Requirements Engineering I

Chapter 2

# Fundamentals

# 2.1 Principles of Requirements Engineering

## Nine basic principles

1 Value-orientation: Requirements are a means to an end, not an end in itself

2 Stakeholders: RE is about satisfying the stakeholders' desires and needs

3 Shared understanding: Successful systems development is impossible without a common basis

4 Context: Systems cannot be understood in isolation

5 Problem – Requirement – Solution: An inevitably intertwined triple

6 Validation: Non-validated requirements are useless

7 Evolution: Changing requirements are no accident, but the normal case

8 Innovation: More of the same is not enough

9 Systematic and disciplined work: We can't do without in RE

# Principle 1: Value-orientation

*Requirements are a means, not an end.*

Traditional Requirements Engineering: always write a complete specification

However...

- Customers typically pay for systems, not for requirements
- Many successful projects don't have a complete specification
- Good Requirements Engineering must create value
- Value comes indirectly

# Requirements are a means, not an end

[Glinz 2008]

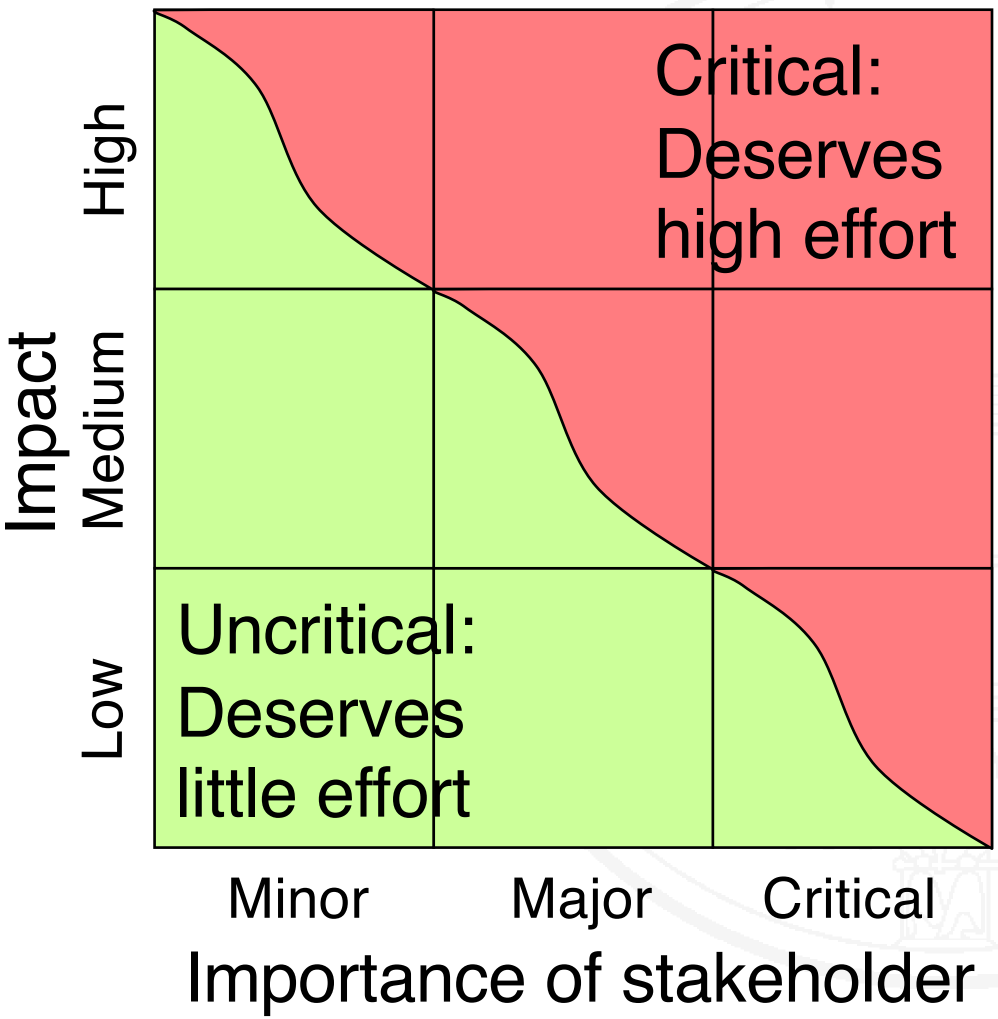
- Requirements shall deliver value
- Value of a requirement:
  - The benefit of reducing development risk
    (i.e. the risk of not meeting the stakeholders' desires and needs)
  - minus the cost of specifying the requirement

☞ Adapt the effort put into RE such that the specification yields optimum value

- Low risk: little RE High risk: full-fledged RE

☞ Assessment of value requires assessment of risk

# Assessing risk




[Glinz 2008]

- Assess the criticality of the requirement
- Consider other factors (next slide)
- Use requirements triage techniques

# Assessing risk: other factors

- Specification effort
- Distinctiveness
- Shared understanding
- Reference systems
- Length of feedback-cycle
- Kind of customer-supplier relationship
- Certification required

The effort invested into requirements engineering shall be inversely proportional to the risk that one is willing to take.

# Principle 2: Stakeholders

*RE is about satisfying the stakeholders' desires and needs.*

Who is "the customer"?

In our sample problem: The resort owner? The skiers?

In reality: Many persons in many roles are involved

DEFINITION. Stakeholder – A person or organization who influences a system's requirements or who is impacted by that system.

Note that influence can also be indirect.

[Glinz and Wieringa 2007]
[Glinz 2020]
[Macaulay 1993]

# Viewpoints

The same building.
Different views.

Different viewpoints by different stakeholders must be taken into account.

[Nuseibeh, Kramer und Finkelstein 2003]

# Consensus and variability

The viewpoints and needs of different stakeholders may conflict

Requirements Engineering implies

- Discovering conflicts and inconsistencies
- Negotiating
- Moderating
- Consensus finding

