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| IU |
| Requirements Management |
| Course Code  Author  If you do not wish to be credited, please indicate it below:  *No need for indication as author* |

# Learning Objectives

Project are always the creation of a new system, that is being developed in an operation that has never been done before. In contrast to serial production of technical systems, projects do not have a precedent, but need to be developed without an example.

The novelty lies in a unique mix of the desired function of the system, the environment of corporate structures, processes, strategic business needs and overall technological structure. This unique mix creates a very specific set of requirements on the part of any client organization.

Again, in contrast to goods produced in serial production, the novelty and the specific requirements create a disconnect between the client and the contractor. This gap can only be closed by a dedicated effort to precisely analyze what the client needs.

Relying on the client coming forward with a detailed list of requirements is only possible in smaller and technologically trivial projects. Thus, any project contractor is expected to specify requirements.

Requirements are highly specific statements on what a client is expecting from a system, that is being developed in the context of a project.

These statements are legally binding instructions that facilitate a seamless project lifecycle and minimize errors due to misunderstanding.

When working in a project, you will most likely be confronted with some sort of Requirements Management; regardless of your particular role in the project.

This course is intended…

* to familiarize you with the requirements discipline for you to understand the role and importance of requirements in real-life projects.
* to show you the tasks and responsibilities of Requirements Management’s for you to know the scope of your work, when responsible for these tasks.
* to provide you with tools for you to apply when working with requirements in a project during your career.
* to demonstrate Requirements Management in different industries for you to learn to apply your understanding and the tools to your own professional environment.

Keep in mind, everyone involved in projects, is responsible for analysis, management and implementation of requirements. While there are some dedicated requirements teams or consultants in larger projects, small- and medium-size projects are often distributing requirements-related tasks across the project team.

## Basic Reading

Project Management Institute. (2016). Requirements Management : A Practice Guide. Newtown Square, Pennsylvania: Project Management Institute.

Mario Kossmann. (2012). Requirements Management : How to Ensure You Achieve What You Need From Your Projects. Burlington, VT: Routledge.

Hood, C. et. al. (2008). Requirements Management : The Interface Between Requirements Development and All Other Systems Engineering Processes. Berlin: Springer.

**Possibly not appropriate in English script due to German language:**

Rupp, C. (2014). Requirements-Engineering und – Management – Aus der Praxis von klassisch bis agil. München: Carl Hanser Fachbuchverlag.

## Required Reading

### Unit 1

Rupp, C. (2014). Requirements-Engineering und -Management. Aus der Praxis von klassisch bis agil. München: Hanser, pp. 9 – 32

Ullrich, A.; Bertheau, C.; Wiedmann, M.; Sultanow, E.; Körppen, T.; Bente, S. "Roles, tasks and skills of the enterprise architect in the VUCA world," 2021 IEEE 25th International Enterprise Distributed Object Computing Workshop (EDOCW), 2021, pp. 261 – 270

### Unit 2

Garcia, Y.-M., Montes, A., Lira, J., & Martinez, J. (2019). Requirements Management Techniques and Tools in Small and Medium Enterprises (SMEs): A Systematic Review. *2019 IEEE International Autumn Meeting on Power, Electronics and Computing (ROPEC), Autumn Meeting on Power, Electronics and Computing (ROPEC), 2019 IEEE International*, pp. 1–7.

Project Management Institute. (2021). A Guide to the Project Management Body of Knowledge (PMBOK® Guide) – The Standard for Project Management. Newtown Square, Pennsylvania: Project Management Institute, pp. 8 – 15 and p. 147

## Further Reading

### Unit 1

Hood, C., Wiedemann, S., Fichtinger, S., & Pautz, U. (2007). Requirements Management: The Interface Between Requirements Development and All Other Systems Engineering Processes. Berlin: Springer Science & Business Media. (p. 11 - 19)

Chemuturi, M. (2012). Requirements Engineering and Management for Software Development Projects. Berlin: Springer Science & Business Media. (p. 13 – 25)

### Unit 2

Hruschka, P. (2019). Business Analysis und Requirements Engineering: Produkte und Prozesse nachhaltig verbessern. München: Carl Hanser Verlag. (p. 29 – 59)

Young, R. (2006). The Requirements Engineering Handbook. New York: Artech House. (p. 45 – 60)

Kupersmith, K., Mulvey, P., & McGoey, K. (2013). Business Analysis For Dummies. John Wiley & Sons. (p. 7 – 18)

**Important but possibly not appropriate in English script due to German language:**

Rüegg-Stürm, J. (2003). Das neue St. Galler Management-Modell: Grundkategorien einer modernen Managementlehre; der HSG-Ansatz. Bern: Haupt.

# 1. Basics and Drivers of Requirements Management

**Study Goals**

On completion of this unit, you will be able to …

… understand necessity and purpose of Requirements Management.

… define the terms *requirement, management* and *requirements management.*

… know and define the most important types of requirements.

… contextualize the need for Requirements Management with environmental trends.

… understand the role of Requirements Management in the project context.

## Introduction

No project is like the other, a commonly used proverb says. *The system*, the technical and operational outcome of the project, may be the same in some instances, but the *conditions* (client, environment, stakeholders etc.) vary from project to project. Projects, in that sense, are usually the creation of something that has never been created before (Rattay, 2013, S. 70).

According to the Project Management Body of Knowledge (PMBOK), one of the most widely applied project management guidelines, a project is an endeavor, limited by time and resources with the goal to create a unique product, service or result (Wuttke, Snijders & Zandhuis, 2014, S. 21). Based on this definition we are directly confronted with a major challenge, that is unknown to many individuals operating in an non-time-limited ongoing business: two parties, the client and the contractor need to agree on specific characteristics of a deliverable, that has never been built before under the conditions at hand and – more accurately – something that has never been *specified* before.

The challenge, at this point, is the specification of requirements. It might appear simple to translate the needs of the client into a list of characteristics, with the goal of incorporating these requirements into a binding contractual framework. This thinking puts a lot of pressure on both, the client and the contractor, as a simplistic view on requirements presumes a set of unrealistic statements:

* The client is capable of identifying *all* individuals, departments and further stakeholders.
* These stakeholders know their requirements down to the most segmented detail.
* The stakeholders are able to communicate these requirements in a way that is understood by anyone involved.
* The client will rationally document and prioritize these requirements.
* The contractor will understand the requirements in every detail.
* The contractor will implement the requirements into project deliverables right as planned.
* No changes need to be made to the requirements in a later stage of the project as no unexpected events will occur.
* A system to control the requirements is unneccessary because the requirements were effectively delivered at a degree of precision that left no further question regarding the equally precise implementation by the contractor.
* We can assure you, these assumptions have never been true in any project above the lowest imaginable degree of complexity.
* This negative example illustrates the neccessity of a consious effort to define and manage customer requirements in the early stages of a project; but also through the entire project lifecycle.

A survey by Joseph Carr attributes only 40% of significant mistakes in a project to mistakes in the realization phase; a share of 60% of all mistakes is attributed to the analysis phase. Carr also analyzed the costs for fixing errors depending on *when* the fix is being done. If an error from the analysis phase is corrected in the test phase, the costs are multiplied by a factor of 25 (compared to fixing it right away). If an analysis-error is being fixed in the operational phase, the costs can be multiplied by 100. Getting the analysis right, understanding early on what the customer really needs, is an investment worth making in the beginning of the project.

In other words, a lack of requirements definition and planning might lead to

* errors that require costly repetitions of tasks.
* delays and even longer interruptions of the project.
* lack of compatebility with other technical systems (not only limited to IT).
* challenging integration into processes of operation & maintenance.

Requirements Management is the art of connecting the known and unknown requirements of the client to the capabilities, the planning and execution on the side of the contractor.

## 1.1 Definition of Requirements and Management

In order for us to understand the general context of this course book, we need to take a closer look at the courses title. Requirements Management accommodates three terms: 1) *Requirements*, 2) *Management* and 3) *Requirements Management*.

