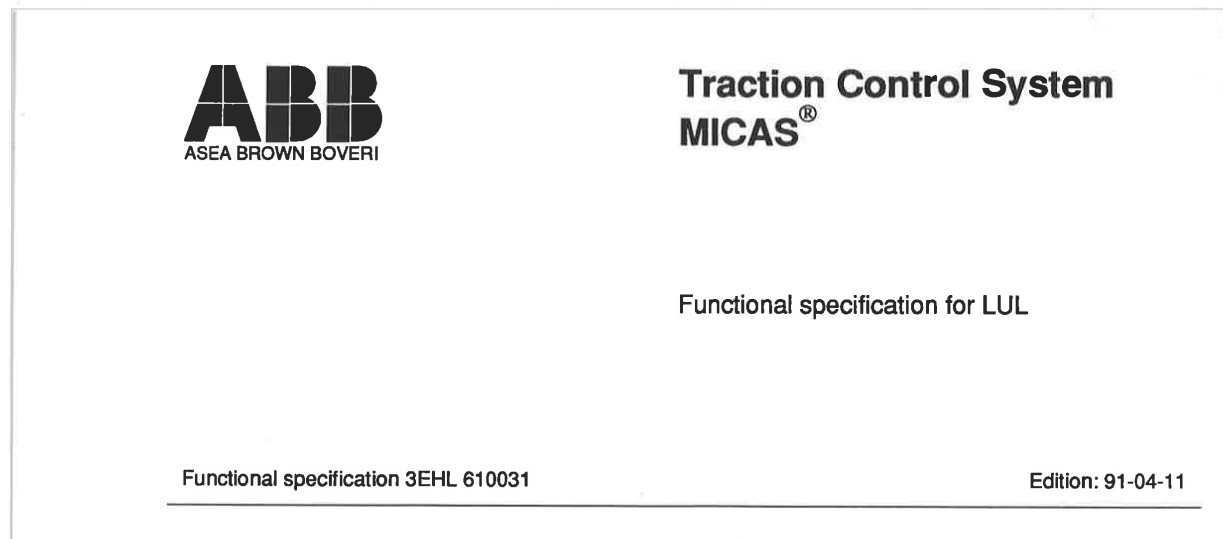
- **Feature** – A distinguishing characteristic of a system that provides value for stakeholders

Order history is downloadable by subscribers.

Work products and their purposes – 5

Documents and document-like structures

- System requirements specification, business requirements specification, stakeholder or user requirements specification – providing a baselined or released requirements document



Work products and their purposes – 6

Documents and document-like structures

- **Product and sprint backlog** – managing a list of work items, including requirements

Pos	ItemID	Type	Content	Size
1	US-103	User Story	As a runner, I want to register at the portal to use the app.	L
2	US-107	User Story	As a runner, I want to configure my training parameters to prepare my first training.	XL
...				
18	US-243	User Story	As a coach, I want to see the runner's speed and heart rate in real time so that I can recognize when the runner is pushing too hard during a training session.	M
...				
31	T-2	Technical	Implement the training data transfer between app and portal.	M
...				