But: also determine where variability is needed

For stakeholder identification and management, see Chapter 4

# Principle 3: Shared understanding

*Successful systems development is impossible without a common basis.*

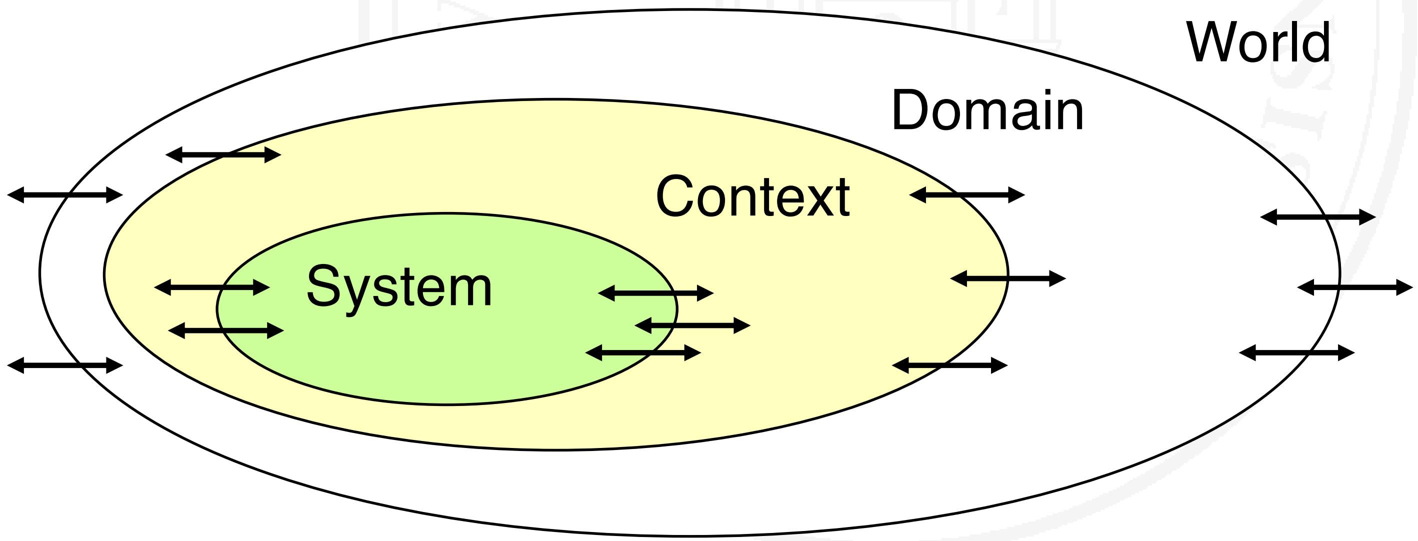
- A basic prerequisite for any successful development of systems
- Created, fostered and assured in Requirements Engineering

→ Chapter 2.3

# Principle 4: Context

*Systems cannot be understood in isolation.*

Systems are always embedded in a context.



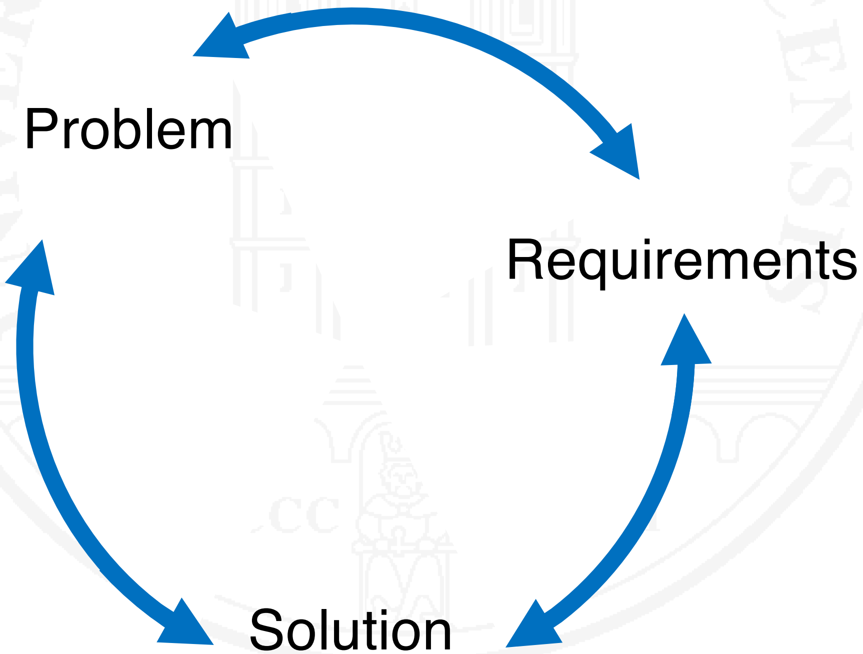

→ Chapter 2.4

# Principle 5 Problem – requirement – solution

[Swartout and Balzer 1982]

*An inevitably intertwined triple.*

Having a problem, we need requirements for a system that solves the problem.



# Specification-Implementation Intertwinement

[Swartout and Balzer 1982]

- Traditional Requirements Engineering: the waterfall
  - Start with a complete specification of requirements
  - Then proceed to designing and implementing a solution
- Does not work properly in most cases
- Specification and implementation are inevitably intertwined:
  - Hierarchical intertwinement: high-level design decisions inform lower-level requirements
  - Technical feasibility: non-feasible requirements are useless
  - Validation: what you see is what you require

# Requirements vs. solution decisions

The system shall provide effective access control to the resort's chairlifts.