### 1.1.1 Definition Requirements

All further discussions in this course book require a precise definition of the concept of requirements in the context of requirements management. “A requirement is a need, expectation, constraint or interface of any stakeholders that must be fulfilled by the proposed […] product during its development” (Chemuturi, 2012, S. 3)

*Graphic X: Elements of the Requirements Management definition based on Chemturi (2012)*

**Need:** The origin of any requirement is the business need of a customer. All requirements are targeted at precisely specifying the characteristics of a system and a project that directly or indirectly serve the realization of the business needs of the client. Needs exist without being formalized or specified.

**Expectation:** Expectations build a bridge between a need and a requirement. In the requirements context, an expectation is a need that is targeted at a person or a company with the clear intention of them fulfilling the need.

**Constraints:** Needs and expectations can be satisfied in multiple ways. In real-life projects, the ways to fulfill needs is always limited by constraints. While time and budget are among the most common constraints, they can extend to all characteristics of the project. Constraints are thereby limiting conditions for the realization of all needs and expectations.

**Interface:** Any system that is being developed in a project is (in some form or another) connected to other systems, groups, and individuals. These interfaces are crucial in the definition of requirements, as being connected to the system creates the necessity for a precise analysis of the needs of the system, groups, or individuals on the other side of the interface.

**Stakeholder:** Anyone who is directly or indirectly affected by the system, or the project is a potential stakeholder. Stakeholders are sources and accelerators of requirements but also cause for challenges Requirements Management needs to deal with. Therefore, the stakeholder concept is central to the entire requirements discipline.

**That must be fulfilled:** Needs are transformed into expectations in order for them to be fulfilled. Requirements are highly expectations, which have been processed by Requirements Management and thereby transformed into a form that maximizes the likelihood of their fulfillment.

**The proposed product:** In a client-contractor relationship, especially when related to a project, there is always an object in the center of the project effort. We will call this object of the project *the system* throughout this course book. While projects often produce technical systems (buildings, machines, IT), there are many industries that create social systems, such as events or social projects. We therefore understand the term system in the broadest sense as the object, that is being developed and implemented in the context of the project.

**During its development:** Requirements are parts of any (business) transaction. They are, however, more easily specified, when products are produced in an ongoing production process, such as most consumer goods. Whenever something is being developed from the ground up, without much experience and in new conditions, requirements become a lot more important. The development of new systems is always happening over a limited time period; this period generally starts with the analysis of requirements and ends with the final approval and the acknowledgment of the client, that all requirements have been met.

So what types of requirements can be identified in the practice of real-life Requirements Management experience?

#### Types of Requirements

#### The most trivial distinction between different types of requirements is functional vs. non-functional (Hruschka, 2019). While functional requirements specify all activities a system needs to perform (it’s functions), non-functional requirements cover all further requirements, e.g. requirements towards quality, legal conditions, project management, user interface etc. (Hood et al., 2007).

*Graphic X: Different types of requirements*

**Solution requirements:** Solution requirements (often referred to as functional requirements) describe the functionalities and functional characteristics of the system (Gareis & Gareis, 2018). Solution requirements therefore describe how the system will deliver value to the client after the project is completed.

* activities, the system can perform independently
* characteristics of the interface with a user or with another system
* further functional agreements

Examples would be an precise temperature, to which an air conditioning system can cool down a large office space to, the certain weight an elevator needs to carry, the compatibility of a new train with the existing electric infrastructure of the railroad system.

**Quality requirements:** Different environmental conditions put different stress levels on technical systems. It is therefore of paramount importance to analyze possible environmental stressors. Mining technology companies pay a lot of attention to the soil, their machines need to operate in. It is the goal of quality requirements to ensure reliability, operational endurance and ease of service. An example is serviceability; to ensure the easiest possible way to maintain a system during future operations. The varying conditions, within which a system needs to operate, highly influence the quality characteristics, a client may require for their system. These are usually specified as quality requirements (Berry & Franch, 2011).

**Business requirements:**Any project has a very particular business goal**.** Business requirements are specified in order to ensure, these business goals are being met by the future operation of the system (Cox, 2021) (Hay, 2003). If an automotive manufacturing company, for example, orders a revamp of a production line in order to increase the line’s throughput by 20%, this will be stated in the business requirements.

**Architectural requirements:** Any technical system is places into an environment of other technical systems, they need to interact with. Architectural requirements are the result of a precise analysis of the technological environment of the desired system. The most obvious example is the compatibility of an IT system with other systems (Alebrahim, 2017). Requirements managers need to ensure, the new system is seamlessly integrating into data processes. The construction of a chemical plant needs to safeguard compatibility with the company’s maintenance and repair network and a modern office building needs to connect to utilities and telecommunication.

**User requirements:** Requirements Management is the art of mitigating customer’s requirements in a way that leads to the most beneficial system deliverable (Sutcliffe, 2012). The customer, however, is not just represented in the persona of the company’s solution architect. Anyone who will work with the system, is a potential source of requirements (more on that in the next section). Users are operators of machines, facility managers in buildings, applicants of an IT system, maintenance personnel etc. These stakeholders are able to provide a unique perspective on what design perks would increase the benefit of the new system (Prakash & Prakash, 2018) (Laplante & Kassab, 2022).

**Implementation requirements:** Projects are often cause for a major transition in a company’s operational routines. Therefore, in many cases, just building a system will not be satisfactory to the client. Personnel in charge of operations and maintenance needs to be educated, data need to be migrated, processes need to be redesigned etc. Sales departments have often used these extra-services in the sales process to convince the client, when the main system would not be all too different from the competitor systems. Recently, however, there has been a trend towards an expectation on the clients’ side to include these services into the project scope. In order to manage expectations, there is a mutual interest to specify the requirements before dealing with different expectations later on.

These definitions will guide us through this course book. In the practical reality of most systems, they are sufficient. Keep in mind, this selection is not exhaustive and might be extended in the individual projects, you might encounter over your career lifetime.

### 1.1.2 Definition Management

The purpose of discussing the term management in a context, that is mainly targeted at Master-level business students, overlaps with the purpose of establishing a structure of requirements: In order to ensure an understanding between the reader and the author that reaches further than a surface-level understanding, we need to agree upon the very particular definition of what we are *actually* talking about, when we talk about terms, such as *management*.

The essence of the term management, that best describes the way we will understand management in this course book, was defined by Leontiades as “creation, adoption, and coping with change” (Leontiades, 1982).

*Graphic X: Elements of the management-definition based on Leontiades (1982)*

These three terms perfectly contextualize management (and the manager’s role) in a complex, ever changing business world. An economic environment that is always changing requires strong decisions for the creation of goods, and more specifically the creation of conditions, under which goods can be produced. A changing environment, furthermore, requires the constant adoption of previous decisions based on the new necessities of the environment. Once adaptive decisions have been made, the organization needs to be changed in a way that enables successful execution.

Besides matching our understanding of a changing world, the applied definition perfectly caters the term’s application in a requirements-context.

#### Requirements and Management as *creation*

The creation-aspect of requirements refers to the creation of a solid system of requirements that enable the further creation of the system, that is object of the project. Thereby the creation aspect focuses on the analytical tasks in the beginning of each project.

#### Requirements and Management as *adoption*

Once the project-requirements are analyzed and defined, the actual project management is picked up. Especially in more complex projects, minor errors or environmental changes can trigger the need for changes in requirements. The activity of adjusting the requirements in a way that is beneficial to the contractor, the project and the project matches the *adoption-element* of the term management.

#### Requirements and Management as *coping with change*

Changes are normally agreed upon by the change control board of a project. But there is still some work to do, for these changes to be implemented. The traceability, the management of implementation of requirements is another central task in Requirements Management. This perfectly squares with the third aspect of our understanding of management: guiding the project in a way that allows it to cope, deal, work with the agreed upon changes.