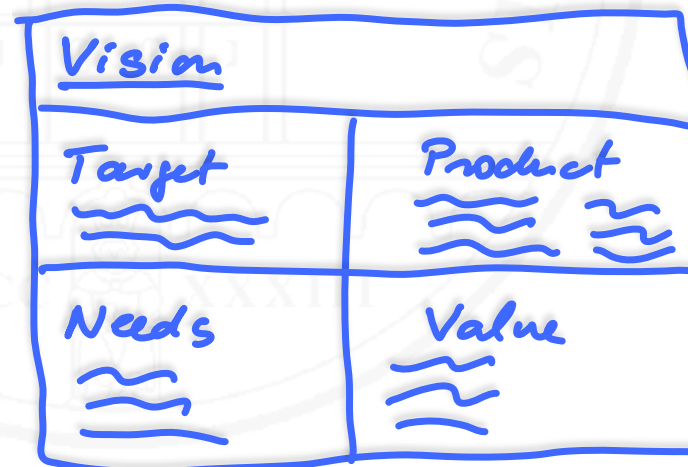
Work products and their purposes – 7

- **Story map** – visual arrangement of user stories

Marketplace

Find merchandise		Select merchandise		Purchase merchandise
FWCYL-E-21 Open Fredwin Cycling app	FWCYL-E-22 Search for products	FWCYL-E-23 View product details	FWCYL-E-24 Add to cart	FWCYL-E-25 Review order
FWCYL-372 Add marketplace to app navigation	FWCYL-373 Search for product name	FWCYL-376 View product description	FWCYL-378 Select quantity	FWCYL-381 Select delivery method
	FWCYL-374 Search for product category	FWCYL-377 View product images	FWCYL-396 Add to cart	FWCYL-382 Proceed to checkout
	FWCYL-375 Search by partner / brand	FWCYL-395 See reviews	FWCYL-380 Continue shopping	FWCYL-383 Remove from cart

- **Vision** – a conceptual imagination of a future system or product



Work products and their purposes – 8

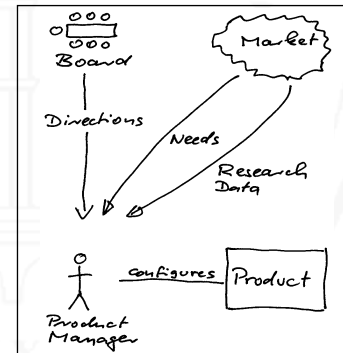
Other RE-related work products

- **Glossary** – providing an unambiguous and agreed common terminology
- **Textual note** or **graphic sketch** – serving for communication and understanding
- **Prototype** – understanding or validating requirements

Safety shutdown — A situation where the operation of a device has to be shut down immediately due to the violation of a safety condition.

Abbreviation: SSD

Synonym: Emergency shutdown (ESI)



3.2 Classic requirements specifications

Full-fledged requirements specifications are typically needed

- When customers want **contractually fixed** requirements, costs and deadlines
- When systems are built by an **external contractor** based on a set of given requirements (**tendering, outsourcing**)
- In **regulated environments** where regulators check compliance of developed systems to their requirements

Document types

[ISO/IEC/IEEE 2018]

- **Stakeholder requirements specification** (also called **customer requirements specification**; *Lastenheft* in German)
What the **stakeholders want** (independent of any system providing it)
- **System requirements specification** (*Pflichtenheft* in German)
The **system or product to be developed** and its context
- **Software requirements specification**
If the system is a **pure software system**
- **Business requirements specification**
High-level specification of business needs or goals

Stakeholder requirements specification

- Written when **stakeholder needs** shall be documented before any system development considerations are made
- Typically written by **domain experts** on the **customer** side (maybe with help of RE consultants)
- If a stakeholder requirements specification is written, it **precedes** and **informs** system or software requirements specifications

System/software requirements specification

- The **classic** form of a requirements specification
- **No methodological difference** between **system** requirements specification and **software** requirements specification
- Typically written by **requirements engineers** on the **supplier** side

Mini-Exercise

To which type of specification do the following requirements belong:

- System/software requirements specification?
- Stakeholder/user requirements specification?
- Business requirements specification?

(a) As a chairlift manager, I want daily statistics about chairlift usage so that I have data for my business decisions.

(b) The new system shall reduce ticket handling costs by $> 20\%$ and increase sales by $> 5\%$.

(c) The system shall operate under harsh weather conditions (snowfall, strong wind, temp range of -30° to $+36^{\circ}$ C).

3.3 Requirements in agile development

No classic requirements specification document (unless mandated by regulators)

Various work products that ...

- ... specify requirements: vision, user stories, epics, use cases, models...
- ... have requirements-related content: Prototypes, mock-ups, storyboards, roadmap, early product versions (e.g., MVP – minimum viable product)

Value-driven creation of work products

3.4 Glossary

RE typically is a multi-person endeavor

→ Danger of **missing shared understanding** in terminology

DEFINITION. **Glossary** – A collection of definitions of terms that are relevant in some domain.

A glossary defines

- Context-**specific terms**
- **Everyday terms** that have a **special meaning** in the given context
- **Abbreviations** and **acronyms**

Safety shutdown — A situation where the operation of a device has to be shut down immediately due to the violation of a safety condition.