A requirement

Manual control

Automatic control

Potential solution decisions

Requirements about selecting and training people

Requirements about turnstiles, access cards, and control software

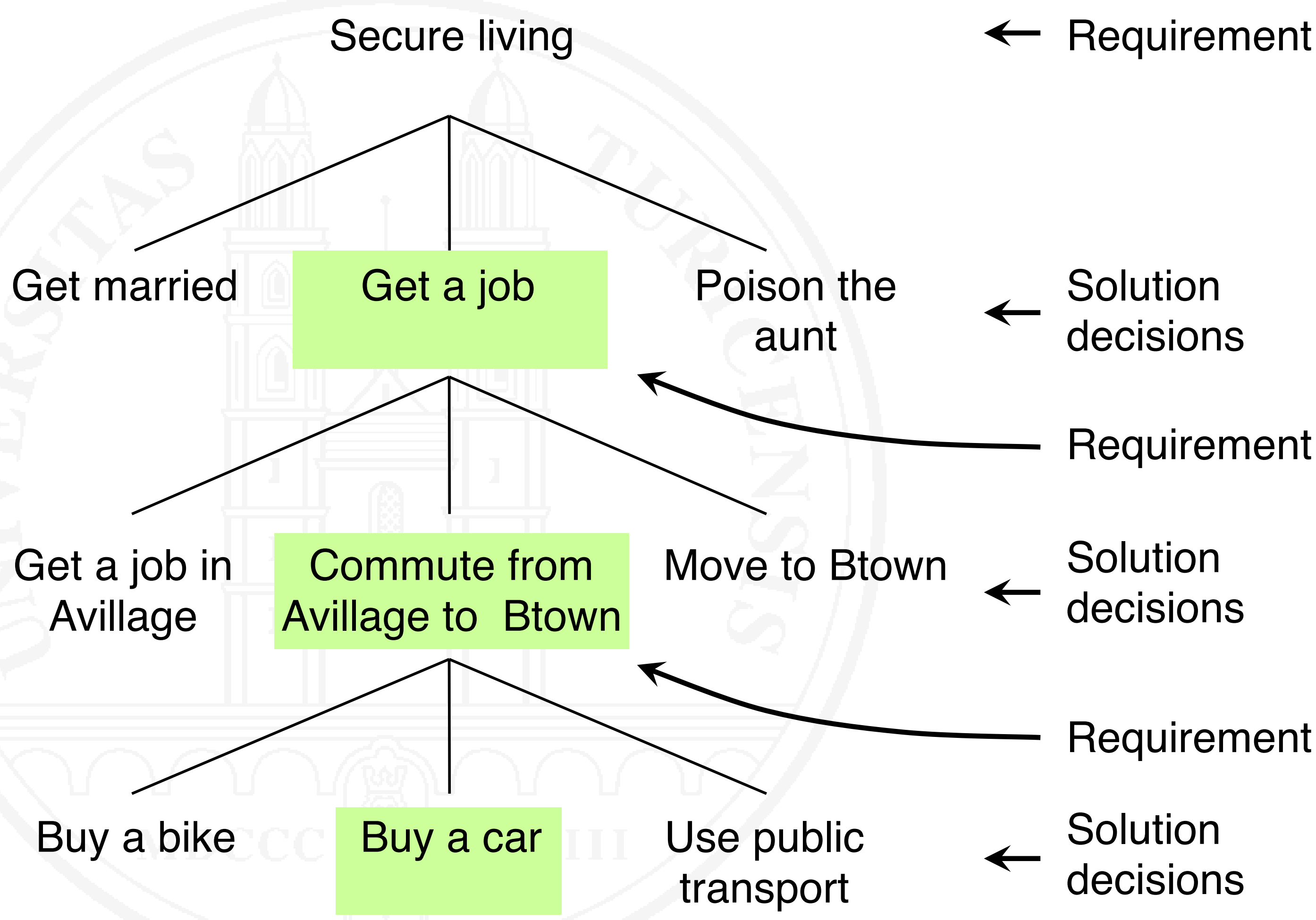
Lower level requirements

⇨ Solution decisions inform lower level requirements

⇨ Requirements and solutions are inevitably intertwined

# Requirements vs. solution decisions

Problem: Sonja Müller has completed her university studies and does no longer receive any money from her parents. Hence, she is confronted with the requirement to secure her living. She is currently living in Avillage and has a job offer by a company in Btown. Also, she has a rich boy friend and she is the only relative of an equally rich aunt.



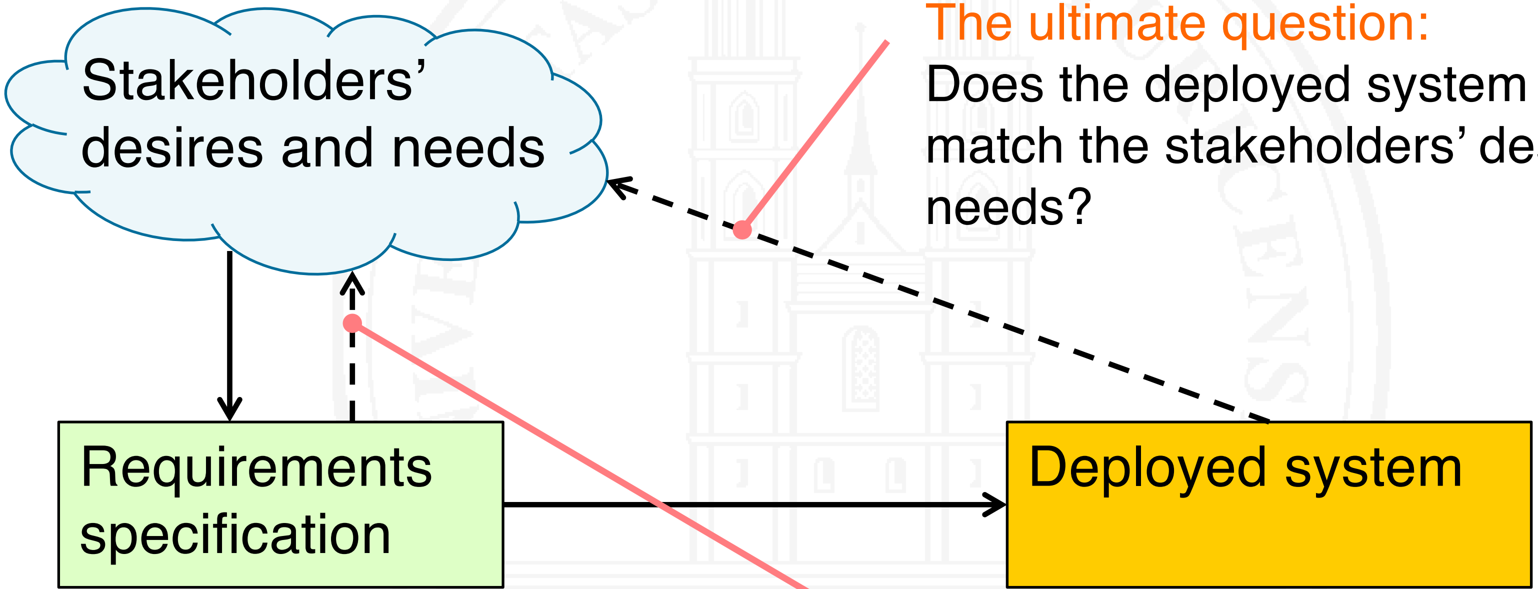
# Typical requirement layers

Using a railway system as an example

- Business: “More people than today shall be transported using the existing tracks.”
- System: “The minimal distance between two trains shall always be greater than the current maximum braking distance of the successive train.”
- Software: “The current maximum braking distance shall be computed every 100 ms.”

# Principle 6: Validation

*Non-validated requirements are useless.*




The ultimate question:
Does the deployed system actually match the stakeholders' desires and needs?

The risk-reduction question:
Do the documented requirements match the stakeholders' desires and needs?

Every requirement needs to be validated

→ Chapter 9

# Principle 7:  Evolution

*Changing requirements are no accident, but the normal case.*

The world evolves.

So do requirements.

The problem:

Keeping requirements stable...

... while permitting requirements to change

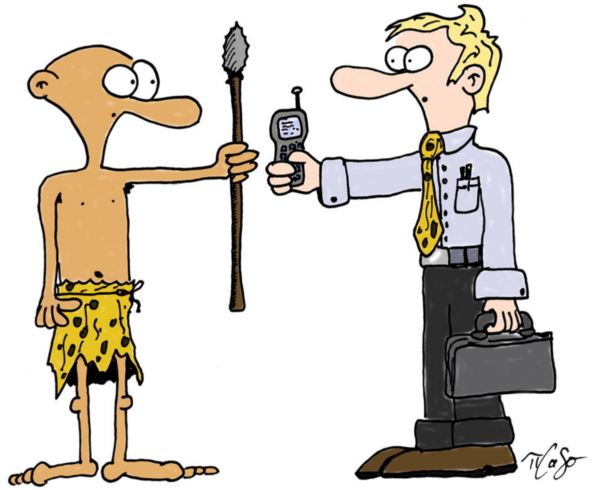


Image © C. Sommer /EKHN

Potential solutions

- Very short development cycles (1-6 weeks)
- Explicit requirements change management

→ Chapter 10

# Principle 8:  Innovation

Image © Apple

*More of the same is not enough.*

"Give the customers exactly what they want."

Maybe the worst you can do onto them.

"We know perfectly well what is good for the customer."

Your customers will love you for your attitude.

"Our new system does all the rubbish we did manually before. But it's much faster now."

Wow, what a progress.

- Don't just automate.
- Satisfying stakeholders is not enough: strive for making them happy and excited

→ Chapter 4

# Principle 9: Systematic and disciplined work

*We can't do without in RE.*

Requirements need to be elicited, documented, validated and managed systematically

- using a suitable process
- with suitable practices

Also applies for agile development, just with a different process and maybe different practices

Systematics does not mean "One size fits all"

- Adapt your processes and practices to the problem
- No unreflected reuse of RE techniques from previous projects

# 2.2 Classifying requirements

The turnstile control software shall count the number of ‘unlock for a single turn’ commands that it issues to the controlled turnstile.