### 1.1.3 Definition Requirements Management

Requirements discipline: The science and art of engineering and managing requirements

There is no scientific consensus on the definition of the entire requirements-discipline. Regardless of the titles and definitions, most scholars and practitioners agree on a more or less fixed set of different requirement-related tasks. The majority of time and effort is often being attributed to the analysis of requirements. This discipline (and all tasks related to the analysis) is referred to as Requirements Engineering QQ. Once the requirements are defined and agreed upon, there is a set of further tasks related to requirements, such as administration, adding further requirements, mitigating conflicts, managing the requirements change process etc. These further tasks are usually referred to as Requirements Administration. Hood et al. follow this thinking in their definition of Requirements Management as “the sum of all activities in connection with requirements that take place after the requirements have been developed or engineered.” (Hood et al., 2007, S. 59).

In this course book, we are applying a comprehensive view on Requirements Management. Consequently, we do not separate tasks into Requirements Engineering and Requirements Administration, but in ongoing and sequential tasks of the entire requirements discipline.

1. Ongoing tasks are tasks, which are necessary during the entire project process
2. Sequential tasks are merely located in very particular phases of the project; they are still relevant in other phases but have a clear focus in the sequence

Based on our holistic understanding of Requirements Management, we can identify eight major tasks and locate them in the ongoing or the sequential part of the entire requirements discipline.

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| **Scoping:** | Requirements Management takes a leading role in defining the scope of the system that is being developed or constructed, as well as the system’s environment. |
| **Requirements Analysis:** | Requirement Management analyzes the requirements of the client stakeholders and actively investigates possible unknown requirements. |
| **Requirements Modeling:** | Requirements Management shapes the loose lists of requirements into different kind of models for all stakeholders to process them into their project activities. |
| **Attribution and Filter Management:** | In order to integrate each requirement into a wider set and context of requirements, further attributes are necessary. These attributes support implementing filters to make sure the right requirements are visible to the right roles in the project. |
| **Prioritization Management:** | Oftentimes there is a difference between the priorities of the client and what makes sense from a PM perspective. Sometimes, the client needs a “quick win” to win hearts and minds of their employees. Managing these questions is part of Requirements Management, as well. |
| **Traceability Management:** | There is always a certain likelihood, a requirement will get lost over the project lifecycle. Making sure, no requirement vanishes over the complications and complexities of the implementation phase, Requirements Management is tasked with tracing the requirements through the entire lifecycle. |
| **Modification Management:** | Whenever changes need to be made in the specification sheet (more on that later), a certain level of care is required in order to get any necessary stakeholder on both sides into agreement on the changes. This is usually done by Requirements Management. |
| **Version Management:** | In most projects, there will be a high number of changes necessary. These changes create new versions of different documents. Requirements Management is tasked with the challenge of making sure, everyone is working with the most recent version. |

*Table X: Tasks of Requirements Management*

This course book will guide you through these tasks, their purpose, the specifics and sub-tasks, as well as tools related to these tasks.

Self-check questions

What are the six main types of requirements?

1. Types of Requirements
2. Solution Requirements
3. Quality Requirements
4. Business Requirements
5. Architectural Requirements
6. User Requirements
7. Implementation Requirements

What are the main tasks of Requirements Management?

1. Scoping
2. Requirements Analysis
3. Requirements Modeling
4. Attribution and Filter Management
5. Prioritization Management
6. Traceability Management
7. Modification Management
8. Version Management

## 1.2 Requirements Management as an Answer to the VUCA World

The silent revolution: Re-orientation of companies after a severe economic crises in the 1970s that resulted in a massive push for globalization in the 1980.

Even though, projects have always had a need for the specification of requirements, the discipline of requirement management emerged as late as the 1970s in the context of the silent revolution. This can largely be attributed to social, economic and technological developments, that have shaped the world in an ongoing developmental process. These developments, that influence any aspect of our professional and personal realities, are often conceptualized in the high level framework VUCA, an acronym that describes a rise in volatility, uncertainty, complexity and ambiguity (Mack et al., 2015) (Tulder et al., 2019) (Lin & Huang, 2020). VUCA proved itself a solid concept to derive key insights on a wider variety of practical issues. In order to understand, why Requirements Management is a critical element of project management (while it may not have been 100 years ago), we will take a closer look at the different elements.

**Complexity:**

Incomputable amount of causes and effects

**Volatility:**

Rate and velocity of change

**Ambiguity:**

Lack of common understandingx

**Uncertainty:**

Lack of predictability of future events

Do you know the situational conditions?

Can you predict an outcome

*Graphic X: The VUCA-matrix (Lin & Huang, 2020)*

**Volatility:** Changes in the economic and technological environment are happening with accelerated speed and frequency

**Ambiguity:** Cause-and-effect relationships are more difficult to rationalize, than they have before

**Uncertainty:** Future events can barely be foreseen and happen in greater suddenness

**Complexity:** The number of elements, which are the cause for an event, is rising exponentially

In order to familiarize you with the challenges that wait for you in project management, we will elaborate on these four developments. It is the purpose of the following sections to familiarize students with a precise concept of the difficulties that accompany managers in their everyday business. It is the challenge of this section to draw a connection between the high-level VUCA concept and personal experiences.

### 1.2.1 Volatility: More rapidity and higher frequency in changes

Volatility, best characterized by the American sociologist Kenneth Rogoff), describes a condition, in which technological innovations lead to rapid and unforeseen changes in people’s behaviors (Rogoff & Reinhart (2020). The interrelation between the increased number of single developments thereby increases the frequency of changes. In volatile situations, there is transparent knowledge on the causes for and consequences of developments. The practical problem is caused by *velocity* and *number* of change occurrences (Tulder et al., 2019). Volatility describes

* Rapidity of change: changes occur faster
* Frequency of change: changes occur in quicker successions
* Dynamics of change: even a singular change process is volatile

In any project, however, a minimum amount of planning is necessary. In an ideal world, the entire project lifecycle can be planned in advance and implemented accordingly. In a volatile environment, this ideal will barely reflect your practical reality. Volatility impacts projects and project requirements in various shapes and form. While it makes a certain amount of sense to analyze as many requirements in the beginning of a project, the specification sheet should not be considered a fix document. Changes in the client’s environment can occur very rapidly which may change the client’s requirements in the project. Keep in mind, this is not necessarily an expression of so-called flip-flopping on the client’s part but rather an expression of a capability to quickly and responsibly react to a volatile environment. It is a strength of any requirement manager to understand the necessity for quick reactions to requirement changes and integrate them responsibly into the entire network of project requirements.

### 1.2.2 Uncertainty: Lack of stable assumptions on the future

Uncertainty in the VUCA context is referring to an absence of stable key assumptions on future events. The US-Lebanese economist and former stock exchange trader Nicholas Taleb (2018) elaborates on a human flaw during the housing crisis of 2008. Managers placed their trust in a linearity of history and thereby disregarding changes in the environment that require a re-evaluation of assumptions. In simpler terms, the fundamental assumption of most traders (and managers, for that matter) was:

* If something has not happened before, it will not happen in future
* If something has worked before, it will work in the future

Uncertainty has a major impact on project and requirements management. First of all, external shocks can lead to dramatic changes in project requirements and even the most bizarre causes can not be excluded (see volatility). More uncertainty-specific is the implication, that project and requirements management in the VUCA-world only allow management based on experience to a limited extent. It is crucial for students to understand that the question *whether something works or not* is always dependent on a chaotic variety of external influences. These are never the same, even in clients that operate in the same industry. Those external influences might be current trends in the client’s industry, specifics of the technical structure, even down the different organizational cultures. All this strongly implies to never overestimate judgement based on previous experience and to never underestimate a clear and unprejudiced assessment of any new project environment (Tulder et al., 2019).