Abbreviation: SSD

Synonym: Emergency shutdown (ESD)

Rules for creating and maintaining a glossary

- Consistently **structured**
- Centrally **managed**
- Defined **responsibilities** for creation and maintenance
- **Maintained** over the entire course of a project
- Usage of terms as defined in the glossary is **mandatory**
- Stakeholders must **agree** upon the glossary
- Synonyms and Homonyms properly treated
 - **Synonyms** (different terms denoting the same thing) marked
 - **Homonyms** (same term for different things) avoided or marked

3.5 Prototypes

DEFINITION. **Prototype** – In software and systems engineering: A preliminary, partial realization of certain characteristics of a system.

Serves for **exploring**, **communicating** or **validating** concepts and requirements.

The realization may be in **any physical form**, from paper and sticky notes over clickable pages to executable source code.

In RE, a prototype is a means for

- **specifying** requirements **by example**
- **validating** requirements
- **supporting** stakeholder **communication** and **shared understanding**

Forms of Prototypes in RE

[Lichter et al. 1994]

- *Exploratory prototype:*
 - Creating **shared understanding**
 - **Clarifying** requirements
 - **Validating** requirements on different levels of fidelity
 - **Thrown away** after use

- *Evolutionary prototype:*
 - **Pilot system** forming the **nucleus** of a system to be developed
 - Final system **evolves** by incrementally extending and improving the prototype

Exploratory prototypes

○ *Wireframe*

- Low-fidelity prototype
- Built with paper or other **simple materials**
- Primarily serves for discussing and validating **design ideas** and user **interface concepts**

○ *Mock-up*

- Medium-fidelity prototype
- Demonstrates **characteristics of a user interface** without implementing any real functionality
- Real screens and click flows, but without functionality behind
- Building a mock-up may be **automated** with tools or GenAI
- Primarily serves for specifying and validating **user interfaces**

Exploratory prototypes – 2

○ *Native prototype*

- High-fidelity prototype
- **Implements critical parts** of a system to an extent that stakeholders can work with the prototype
- **GenAI can help** with fast creation of native prototypes
- Primarily serves for validating that the prototyped part of the system will **work and behave as expected**

Exploratory prototypes can be **expensive** work products

- Choose proper level of fidelity
- Trade-off between cost and value gained

Mini-Exercise

What forms of prototypes do we have here?

(a)