A function

The operator shall be able to run the system in three modes: normal (turnstile unlocked for one turn when a valid card is sensed), locked (all turnstiles locked), and open (all turnstiles unlocked).

A behavior

The system shall be deployed at most five months after signing the contract.

A project requirement

The system must comply with the privacy law of the country where the resort is located.

A legal constraint

The reaction time from sensing a valid card to issuing an ‘unlock for a single turn’ command must be shorter than 0.5 s.

A performance attribute

The system shall be highly available.

A quality attribute

# Requirements have a concern

Application order →

| Question | Kind of requirement |
|---|---|
| Was this requirement stated because we need to specify ... | |
| ... some of the system's behavior, data, input, or reaction to input stimuli – regardless of the way this is done? | functional requirement |
| ... restrictions about timing, processing or reaction speed, data volume or throughput? | performance requirement |
| ... a specific quality that the system or a component shall have? | specific quality requirement |
| ... any other restriction about what the system shall do, how it shall do it, or any prescribed solution or solution element? | constraint |

# Kinds of requirements

DEFINITION. Functional requirement – A requirement concerning a result or behavior that shall be provided by a function of a system.

DEFINITION. Quality requirement – A requirements that pertains to a quality concern that is not covered by functional requirements

Can be sub-classified into:
- performance requirement
- specific quality requirement

DEFINITION. Constraint – A requirement that limits the solution space beyond what is necessary for meeting the given functional requirements and quality requirements.

# Classification according to kind

[Glinz 2007]

- Requirement
  - Project requirement
  - System requirement
    - Functional requirement
      - Functionality and behavior: Functions, Data, Stimuli, Reactions, Behavior
    - Quality requirement (Attribute)
      - Performance requirement
        - Time and space bounds: Timing, Speed, Volume, Throughput
      - Specific quality requirement
        - "-ilities": Reliability, Usability, Security, Availability, Portability, Maintainability, ...
    - Constraint
      - Physical, Legal, Cultural, Environmental, Design&Im-plementation, Interface, ...
  - Process requirement

Also called non-functional requirement

# Beyond kind: A faceted classification

[Glinz 2005b, 2007]

Requirement

**Representation**

- Operational
- Quantitative
- Qualitative
- Declarative

**Kind**

- Function, Data, Behavior
- Performance
- Specific Quality
- Constraint

**Satisfaction**

- Hard
- Soft

**Role**

- Prescriptive
- Normative
- Assumptive

# Classification according to representation

The system shall be highly available. **Qualitative**

During the operating hours of the chair lift, the system must be available for 99.99% of the time. **Quantitative**

The system must comply with the privacy law of the country where the resort is located. **Declarative**

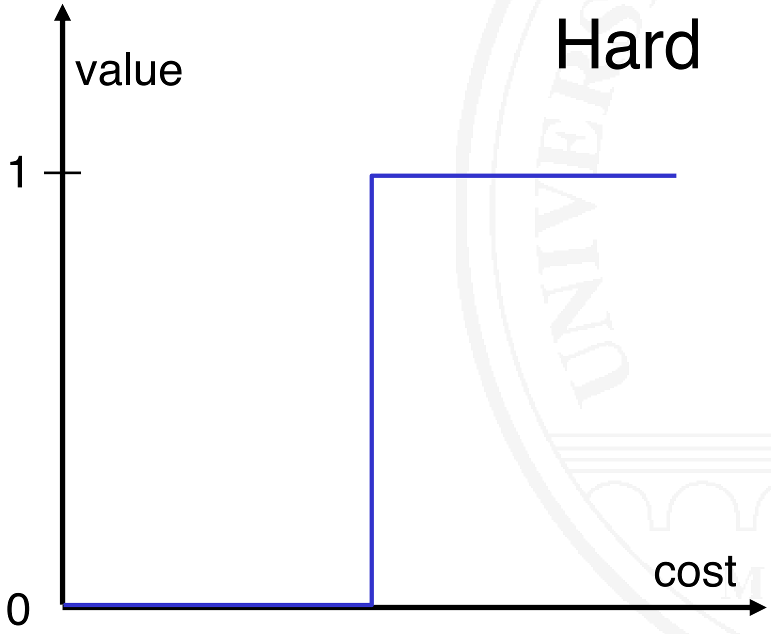
The turnstile control software shall count the number of ‘unlock for a single turn’ commands that it issues to the controlled turnstile. **Operational**

# Representation informs validation

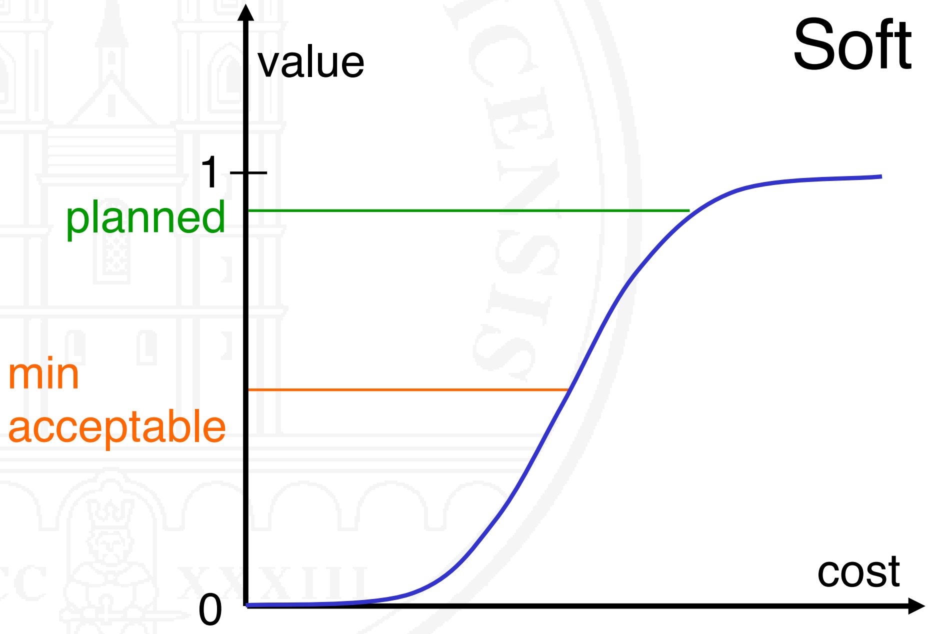
| Representation | Validation technique(s) |
|---|---|
| Operational | Test, Review, Formal verification |
| Quantitative | Measurement |
| Qualitative | No direct validation technique. Use<br>• Stakeholder judgment<br>• Prototypes<br>• Indirect validation by derived metrics |
| Declarative (informally) | Review |
| Declarative (formally) | Review, Model checking |

# Classification according to satisfaction

- Hard – The requirement is satisfied totally or not at all
- Soft – There is a range of satisfaction




Binary acceptance criterion




Range of acceptable values

# Classification according to role

Prescriptive: “Classic” requirement pertaining the system-to-be
“The sensor value shall be read every 100 ms.”

Normative: A norm in the system environment that is relevant for the system-to-be
“The social security number uniquely identifies a patient.”

Assumptive: Required behavior of an actor that interacts with the system-to-be
“The operator shall acknowledge every alarm message.”