### 1.2.3 Complexity: incomputable causes for effects and effects for causes

Complexity, in general, describes a chaotic relationship between causes and effects (Baraldi, Corsi, & Esposito (1999); Mainzer (2012); Luhmann (1987)). The business world in general is dominated by causal relationships – after all, there has to be an assumption that a certain action (cause) will lead to a desired goal (effect). These effects can be causes for further effects and so on. An effect can be anything that happens in a project, in order to exemplify, we will stick with the example of an effect as a *problem*, for the moment. Whenever you are dealing with a problem, there are causes – and in order to find an effective and sustainable solution, knowledge of the causes is a crucial element in the process of finding a solution. You may imagine any management context as a network of interrelated occurrences. This leads to a number of insights on this network:

* When you need to solve a practical problem, there is a convoluted number of causes (decisions by other departments and project streams etc.)
* These causes are often hidden, and it is not obvious how they are interacting together in the causation of the problem
* Whenever you are making a decision, this decision can become a hidden cause for further problems
* The effects of your decision making are often unknown to you, whether they may have a positive or negative effect; and they might be unknown to the person/team dealing with the effect

In a project context this condition is tied to the core of Requirements Management. Gathering requirements from the entire spectrum of stakeholders will inevitably lead to conflicts and inconsistencies between requirements. For example: Three varying requirements can be the cause for a conflict on a certain functionality of a machine. These causes may be the effect of underlying differences in the stakeholder spectrum, two departments, for example. In a complex VUCA-world, these investigations need to be made in order to effectively solve a problem (Mack et al., 2015). It is critical to understand: There is a wide spectrum between uncovering any causal element and ignoring these elements altogether. The key is to stop investigating when you and your team are certain to have a solution *that works*. Perfectionism and investigative drive are usually regarded as time killers in a project and – while useful to a certain degree – should be kept under control in a real life project context.

### 1.2.4 Ambiguity: Lack of clarity in meaning

The final characteristic of the VUCA-world is ambiguity. In formal terms, ambiguity refers to a condition in which occurrences can have multiple meanings without a clear indication which meaning is right or useful (Kieser & Walgenbach (2010)). This is caused by both, factors in how human cognition realistically operates and an accelerated functional differentiation of tasks.

Human cognition is always dependent on interpretation. When a requirement for a certain function of a system is uttered in an interview, there will always be gaps between what the interviewee thinks, says and what the interviewer will understand.

This condition is impeded upon by the growing increase in functional differentiation even in smaller more focused companies and projects. What an interviewee thinks about requirements and the way he/she puts them into words is strongly dependent on their function in the company, their educational and professional socialization.

In the same logic, interpretation on the part of the interviewer is influenced by his/her socialization – this way, what an interviewee wants to say and how an interviewer understands it may vary to an extent that endangers the usefulness of the requirement altogether. Time pressure and incomplete information on the situational context complicate a precise understanding even further.

The techniques of requirements engineering (the analytical steps in the beginning of each requirements process) were specifically developed to overcome this gap. We will get back to these techniques in the fourth lesson of this script.

Self-check questions

Q: What is volatility referring to in a VUCA-context?

A: Volatility accelerated and more sudden changes in the economic and technological environment.

Q: What is Ambiguity referring to in a VUCA-context?

A: Ambiguity refers to a cause-and-effect relationships and how these relationships are increasingly difficult to rationalize.

Q: What is uncertainty referring to in a VUCA-context?

A: Uncertainty refers to the lack of foreseeability of future events and their occurrence in greater suddenness.

Q: What is complexity referring to in a VUCA-context?

A: Complexity describes the number of elements, which are the cause for an event; these numbers have risen dramatically.

## 1.3 External and Internal Drivers for Requirements Management

Requirements Management emerged in the 1970 due to economic and technological developments and has developed into a full-blown business discipline at the interface of management and technical subjects.

After connecting the rise of Requirements Management to the VUCA-concept on a rather high-level, further elaboration on the drivers of requirements management in projects are necessary. While we are able to derive some implications for practical project management, from the VUCA perspective, a discussion on drivers for the development of requirements management will help you to better understand practical challenges of Project and Requirements Management.

### 1.3.1 Driver 1: Technical and social systems have become more fragmented

The first and one of the most important drivers for Requirement Management is the fragmentation in the technical nature of most systems. Projects can be characterized as a limited-time effort to process a set of defined materials in a way that results in the shape of something new. Technological advancements have led to an increase in the number of (technical) components that are being processed in each project (Young, 2006). Take the example of an apartment building. In the 1950, the number of components was significantly lower than in a fully modern apartment system, that would be built today (which is why we no longer just have janitors but also facility managers). What does it mean for project requirements?

The essence of management in general is, to guide a system of individuals with highly specific skills and knowledge; a system within which nobody understands the full extent to the most specific details. These details, however, are understood only by very particular employees. All individual employees combine these skills in a system that is more than just the sum of it’s parts. In this thinking it is not a given, that the client really understands the complexity of a system you may be tasked to build in a project. Consequently, you cannot just rely on the client to know all details of what it is, they really want. This has strong implications for project management and Requirements Management:

* The more fragmentation of into little highly specific tasks that require specific knowledge, the higher the number of technical experts, that are needed to complete the entire project.
* The more fragmented the systems become, the more sub-contractors tend to be involved; so the contractors are increasingly limited in their ability to understand the input of their sub-contractors.
* The more fragmented and specialized elements of the system and the projects are, the fewer oversight on the part of project management regarding *what needs to be done*.
* So sum this up: The more fragmentation, the fewer clarity, how the different technical and organizational components interact with each other.

The trend of fragmentation in highly specialized project tasks and system is a major driver for the development and application of Requirements Management tasks and techniques. Requirements Management was made to eliminate projects from the burdon of *nobody really knowing what’s supposed to be done*.

### 1.3.2 Driver 2: Projects have become more individualized

As the entire world becomes more fragmented and complex, so do the needs of individual clients. Individualization has made it’s mark on mass customization in ongoing industrial manufacturing. While Henry Ford manufactured only one edition of his first automobiles (Olson, 2015), nowadays’ customers can order an infinite number of customizations, which match their exact requirements. The social development of individualization extends upwards the supply chain, not only to highly customized product manufacturing line – which is, of course, result of a project, that was characterized by requirements, that no other car manufacturer had. In order to complete this project, the supplier, that was contracted to manufacture VW’s assembly line, also needed to formulate highly specific and individualized requirements to the next supplier up the supply chain (Slamanig, 2010).

While the proverb *any project is different* has always been true, differences may appear in varying degrees – and the degree of individualization has massively increased since the 1970s. While the Krupp Corporation was building *standard* mining equipment for mines in Europe in the 19th century, they had to adjust for different geological and thermic conditions, when the company started targeting global markets, such Latin America of Africa. Projects, nowadays, are not just characterized by a higher number of technological and organizational elements, these elements vary from project to project. So what are the implications for Requirements Management?

* The more individualized the needs of clients are, the fewer knowledge of the project the contractor has.
* The more individualized the needs to the client, the fewer knowledge the clients have themselves.
* The more individualized the needs, the fewer can contractors rely on previous experiences in similar projects.

The driver of individualization largely pressures both, contractors and clients, to apply a high degree of effort to precisely specifying the requirements, that will lead to a system that will serve the business needs to the client.

### 1.3.3 Driver 3: Projects have become more time intensive

As global competition has picked up, western companies could not secure their global dominance against low-cost labor countries, such as the Republic of China. Some goods have become commoditized, meaning, there is no real difference between the quality of systems. A company that needs to build a new cement plant in Vietnam always has the option of choosing a low-cost Chinese product, that might not even be a lower-quality product that a system from a German competitor. Time, however, has become a crucial resource in the competition for new projects (Rüegg-Stürm, 2003).

* Customers highly emphasize time efficiency; every day the handover of a system is delayed, can be financially measured. High price systems may end up being more beneficial, if completed in time.
* Unclear specifications are among the most destructive elements when it comes to keeping a project’s schedule.
* The delays can largely be attributed to situations during the implementation where project managers have worked with *wrong assumption* on what the client *actually* requires. Assumptions, in this sense, is the opposite of a specified requirement.