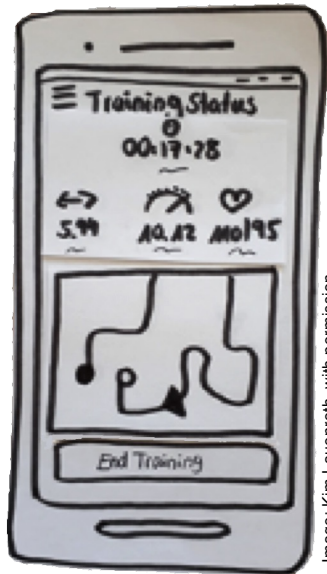
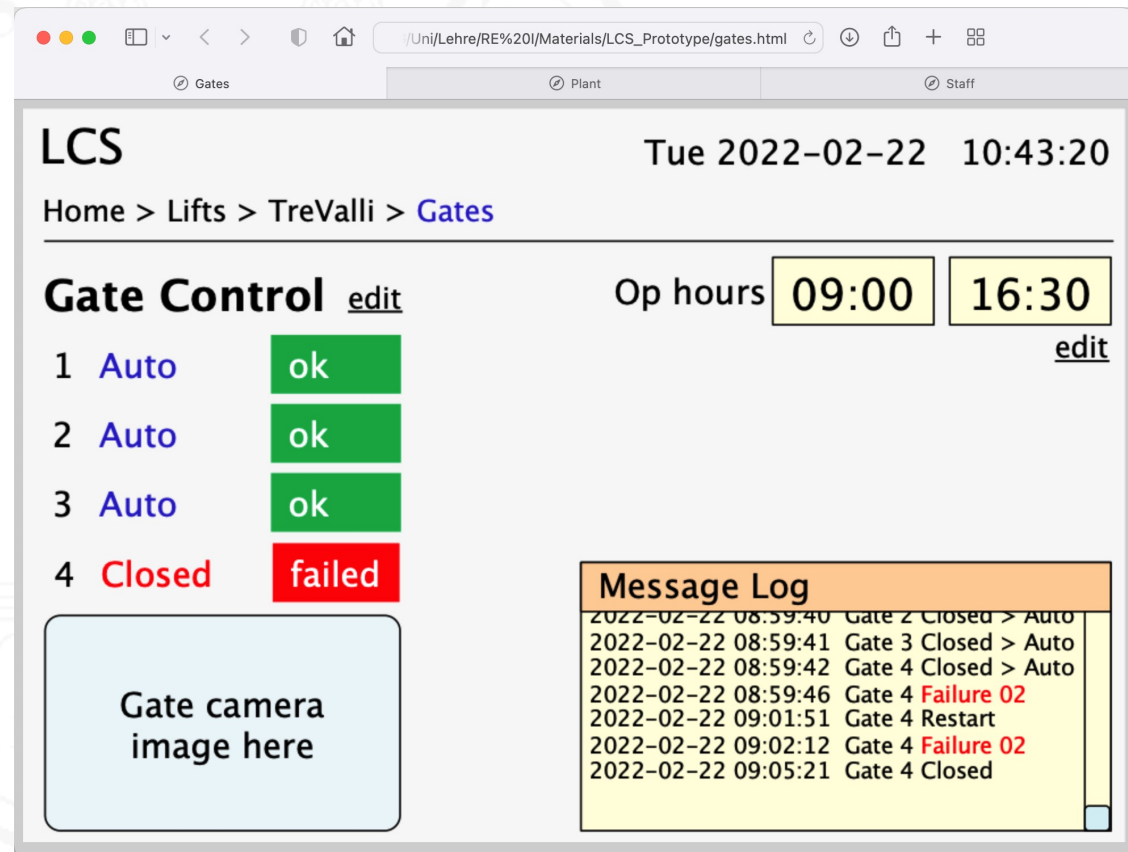


Image: Kim Lauenroth, with permission

(b)



3.6 Aspects to be documented

Independently of any language, method, and documentation style, **four aspects** need to be documented:

- **Functionality**
 - **Structure and Data:** Static structure, (persistent) data
 - **Function and Flow:** Functions (results, preconditions, processing), flow of control and data
 - **State and Behavior:** State-dependent dynamic system behavior as observable by users
 - Both **normal** and **abnormal cases** must be specified

Aspects to be documented – 2

○ Quality

Performance

- Data volume
- Reaction time
- Processing speed
- Specify measurable values if possible
- Specify more than just average values

Specific Qualities

- “-ilities” such as Usability, Reliability, Availability, etc.

Aspects to be documented – 3

○ Constraints

Restrictions that must be obeyed / satisfied

- **Technical**: given interfaces or protocols, etc.
- **Legal**: laws, standards, regulations
- **Organizational**: given structures, policies, processes
- **Cultural**: culturally shaped user habits and expectations
- **Environmental**: e.g., energy consumption, heat dissipation
- **Physical**: laws of physics, properties of materials
- **Solutions / restrictions** demanded by important stakeholders

Aspects to be documented – 4

- **Context and Boundary**
 - Domain requirements and domain assumptions in the context of a system
 - Embedding of a system in its context
 - Interaction between a system and the actors in the context

3.7 How to document

Sample standards for classic requirements documents

ISO/IEC/IEEE Std 29148

- Templates for business, stakeholder, system & software specs
- Flat and rather unsystematic → not such useful

VOLERE

- System and project requirements in 27 chapters

IREB

- Simple template for system/software requirements specs

Enterprise-specific standards

- Imposed by customer or given by supplier

ISO/IEC/IEEE 29148 Standard

[ISO/IEC/IEEE 2018]

1. Introduction

- 1.1 System purpose
- 1.2 System scope
- 1.3 System overview
 - 1.3.1 System context
 - 1.3.2 System functions
 - 1.3.3 User characteristics

2. References

3. System requirements

- 3.1 Functional requirements
- 3.2 Usability requirements
- 3.3 Performance requirements
- 3.4 Interface requirements
- 3.5 System operations
- 3.6 System modes and states
- 3.7 Physical characteristics