→ Makes norms and assumptions explicit

# Where and for what are requirements used?

## Another classification:

System requirements – How a system shall work and behave

Stakeholder requirements – Stakeholders' desires and needs from a stakeholder perspective

User requirements – A subset of the stakeholder requirements

Domain requirements – Required domain properties of a socio-technical or cyber-physical system

Business requirements – Focus on business goals, objectives and needs of an organization

→ Chapter 3

# 2.3 Shared understanding

[Glinz and Fricker 2015]

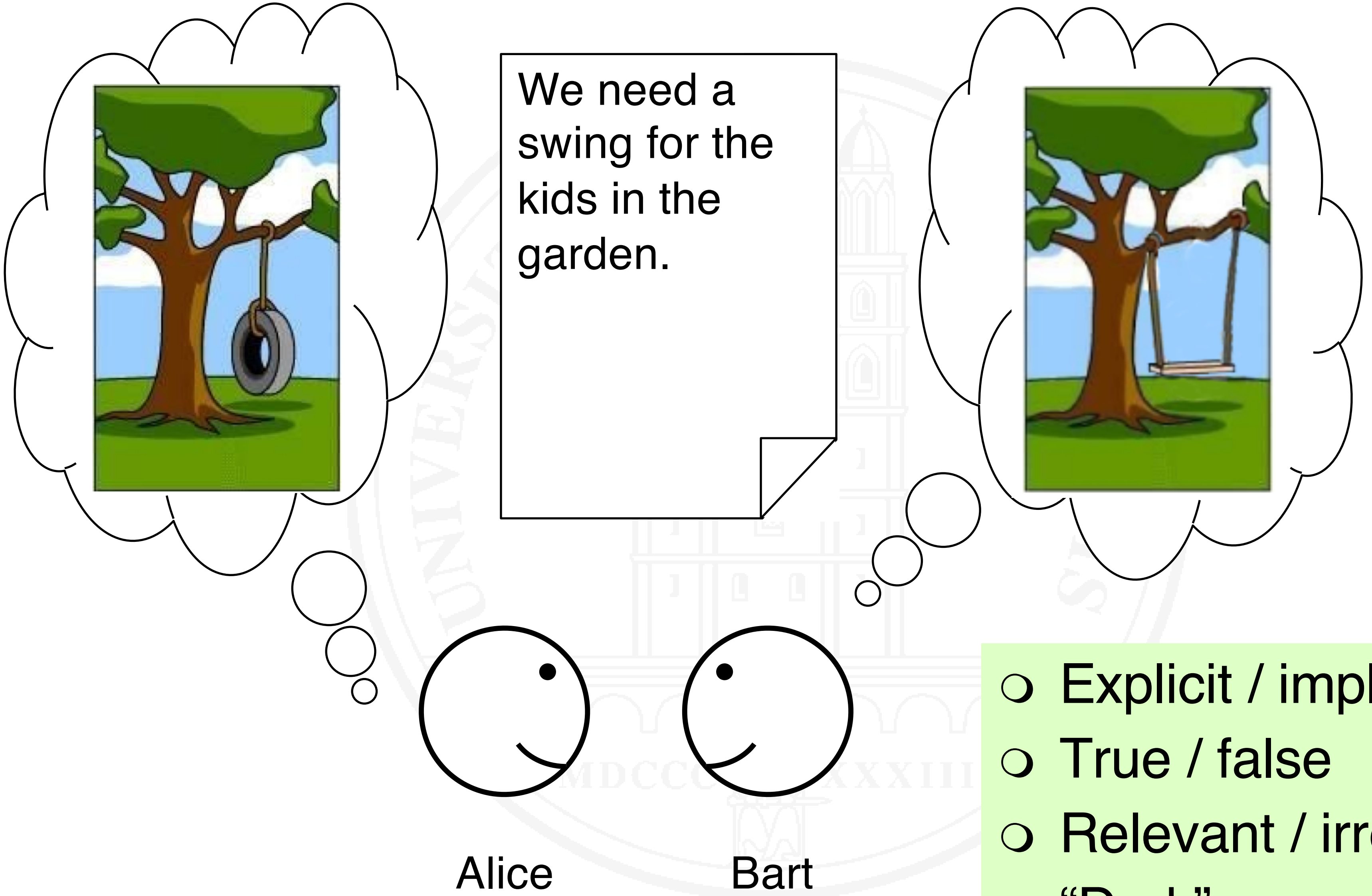
Two disturbing observations:

- Specifying everything explicitly is impossible and infeasible
- Explicitly specified requirements may be misunderstood

→ Requirements Engineering has to deal with the problem of shared understanding

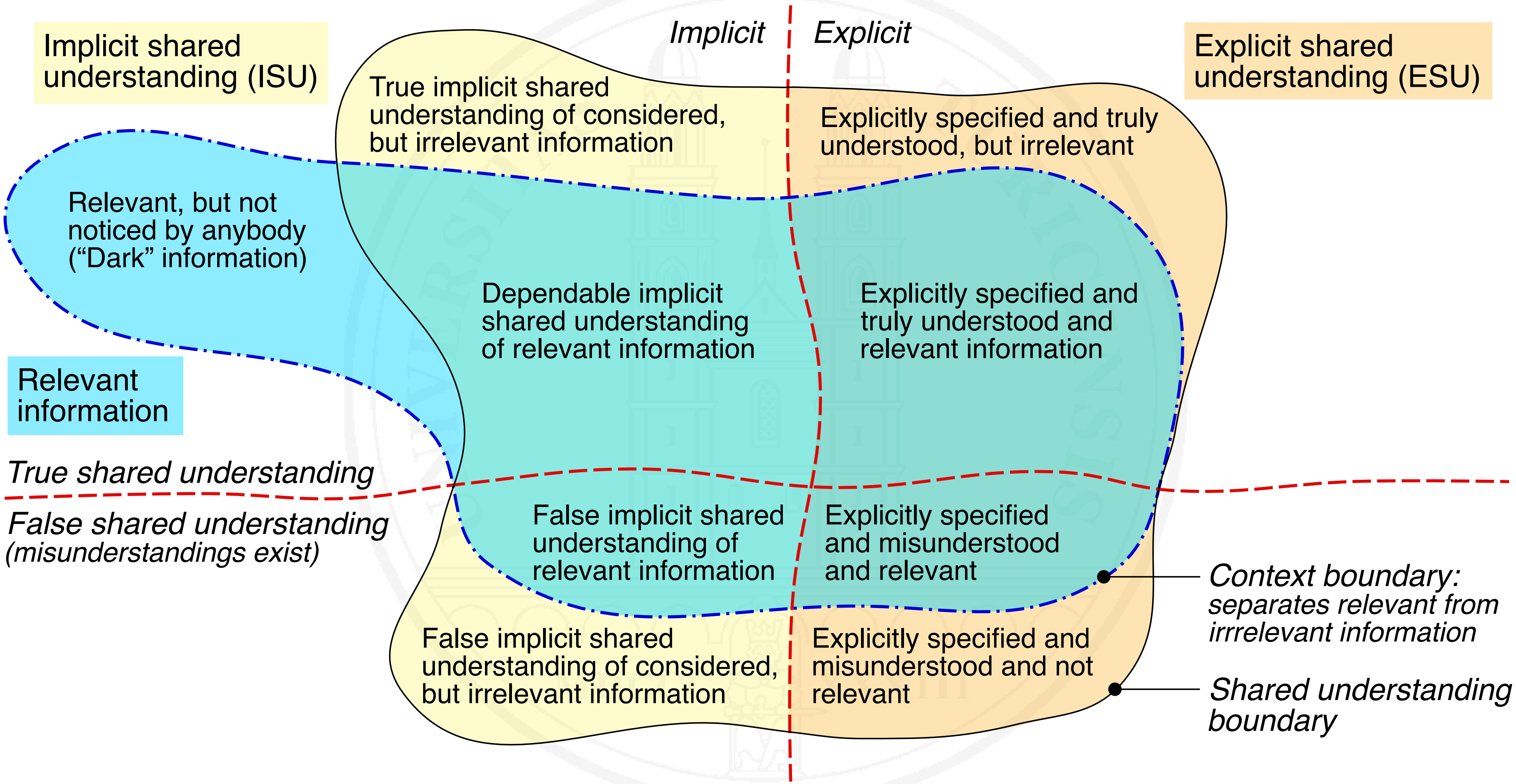
  - How do we establish shared understanding?
  - How can we rely on shared understanding?