Well performed Requirements Management, can therefore become a critical resource in project negotiation and in securing a stable position in global markets.

### 1.3.4 Driver 4: Projects have become more globalized

Communication between client and contractor is always based on a common understanding of what the customer needs. It is a practical impossibility to predetermine any handgrip that will be made in a project; that’s why there is always room for interpretation (Rüegg-Stürm, 2003). The way humans apply interpretation is culturally determined. This determination makes communication with people and organizations from someone’s own cultural hemisphere more efficient (Dellner, 2010). Once working abroad a lot more emphasis needs to be placed on the mutual understanding of what should be the end result of a project. The 1970 were shaped by a wave of globalization that created multinational networks of corporations, where individuals from all cultural backgrounds came together to perform (increasingly) complex projects (Butler, 2021). There are multiple examples and experiences, where these projects were threatened by managers, who relied on intuitive communication.

What does globalization mean for multinational projects?

* The more individuals and organizations of different cultural background are involved, the less self-evident customer needs will be to all parties involved.
* The more global a project, the higher the need for a specific internationally agreed-upon code of transforming needs into requirements.

Requirements Management (and especially Requirements Engineering, more on that later), was designed as a new language that is understood by anyone across the cultural hemispheres. Managers realized, it is not enough to just agree on English (or any other language) to enable successful communication in multinational projects. Requirements Management entails a code on how to use English (or any other language) to minimize the need for culturally varying interpretation (Pohl & Rupp, 2021).

### 1.3.5 Driver 5: The number of stakeholders has increased and so has the number of perceptions of the project’s goal

Stakeholders are interest groups (or individuals) who have some sort of interest in the project goal. In a more trivial organizational environment, there is a *single point of contact* in the client organization who can be addressed regarding requirements. In a more trivial technological environment, the client will be able to name all requirements of the project subject. The increased organizational and technological complexity, which we have seen since the 1970s, forces project managers to put more emphasis on integrating a multi-layered network of project-stakeholders (Pohl & Rupp, 2021) (Pohl, 2010). In larger corporations, there can be multitudes of organizational entities that might be (even unknowingly) be affected by the way, the project will be designed and implemented. A more diverse set of individuals will be affected, as companies become more complex and intertwined, the increase in interorganizational linkages and dependencies create further stakeholders and so do administrative bodies of the respective government, environmental groups, unions and the client’s customers (Pohl, 2010). Furthermore, these stakeholders may have conflicting interests regarding characteristics, budget and time constraints.

So how is the number of stakeholders driving the demand for Requirements Management?

* This more stakeholders in a project, the higher the need for project managers to investigate in a chaotic stakeholder environment.
* The more stakeholders with particular needs, the higher the likelihood of conflicting interests regarding project requirements.

The increasing amount of stakeholders has been a major driver for the emergence of Requirements Management. Investigative techniques for a large network of stakeholders is part of this discipline and so are techniques for the mitigation of conflicts between them.

Self-check questions

Q: How is the fragmentation in the technical nature of systems imposing a challenge to Requirements Management?

A: The diversity of technical components force project managers to gather a wider variety of specialized skills. It is difficult to define requirements regarding the nature of unknown components.

Q: How has globalization accelerated the development of Requirements Management?

A: Commonly shared assumptions on how to deliver a project are evaporating. Requirements need to be stated in greater detail, the more global a project is set up.

## 1.4 Project Management and Requirements Management

Requirements Management has become an essential part of project management. While the techniques are often applied in other management disciplines, as well, project management has implemented Requirements Management as a commonly applied technique.

It needs to be pointed out, however, that companies sometimes see no need in the creation of a Requirements Management department or the appointment of a dedicated Requirements Manager. Requirements Management describes a fixed set of tasks that have become a necessity in most projects. These tasks can be taken over by project managers who can flexibly change work streams. In consulting and PMO companies, it often is a prerequisite for a successful career to obtain Requirements Management certifications, such as the *Certified Requirements Management Professional* by the *International Requirements Engineering Board* (IREB) (Pohl & Rupp, 2021) (Ebert, 2019).

The highest share of the overall requirement effort can certainly be seen in all tasks related to the analysis of requirements, often referred to as Requirements Engineering. Even when there is a dedicated Requirements Management team, it makes sense to involve PMO into these tasks (Ebert, 2019). It needs to be guaranteed that the work and findings of Requirements Management impact the path of the project from the very first day.

Seld-check questions

Q: Is a requirements manager necessary in any project?

A: It is necessary for someone in the project to manage requirements. It is not necessary to have a dedicated full-time requirements manager in smaller and less complex projects.

Q: Does a project management officer have to be involved in Requirements Management?

A: Yes, they should be involved in major decisions and should be monitoring developments from a requirements-perspective.

Summary

Clients have unique requirements on a technological, structural, processual and interpersonal (stakeholder!) level. When performing a project for a client, it is necessary, to bridge the communicative gap between the client’s needs and the contractor’s ideas. Without Requirements Management, this gap remains open and will cause errors and interruptions.

Requirements Management is a discipline that safeguards the development, the management and the implementation of requirements. There are sequential elements of Requirements Management, which are mostly executed in the early stages of the project, namely requirements analysis, requirements specification and requirements documentation. These are the prerequisites for a successful start of the project. However, Requirements Management tasks don’t end there. In a complex project environment, requirements tend to change, and Requirements Management is responsible for guiding the change process. Monitoring the successful implementation of requirements in all project stages is the second most prominent ongoing task of Requirements Management.

Any Requirements Management process separates requirements into different categories. This helps both, client and contractor, to tweak the rules of analysis, management and implementation based on the specific conditions, any type of requirement imposes on its handling.

Requirements management, like most modern project management methodologies, has become necessary due to major environmental developments. Since a major push in globalization and technological development, especially in the 1970s, the (business) world has become more volatile, uncertain, complex and ambiguous.

These conditions stem from economic, technological, political, natural and socio-cultural developments, that directly impact corporations and even particular projects.

Requirements Management is part of any project. It can either be performed by project managers, or by dedicated requirements specialists.

## Self-check questions

Can you explain at least four factors, that drive the necessity for dedicated requirements management?

Can you define the main tasks of requirements management?

Can you define at least five types of requirements?

What is the role of requirements management in project management?

# 2. Classification and Terms of Requirements Management

**Study Goals**

On completion of this unit, you will be able to …

… differentiate Requirements Management from requirements engineering.

… differentiate Requirements Management from business analytics.

… understand the different layers of desire from a company’s survival to requirements.

… know the importance of the specification sheet.

… know the importance of the technical concept in the context of Requirements Management.

## Introduction

The central problem, that Requirements Management addresses, is the natural deficit in clarity regarding communication between what the client needs and what the contractor will deliver. Requirements Management is managing all project- and system-related communication with the goal to maximize clarity on both sides. Clarity in communication on the highest level demands a very clear understanding of the requirements discipline. This understanding goes beyond a definition of specific terms. In this unit, we will delimit Requirements Management from other related disciplines and introduce key elements.

## 2.1 Requirements Management in Relation to Requirements Engineering

Requirements Management and Requirements Engineering are often applied synonymously. Even when both terms are used separately from each other, there is no consensus on how both terms relate to each other. We advise you, whenever necessary, to openly ask for clarification in the beginning of each project. Differing understandings of terms is a common issue, caused by varying usage in science and literature. Most projects recognize this and most project plans contain a section with definitions that safeguards a common understanding of all terms (Project Management Institute, 2021).

Requirements Engineering: The art and science of analyzing and formalizing requirements.