3.8 Environmental conditions

3.9 Security requirements

3.10 Information management requirements

3.11 Policy and regulation requirements

3.12 System lifecycle sustainment requirements

3.13 Packaging, handling, shipping and transportation requirements

4. Verification

(parallel to subsections in Sect. 3)

5. Appendices

5.1 Assumptions and dependencies

5.2 Acronyms and abbreviations

Project Drivers

1. The Purpose of the Project
2. The Stakeholders

Project Constraints

3. Mandated Constraints
4. Naming Conventions and Terminology
5. Relevant Facts and Assumptions

Context and Functionality

6. The Scope of the Work
7. Business Data Model & Data Dictionary
8. The Scope of the Product
9. Functional Requirements

Non-Functional Requirements

10. Look and Feel Requirements
11. Usability and Humanity Requirements
12. Performance Requirements
13. Operational & Environmental Requirements

14. Maintainability and Support Requirements
15. Security Requirements
16. Cultural Requirements
17. Compliance Requirements

Project & Product Issues

18. Open Issues
19. Off-the-Shelf Solutions
20. New Problems
21. Tasks
22. Migration to the New Product
23. Risks
24. Costs
25. User Documentation and Training
26. Waiting Room
27. Ideas for Solutions

Subtitles added by MG, inspired by an earlier version of the template

IREB – A simple document template

[Glinz et al. 2024]

Part I: Introduction

1. System purpose
2. Scope of system development
3. Stakeholders

Part II: System Overview

4. System vision and goals
5. System context and boundary
6. Overall system structure
7. User Characteristics

Part III: System requirements

Organized hierarchically
according to system structure

Per sub-system/component:

- Functional requirements
(structure and data – function
and flow – state and behavior)
- Quality requirements
- Constraints
- Interfaces

References

Appendices

- Glossary
- Assumptions and
dependencies

Mini-Exercise

Where do the following requirements fit best in the IREB template?

- (1) “The system shall provide effective access control to the resort’s chairlifts.”
- (2) “The turnstile control software shall count the number of ‘unlock for a single turn’ commands that it issues to the controlled turnstile.”

Documenting agile requirements

- General guideline: do things only if they **add value**
 - A simple approach:
 - Writing **user stories** (using a standard template; cf. Chapter 6)
 - Adding detail with **acceptance criteria**
 - Structuring stories with **epics** and **features**
 - Organizing stories in a **product backlog**
- Implementation-oriented approach
- Does not scale well to settings with > 1 agile team

[Leffingwell 2011]

Scaled agile requirements documentation

An approach that scales

- Requirements @ **business / system level**:
 - System **vision**
 - For **business** systems: Models of **business processes & data**
 - For **technical** systems: Models of system **behavior & functions**
 - **Domain models**
 - Textual quality requirements and constraints
- Requirements @ **user level**: Use cases – value for users
- Work products **persistently** stored in a structured **repository**
→ preserves the **value** of the requirements

Scaled agile requirements documentation – 2

Mapping to agile development: **story mapping**

- **Decomposing** the business/system perspective
- **Mapping** use cases to **user stories** & **acceptance criteria**
- **Structuring** into **epics** and **features**
- **Prioritizing** and **determining** sequence of implementation
- **Coordinating** agile teams

How to document – language options

Informally

- Plain natural language (narrative text)

Semi-formally

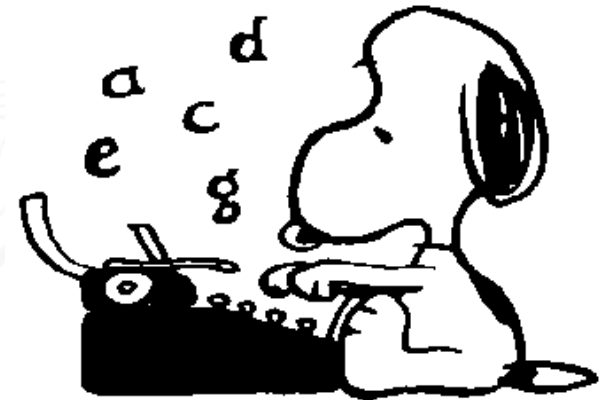
- Structured natural language (using templates or forms)
- Graphic models Typically as diagrams which are enriched with natural language text

Formally

- Formal models, typically based on mathematical logic and set theory

General rules for requirements documentation

- Specify requirements as **small, identifiable units** whenever possible
- Record **metadata** such as source, author, date, status
- Use **structure templates**
- Adapt the degree of detail to the **risk** associated with a requirement
- Specify **normal** and **exceptional** cases
- Don't forget **quality requirements** and **constraints**



© UFS, Inc.