# Shared understanding: the problem




- Explicit / implicit
- True / false
- Relevant / irrelevant
- “Dark”

# Forms of shared understanding




[Glinz and Fricker 2015]

# Rephrasing the problem

Achieve successful software development by:

(P1) Achieving shared understanding by explicit specifications as far as needed,

(P2) Relying on implicit shared understanding of relevant information as far as possible,

(P3) Determining the optimal amount of explicit specifications, i.e., striking a proper balance between the cost and benefit of explicit specifications.

Note that P1, P2 and P3 are not orthogonal

# In fact a value problem (cf. Principle 4 in Chapter 2)

*How can we achieve specifications that create optimal value?*

Value means

- The benefit of an explicit specification

  Bringing down the probability for developing a system that doesn't satisfy its stakeholders' expectations and needs to an acceptable level

minus

- The cost of writing, reading and maintaining this specification

# Shared understanding: Enablers and obstacles

- \+ Domain knowledge
- \+ Previous joint work or collaboration
- \+ Existence of reference systems
- \+ Shared culture and values
- \+ Mutual trust
- +/– Contractual situation
- +/– Normal vs. radical design
- – Geographic distance
- – Outsourcing
- – Regulatory constraints
- – Large and/or diverse teams
- – Fluctuation

# Achieving and relying on shared understanding

- Building shared understanding: The essence of requirements elicitation (cf. Chapter 7)
- Assessing shared understanding
  - Validate all explicitly specified requirements
  - Test (non-specified) implicit shared understanding
- Reducing the impact of false shared understanding
  - Short feedback cycles
  - Build and assess shared understanding early
  - Specify and validate high risk requirements explicitly

# Mini-Exercise

Consider the chairlift access control case study.

(a) How can you make sure that the following explicit requirement is not misunderstood:
"The ticketing system shall provide discounted tickets which are for sale only to guests staying in one of the resort's hotels and are valid from the first to the last day of the guest's stay."

(b) We have used the term "skier" for denoting an important stakeholder role.
How can we test whether or not there is true implicit shared understanding among all people involved about what a "skier" is?

# 2.4 Dealing with the context

*Systems cannot be understood in isolation.*

- Requirements specify a system
- The system may be part of another system
- The system is embedded in a domain context
- The scope of a system may exceed the system boundary

# Which system?

Some requirements for our sample problem:

For every turnstile, the system shall count the number of skiers passing through this turnstile.

The turnstile control software

The system shall provide effective access control to the resort's chairlifts.

Everything: equipment, computers, cards, software

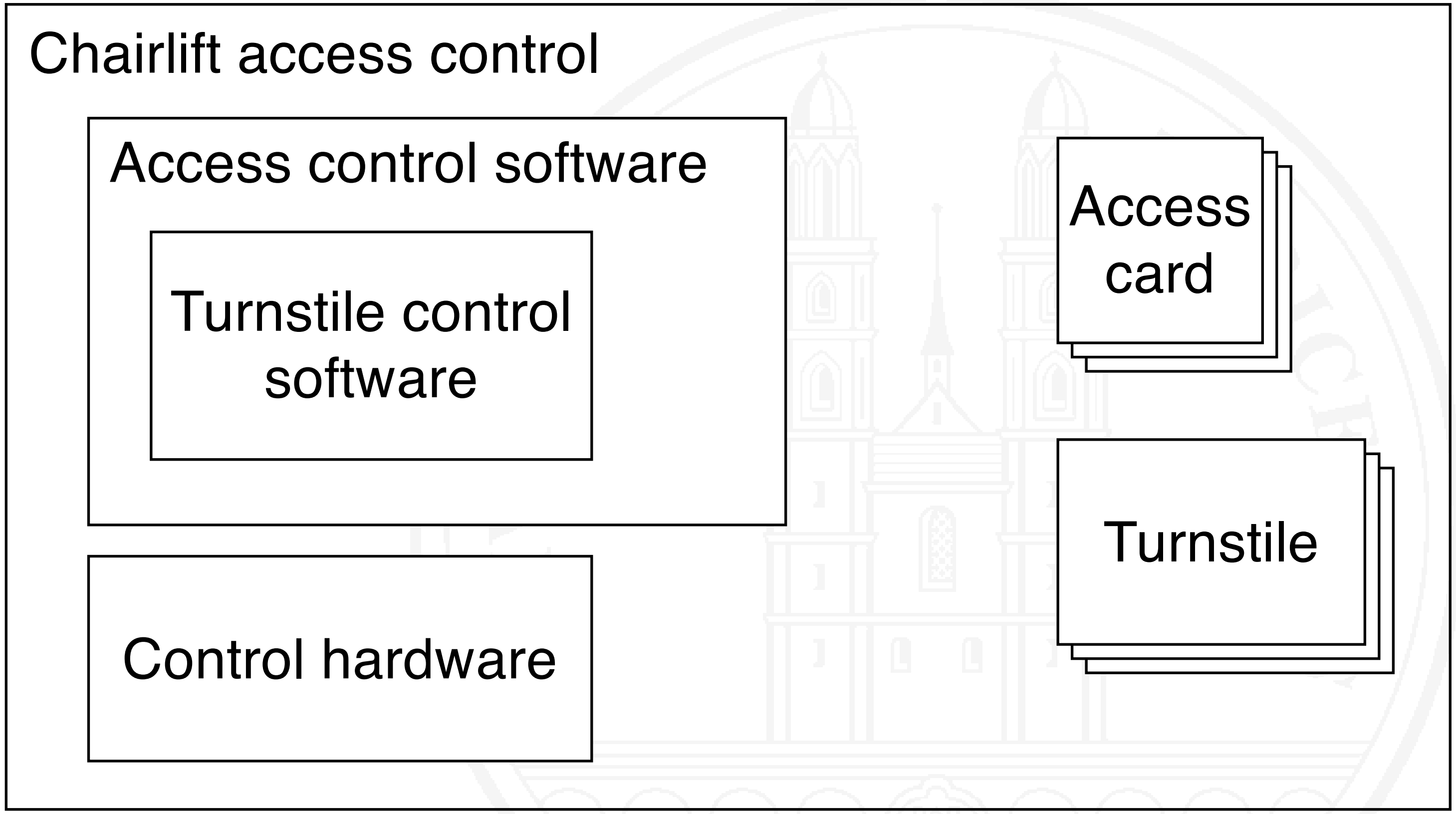
The system shall operate in a temperature range of -30° C to +30° C.