For the sake of clarity – clarity being a central goal of Requirements Engineering/Management – we will provide a contextualization of both terms that suits the purpose of this course book. Even though there are varying opinions on the question, *which term summarizes all other sub-disciplines*, the fundamental idea to separate the sub-disciplines into

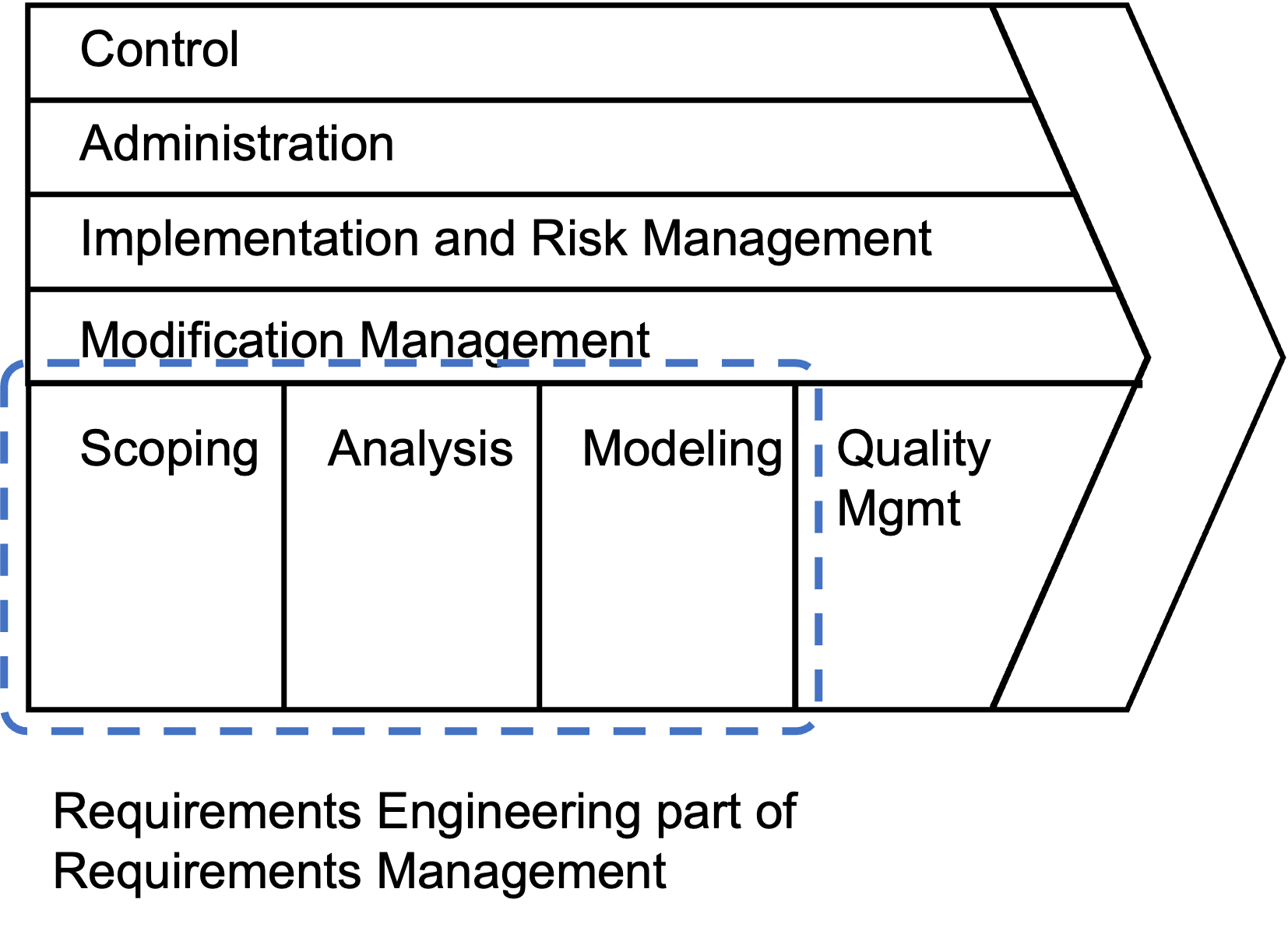
1. the task of *analyzing* requirements in the beginning of the project and
2. a second part that *manages* requirements throughout the project.

In this course book, we define Requirements *Management* as the main discipline that describes all challenges and tasks that deal with requirements in a project.

Requirements *Engineering* refers to the analysis, the development, and the gathering of requirements from the project’s stakeholders . While Requirements Engineering must not to be misunderstood as a limited time effort (since later phases of the project require frequent analysis tasks, as well), *the related tasks are predominantly located in the early stages of the project.*

Requirements Management refers to all tasks in relation to project requirements. Requirements Engineering is one of these tasks, albeit an especially significant one.

Please keep in mind, that there are different ways of applying these terms, depending on the professional context. Confusion in terminology, however, does not change the nature of requirements-related tasks that need to be dealt with in any project.



Graphic X: Requirements Engineering and Requirements Management

These tasks, regardless of the definition of terms, structure and succession in the project.

**Self-check questions**

Q: Where is the greatest share of Requirements Engineering located in a project?

A: The greatest share of work is happening in the beginning of each project.

Q: Why is Requirements Engineering still relevant after the acceptance of the requirements by the steering committee?

A: Requirements are changing and new developments can cause the need for further analysis and specification of requirements, that have (for whatever reason), not been specified in the early stages.

## 2.2 Requirements Management in Relation to Business Analytics

Any project starts with a business need; without a clearly defined business need, projects are devoid of any purpose to serve. Oftentimes, it is not at all easy to define the business need. Requirements Management without dedicated business analysis tends to focus on the solution (the system) for an undefined problem and for an undefined need.

This has often caused a self-referential project implementation, meaning, most activities in the project were performed with the goal of successfully completing the project itself. While this sounds reasonable at first, the primary goal of the project, and more specifically the system, is to serve a very particular business need (see next chapter). Business analysis can thereby be understood as an upstream task that precedes Requirements Management by analyzing and defining the business needs, which then lead to the project (Hruschka, 2019).

While this course focuses mainly on Requirements Management, we need to stress the importance of business analysis. Much like Requirements Management, business analysis is not necessarily a separate discipline with a dedicated team. It can be understood as an important set of tasks which needs to be accounted for in any project – regardless if with a responsible business analysis team/consultant or as a task performed from within the client’s organization and in some instances even the project team.

So what tasks are being done in business analysis?

*Graphic X: Tasks of business analysis*

**Environmental analysis:** The root cause for all business needs lies in developments in the company’s environment. These changes can lead to existential threats and major chances (which, if not taken, lead to existential threats, as well). These developments can be of economic, technological, ecological, or social nature. An analysis of these external developments helps tackling the challenge a lot more consciously. The telecommunications technology manufacturer Nokia failed to use chances, which let to it’s downfall during the event of smartphone technology. Business analysis is in charge of analyzing these root causes in the environment. Yet, it is not a given, that new developments actually impact a business. A plausible impact analysis is critical for understanding, in what way the development will affect the company.

**Gap analysis:** While the analysis of the environment is focusing on external developments, the gap analysis focuses on the internal setup of a company (in relation to external drivers). In some instances, companies can quickly adjust to threats and opportunities in their environment. In that case, no further project is necessary. Oftentimes, the more helpful question to business analysis is: *what prevents the company from quickly adjusting to the new challenges?* The answer is usually analyzed in a gap analysis, which uncovers a difference in skills and resources of the company. These resources are usually located not just in one area of the company, but in many locations. The opportunity to establish a new business area, for example, necessitates strategic, structural, processual, technological and possibly cultural changes. These create the need for a comprehensive change program with both, technical and organizational/cultural aspects; gap analyses usually contain a strong emphasis on deriving needs from the gaps identified in the process. Long before Requirements Management specifies the functional and non-functional requirements of a solution, business analysis prepares the strategic and organizational changes necessary to enable a targeted change effort.