Precision – Detail – Depth

Three dimensions:

How precise?

How deep, i.e., how many layers?

Dimensions influence each other:

- More precision → more detail
- More detail → more depth

How much detail?

Precision: reduce ambiguity

Restrict your language

Use a glossary

Define acceptance test cases

Quantify where appropriate

Formalize



Snoopy quantifies a love letter

Detail

What's better?

“The participant entry form has fields for name, first name, sex, ...”

“The participant entry form has the following fields (in this order): Name (40 characters, required), First Name (40 characters, required), Sex (two radio buttons labeled male and female, selections exclude each other, no default, required),...”

It depends.

- Degree of **implicit shared understanding** of problem
- Degree of **freedom** left to designers and programmers
- **Cost vs. value** of detailed specification
- The **risk** you are willing to take


The risk of specifying too little detail

What the customer specified

“The registration entry form shall have fields for name, first name, salutation, birthday, and address and a submit-button.”

What the supplier delivered

Birthday	<input type="text"/>
Name	<input type="text"/>
First Name	<input type="text"/>
Salutation	<input type="text"/>
Address	<input type="text"/>



Depth

The more precise, the more information is needed

→ Preserve readability with a hierarchical structure

“
...

4.3 Administration of participants

4.3.1 Entering a new participant

4.3.1.1 New participant entry form

4.3.1.2 New participant confirmation

4.3.2 Updating a participant record

”
...

3.8 Quality of documented requirements

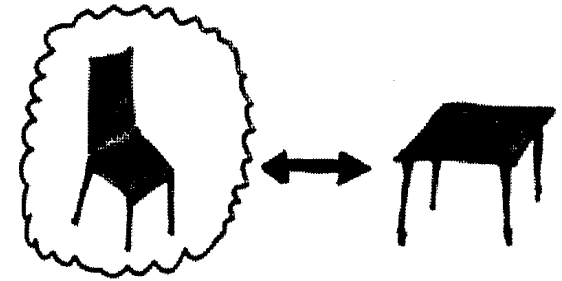
Two aspects of requirements quality

- Quality of **individual** requirements
- Quality of requirements **work products**, for example, a requirements specification



Hint: Don't confuse **quality of requirements** with **quality requirements**

Quality of individual requirements



For **individual** requirements, strive for requirements that are...

- **Adequate** True and agreed stakeholder needs
- **Understandable** Prerequisite for shared understanding
- **Verifiable** Conformance of implementation can be checked
- **Unambiguous** True shared understanding
- **Complete** No missing parts
- **Necessary** Part of the relevant system scope
- **Feasible** Non-feasible requirements are a waste of effort

Quality of requirements work products



When creating a requirements work product, strive for a **work product** that is

- **Consistent**
No contradictions
- **Complete**
Contains the relevant requirements
- **Conformant**
Conforms to prescribed work product structure, format or style
- **Modifiable**
Because change will happen
- **Non-redundant**
Requirements do not overlap
- **Structured**
Improves readability of work product
- **Traceable**
Linked to related artifacts

Quality criteria are in the eye of the beholder

- No general consensus
- **Different, overlapping** sets of quality criteria used in
 - this course
 - RE textbooks
 - RE standards (e.g., ISO/IEC/IEEE 29148:2018)
 - Quasi-standards such as the IREB Certified Professional for Requirements Engineering (see <https://www.ireb.org>)

Not all qualities are equally important

- Adequacy and understandability are key
- Verifiability and consistency are very important
- Achieving total completeness and unambiguity is neither possible nor economically feasible in most cases
- The importance of feasibility, traceability, conformance, etc. of requirements depends on the concrete project/situation



Strive for **value**, not for blind satisfaction of requirements quality criteria!