The computer hardware and the devices

The operator shall be able to run the system in three modes: normal (turnstile unlocked for one turn when a valid card is sensed), locked (all turnstiles locked), and open (all turnstiles unlocked).

The access control software for a chairlift

# Systems of systems



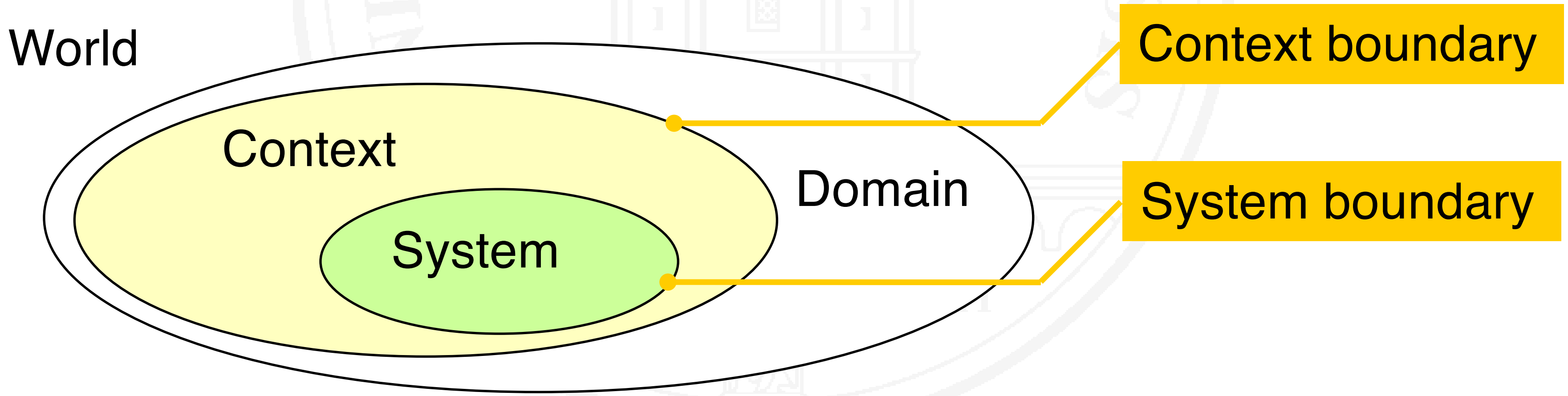

➪ Requirements need to be framed in a context

➪ Dealing with multi-level requirements is unavoidable

# Context

DEFINITION. Context – 1. In general: The network of thoughts and meanings needed for understanding phenomena or utterances. 2. Especially in RE: The part of a system's environment being relevant for understanding the system and its requirements.



# System boundary and context boundary

DEFINITION. System boundary – The boundary between a system and its surrounding context.

DEFINITION. Context boundary – The boundary between the context of a system and those parts of the application domain that are irrelevant for the system and its requirements.

- The system boundary separates the system to be developed from its environment
- RE needs to determine the system boundary
- Information outside of the context boundary is not considered

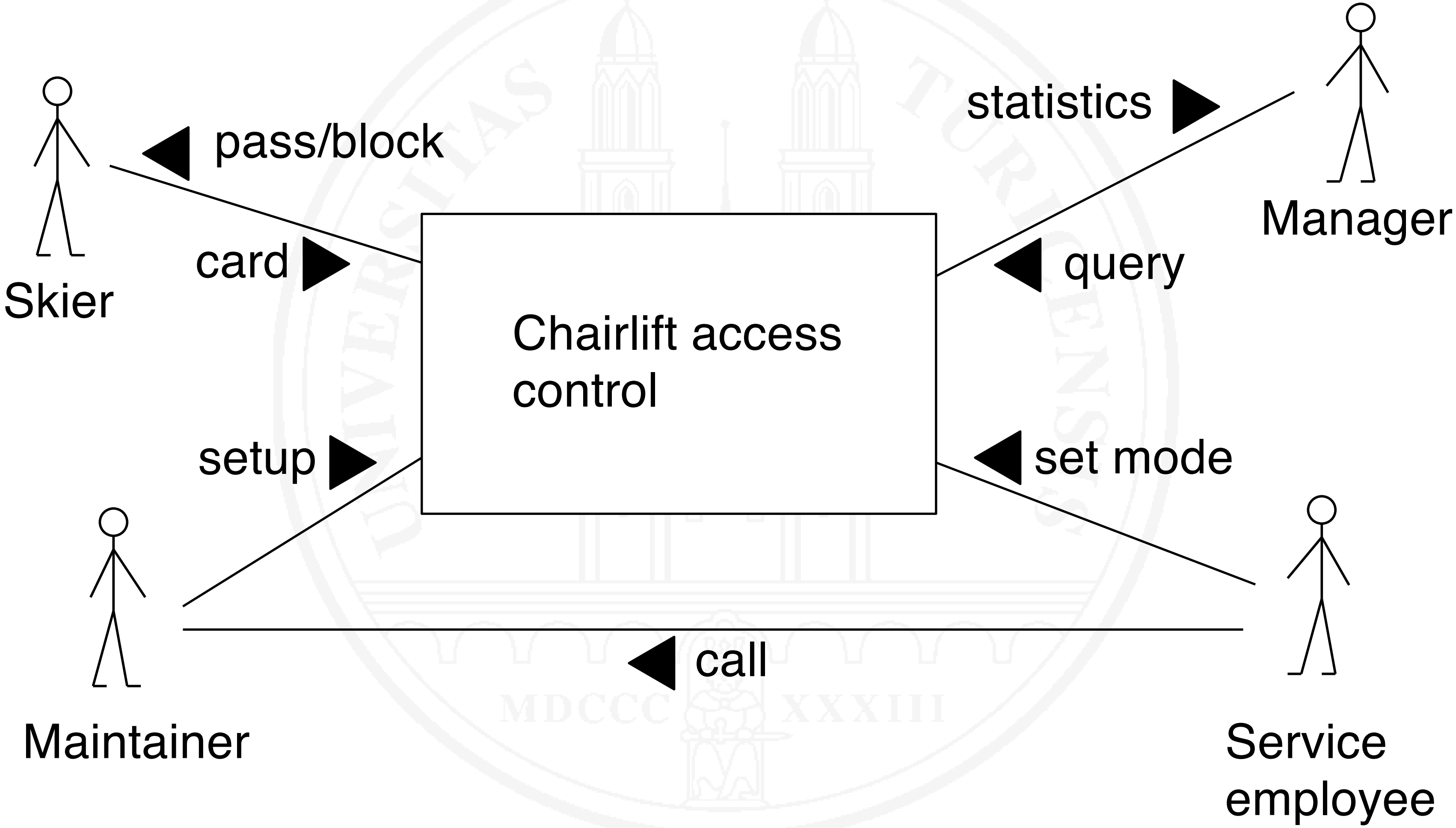
# Context models

Modeling a system in its context

- Determine the level of specification
- Usually no system internals (→ system as black box)
- Model actors which interact directly with the system
- Model interaction between the system und its actors
- Model interaction among actors
- Represent result graphically

# A context diagram



# Mapping world phenomena to machine phenomena: a major RE problem

① A requirement in the world:

For every turnstile, the system shall count the number of persons passing through this turnstile.