**Solution proposal:** The next step in the business analysis process is the proposal of a viable solution, that satisfies the needs identified in the gap analysis. The solution proposal is a high level document that outlines the solution in it’s broadest sense. In contrast to Requirements Management, this stage establishes a business-oriented picture of the inner workings of the solution with emphasis on an integrated view of all mechanisms necessary to enable a functioning solution. A technical system is always only one part of the entire change process – and both, project management and Requirements Management only deal with this “snippet”. Strategic adjustments, process integration, financial calculations (such as business plans) are a prerequisite for the start of a successful project – and they are usually performed beforehand in the context of business analysis. Laying out, how any aspect of the solution integrates into a system that will have a comprehensive impact on the business needs to be recognized by Requirements Management; yet it should usually be completed before a project team enters the stage.

**Implementation support:** At the interface of business analysis and Requirements Management, both responsible individuals/teams need to communicate for successful implementation. Requirements Management needs to target the business needs of a project by starting, where business analysis’ responsibilities end: the design of requirements for a technical solution that is covered within the project scope. Still, individuals/teams in charge of business analysis need to continue supporting all Requirements Management efforts during all phases of the project, especially the implementation phase. The high level of business analysis (compared to requirements) leaves room for interpretation. While this is necessary for the project team to develop discretionary concepts, these concepts need to withstand the critical judgement of business analysts – and so does any step during the implementation phase.

In short, business analysis is a critical prerequisite for any project. While business analysis is tasked with specifying requirements, these requirements are defined on a broader business-related level. When it comes to the technical solution that is object of a particular project, Requirements Management takes over, while being supported by business analysis in the process of specifying, managing and implementing these technical requirements.

|  |  |  |
| --- | --- | --- |
| Characteristic | Business Analysis | Requirements Management |
| Primary focus | Business needs | System development |
| Object | Processes | Products |
| Project type | Off-the-shelf system implementation | Custom system development |
| Change mode | Adjusting organization to system | Adjusting system to organization |
| Typical application | Complex organizational projects | Complex technical projects |
| Requirements types | business, stakeholder, and transition requirements | functional and nonfunctional systems requirements |
| Success measurement | Business value and ROI | Functioning system |

*Table X: Differences between Requirements Management and Business Analysis*

So who is responsible for business analysis? In contrast to the individuals/teams responsible for Requirements Management, business analysis tasks are usually not directly part of the project. Larger corporations employ individuals who are tasked with the specific role of business analysts, who are often tasked with the leadership of change programs. In smaller corporations but larger projects these tasks are often done by external consultants; but can also be performed by internal employees with varying roles. Roles that match the tasks connected to business analysis are often labeled as Business- or Enterprise-Architect as well as Business-Systems-, Data- or Process-Analyst (Hruschka, 2019). Internal roles that often qualify for business analysis are Product Manager, Project-/Program-Manager or Inhouse Consultant.

**Self-check questions**

Q: Is business analysis a natural task for Requirements Managers?

A: Business analysis deals with different objects and different goals than project requirements. It is, therefore, not recommended to combine both tasks in one person.

Q: How are business analysis and Requirements Management differing in focus?

A: Business analysis primarily deals with business needs, while Requirements Management deals with system development.

## 2.3 From Customer Needs to the Specification of Requirements

Any business transaction, especially a complicated one such as a project, start with some sort of *customer need*. In order to differentiate between requirements and customer needs, we can deduce these terms from a hierarchy of desires, any company has.

*Graphic X: Hierarchy of desires of the company*

### 2.3.1 Survival of the company

At the top of the hierarchy there is the business’ desire to survive. Safeguarding the own existence is the fundamental goal of any company that supersedes all other goals, such as profit, growth or industry leadership (Rüegg-Stürm, 2003). While all projects (and all corporate activities, for that matter) *do* serve the mid- to long-term survival of the company, there is no necessity to have an immediate existential threat at hand, in order to justify a project. Just keep in mind, that key performance indicators, such as *revenue*, *profit*, *growth* are never the highest priority, as some companies consciously operate contrary to these KPIs – so long as it serves their survival.

**→ The managerial figure of thought: *We will do anything necessary so the company may survive*.**

Figure of though: A comprehensive idea, that is, in itself, closed and ready to apply in real-life.

### Business Goals

Business goals are designed to serve a company’s primary desire of survival. Examples for business goals can be both, positive and negative: growth and downsizing; investment and divestment, profit and loss (due to investments) – whatever makes the mid- and long-term survival of the company more likely. Keep in mind that, in most cases, there will be a hierarchy of business goals. An increase in profitability will most likely be served by a great number of secondary business goals. An increase in profitability, for example, can be served by very different secondary business goals, such as more efficient processes or an increase in sales (in order to scale more effectively).

**→ The managerial figure of thought: *What goals do we need to follow in order for the business to survive?***

### Business needs

Business needs (often used synonymously with customer needs) specifically refer to company-internal resources which are necessary for the achievement of business goals (Kupersmith et al., 2013). A company with the goal of increased profitability through more efficient production processes may issue the need for a new assembly line that enables the company to realize the business goal(s) of increased profitability through more efficient processes. The new assembly line is the internal resource the company needs in order to achieve the business goal. In practical terms, these needs are usually the product of any project.

**→ The managerial figure of thought: *What internal resources do we need in order to achieve our business goal(s)?***

### 2.3.4 Requirement

Requirements are characteristics of the resources that a system needs to have, for it to actually serve the business need. Business needs are normally too broad and general for a contractor to understand; at least on a level that will safeguard the success of the project. The increasing level of functional and technical differentiation creates an incomputable number of possibilities for a contractor to build the system and to perform the project. The specification of requirements dramatically increases the likelihood, of systems/resources actually contributing to the company’s business needs, which will serve the business goals, which will sustain the company’s existence over time.

**→ The managerial figure of thought: *What characteristics does the system need to have in order to actually satisfy our business needs?***

A few hypothetical examples to illustrate the difference between the different levels of goals, needs and requirements:

|  |  |  |  |
| --- | --- | --- | --- |
| Context | Industrial manufacturer with large portfolio | NGO focused on housing for homeless children | Publicly listed cement producer (see below) |
| Survival | Survival under threat as massive size has caused inflexibility | Not under threat but adjusting to an influx in unaccompanied minor refugees | Not directly under threat but long-term market outlook requires changes |
| Business Goals | 1. Investors pressure for higher stock value  2. Breaking up into two smaller companies | 1. Economies of scale in administration through new target groups  2. New operative area will be established | 1. Increase in stock price through…  2. …higher profitability…  3…. increased output |
| Business Need | Massive re-structuring/ change mgmt. project | New facility for housing minor refugees | New cement plant that supports business needs |
| Requirements | e.g. specified social requirements; time constraints; strategic, structural, technical and cultural requirements | e.g. architectural, technological and budget requirements specifically targeted at housing target group | e.g. requirements towards technical, operational and service-integration into the existing system |

*Table X: Examples for the hierarchy of desires of the company*

#### Practical example

Let’s make one of these examples more tangible with a slightly more elaborate walkthrough of the rationale behind the project of a hypothetical (but close to a real case) publicly listed, medium size French cement producer.

**Example survival:** The survival is not under eminent threat, as the performance is generally high and customers are satisfied. The recent global market has undergone some shifts in production towards China. Chinese companies have attempted to acquire European competitors, in order to transfer technology, establish dominance in the European market and slowly shift productive resources to China. This constitutes a long-term threat to the existence of the company.

**Example business goal:** In order to defend the company from a hostile takeover, the company needs to obtain high stock prices. This goal can be achieved by increasing the distribution of profits for the shareholders. There are different possibilities to achieve this goal; the company decides to increase the overall profitability through increased production, sales, and higher economies of scale.

**Example business needs:** As the current manufacturing plants are already near maximum capacity, the company identifies the construction of an additional plant as the best way to achieve the business goal of increased profitability through increased economies of scale through increased production. But the technical managers of the company are aware, that not just any new plant can generate economies of scale.