② Mapped to a requirement for the system to be built:

The turnstile control software shall count the number of 'unlock for a single turn' commands that it issues to the controlled turnstile.

② satisfies ① only if these domain assumptions hold:

- An unlock command actually unlocks the turnstile device
- When a turnstile is unlocked, a single person passes through it
- Nobody passes through a locked turnstile (e.g. by crouching down)

# The world and the machine

[Zave and Jackson 1997]
[Gunter et al. 2000]
[Jackson 2005]

Requirements must hold in the world.

But we need them to build machines (aka systems).

A machine with capa-bilities described by the specification $S$

Properties $D$ of the domain In the real world

Required behavior $R$ in a real world domain

The requirements problem (according to Jackson):

Given a machine *satisfying the specification S* and *assuming* that the *domain properties D hold*, the *requirements R in the world must be satisfied*: $S \wedge D \vdash R$

# Mini-Exercise

Imagine the problem of two traffic lights that regulate traffic at a road construction site where only a single lane may be used. The following real-world requirement shall be satisfied:

*“Ensure that, at each point in time, traffic flows at most in one direction in the one-lane region and that the control regime is both effective (actual throughput in both directions) and fair (does not favor one direction over the other).”*

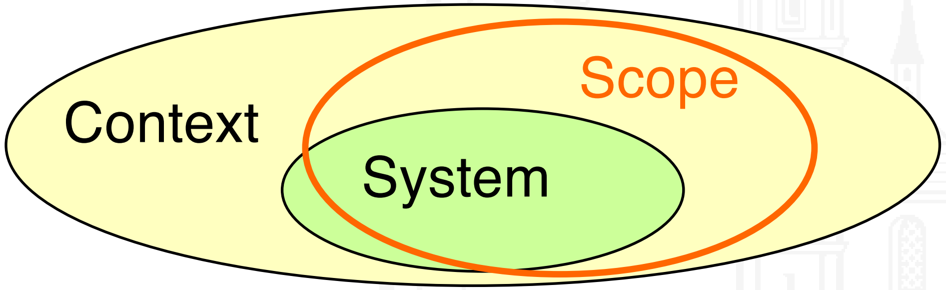
Determine

- the system requirements that the control system must meet
- which domain properties/assumptions must hold

in order to satisfy the given real-world requirement

# The role of the system scope

DEFINITION. Scope (of a system development) – The range of things that can be shaped and designed when developing a system.




System scope ≠ Everything within the system boundary!

- The scope of a system may comprise parts of its context

  If this is the case, (re)-designing the context may lead to better systems than designing the system to a given context

- Some parts of a system may be given and not changeable

# 2.5 Requirements and design

A traditional belief:

- Requirements are about what a system ought to do
- Design deals with the problem of how to realize what has been stated in the requirements
- Requirements Engineering and System Design should be kept separate, with requirements preceding design

- Sounds good and is popular, but does not work

# WHAT vs. HOW in Requirements Engineering

Is this a requirement or a design decision?

"The system prints a list of ticket purchases for a given day. Every row of this report lists (in this order) date and time of sale, ticket type, ticket price, and payment method. Every page has a footer with current date and page number."

It depends.

→ WHAT vs. HOW doesn't provide a useful distinction.

Distinguish operationally:

- If a statement is owned by stakeholders (i.e., changing it requires stakeholder approval), it's a requirement
- If a statement is owned by the supplier (i.e. the supplier may change it freely), it's part of the technical solution

# Design has two facets

- Technical Design: Creating the architectural structure of a system and designing its components in detail
- Product Design: Shaping a product (or a system) with respect to its capabilities, behavior, outer form, and usage

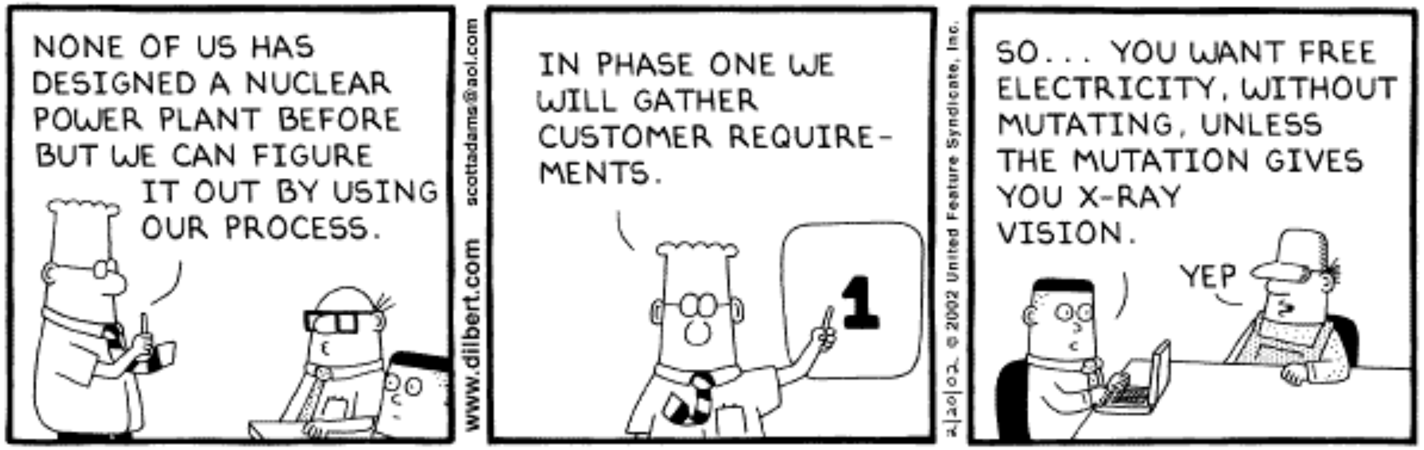
Traditional RE: Product Design comes after RE

Modern RE: Product design shapes the essence of a product
→ crucial for meeting the stakeholders' desires and needs
→ Product Design and RE are strongly intertwined

Product design for digital products is also called "Digital Design"

# Why care about both RE and product design?




→ We need RE competencies


→ and product design competencies

# Complementary contributions

- RE contributes competencies about
  - Stakeholder identification
  - Elicitation of wishes and needs
  - Documentation of non-touchable things
  - Requirements negotiation, prioritization, and validation
- Product Design contributes competencies about
  - Usability
  - User experience design
  - Materials for physical & cyber-physical products, “digital materials” for digital products
  - Empirical product validation

# Meeting requirements may not suffice to satisfy stakeholders

A requirement

The participant entry form shall have fields for the participant data *name*, *first name*, *sex*, and *person ID* and a *submit button*.

can be ruined by bad product design