**Example requirements:** In order to achieve the business need, the plant needs to have very particular characteristics. The managers identify three key elements for the generation of economies of scale: 1) Economies of scale for operation, so operational staff can operate the new plant just like the other plants. 2) Economies of scale for administration, so the interfaces to the digital control systems of the company seamlessly integrate into the digital structure. 3) Economies of scale in repair and maintenance, so the existing and very beneficial contracts with service and spare parts providers can extend to the new plant. The technical managers know, that it will be a larger endeavor to define these requirements – as they are honest with the fact, that knowledge on the specifics is distributed across the organization. In this spirit, they opt to involve a project contractor with a high emphasis on Requirements Management.

**Self-check questions**

Q: Is the primary goal of the company to increase profits?

A: No, the primary goal is survival of the organization.

Q: A company develops a plan for a successful implementation of a new branding strategy. Can this be characterized as a business goal?

A: No, the implementation plan would be a business need. You could connect business goals, such as expansion into new markets to the need.

## 2.4 The Specification Sheet and its significance

A requirement in itself is a customer’s desire for a precise characteristic of a newly implemented system. It exists without being fulfilled and even without being recognized. In order to allow the requirement to be incorporated into the system, it needs to be handled by the different tasks of requirements management. Most and foremost, the requirement has to be added to a *specification sheet*. The specification sheet is the central tool to create a common understanding of the project between a client and a contractor (Pohl & Rupp, 2021; Young, 2006).

### 2.4.1 Purpose of the specification sheet

The purpose of the specification sheet is to define as precisely and in as great detail as possible, how the system, the object and result of the project, is supposed to be designed and implemented. It thereby provides detailed guidance to the contractor and leaves the client assured, their needs will be satisfied with the tasked project. Furthermore, the specification sheet is as a legal document that, after mutual agreement, serves as the binding guideline for all further operations. In case of later disputes between the client and the contractor, both can refer to the specification sheet in order to square project progress and the initially agreed upon terms. When it comes to legal disputes, the document usually contributes to the legal resolution (Pohl, 2010).

In other words, the specification sheet is the central document, wherein the requirements of the customer are specified. Specifying a requirement is referring to the transformation of the requirement as *a generalized desire by a stakeholder* into the language of Requirements Management, that will make the requirement *be universally understood by professionals* throughout the project.

While the requirements sheet is usually printed at some stage, it makes more sense to picture the specification sheet as a general repository that is normally stored in Requirements Management software applications.

### 2.4.2 Content of the specification sheet

Most specification sheets are made of two major components: *business* and *system*. The business section introduces the context of the project and provides information useful and necessary to read the document. The system section gives space to the specification of requirements, based on an initially agreed upon structure and hierarchy.

|  |  |  |
| --- | --- | --- |
| Section | Structure | Description |
| Business | 1. Introduction | Provide a clear introduction that enables readers to connect the project to business requirements |
| 1.1 Purpose of the document | Why is the document written? What are the aspects that are at risk, not to be understood? |
| 1.2 Glossary | Define all terms regarding project, requirements and the system and agree on a common understanding |
| 1.3 Stakeholders | Who needs to be involved in which context? Include names, positions, and contact information |
| 1.4 Goals | What business goals do the project and the system serve? |
| 1.5 References | Refer to important sources of information, specify what role they play and where to find them. |
| 1.6 Instructions to apply the document | Further information on project specifics regarding the usage of the document |
| System | 2. System overview | Provide a high-level overview of the specifics of the system itself |
| 2.1 Context | What is the technical context, within which the system operate? |
| 2.2 Key assumptions | What are the assumptions necessary for implementing the project (analyze, if not expectedly true) |
| 2.3 Technical constraints | List all technical elements, that are necessary for the system to operate in it’s desired environment |
| 2.4 Main exclusions | List all technical aspects and elements, that are *not* supposed to be part of the system |
| 3. Sub-System I | In case of more complex systems, separate into different sub-systems (if not, start specifying requirements) |
| 3.1 Operational entities | Which organizational entities are directly involved with the system operationally? Describe how exactly! |
| 3.2 Operational roles | Which organizational roles are directly involved with the system operationally? Describe how exactly! |
| 3.3 Use cases | Define all (or the most common) use cases for the system and describe them in great detail |
| 3.4 Non functional requirements | Specify the non-functional requirements |
| 4. Sub-System II - n | Repeat as often as necessary to specify each sub-system |
|  | Appendixes | Add further information, technical descriptions, graphics, that you can refer to in the specification. |

*Table X: Components of a typical specification sheet.*

**Self-check questions**

Q: What role is the specification sheet playing in Requirements Management?

A: It is the central document where all requirements are stored.

Q: What are the main components of the specification sheet?

A: Business requirements and system requirements.

## 2.5 The Importance of Functional Specifications and Technical Concept

Use case: Real-life case, in which a system or a method will be applied.

While there are many types of requirements, there is little doubt, that functional requirements are usually in the center of attention for most requirements managers (Ebert, 2019). In order to create consensus on functionalities of a system (that is being developed and built in a project), requirement managers are usually working with an additional document that not only specifies the functionality of the system but delivers a holistic view of function and use case, of which the system will be capable. The *technical concept* (often synonymous with *functional specification document*) is often compared to a detailed user manual, that was written before the system was developed. There are varying schools of thought on what needs to be part of the technical concept – these vary independently between industries and companies, as well as size, complexity and nature of the project e.g. (Adams, 2015; Baumgartner et al., 2021; Haberfellner et al., 2019).

The most general (but not necessarily exhaustive) list of elements:

*Table X: Elements of the technical concept*

Let’s allow ourselves a closer look at each element of the technical specification. Keep in mind, that these elements (in some form or another) are relevant for projects even outside of the technical and IT spectrum, such as event management and social projects.

**Purpose:** The purpose is a definition of the desired result of the project in a business context. You may answer the question, how the system is benefitting the client and thereby create a bridge between technical, operational and business concerns.

**Risks and assumptions:** Just specifying, what needs to be done, is often not enough. No matter in how much detail you specify a system, there will always be some room for discretionary decision-making on behalf of the contractor (Adams, 2015). So it makes sense for any client to use their subject matter expertise to specifically refer to technology- and industry-specific risks, that need to be avoided by the contractor. While the expertise on these risks is on the side of the contractor, it is the requirement manager’s responsibility to inquire about events and elements that could impact the functional design in an undesirable way.

**Functional specification:** The specification of all functions of a system in the technical concept is still different from the specification of functional requirements in the specification sheet. Besides the absence of requirement-specific language in the technical concept, it serves as a description of the functional design. Still, it can be a valuable source for requirements analysis.

**Processes:** No technical system exists in a vacuum. While this sentence normally refers to the system’s integration into other technical systems (last aspect in this list), it is especially true for operational processes. In order for the contractor to understand the operational role of the system in the entire operational system of the client’s business (but also all stakeholders on the client side), this particular role from this particular perspective needs to be describes and understood.

**User roles:** User roles specifically explain the interaction of users with the system. These roles need to be specified and defined so the real-life application of the system can be understood (Baumgartner et al., 2021). This section creates room to demonstrate all further requirements that will come from a user-perspective (usually the center of functional specification) and describes how the users will work with the system.

**Interfaces to other systems:** The technical structure of any company has long become a major success factor for operations. Key element is the question, how well the interfaces between different technical systems are designed. Therefore, the technical concept specifies all interfaces to other technical systems in a descriptive way (Haberfellner et al., 2019). This is obvious in any IT environment, but naturally reaches as far as construction, industrial manufacturing or consulting projects.

To ensure functional requirements in a project, the detailed development of a technical concept or functional specification document is a critical step. Keep in mind, that this document will be subject to changes and further development throughout most project lifecycles. However, it provides all parties with a precise image of what the system will look like from a functional perspective.

**Self-check questions**

Q: Would you agree with the following statement: *Business concerns should not be part of the technical concept*?

A: Any technical concept needs to provide answers to the purpose of the system. Since the purpose is always business-related, these concerns always need to be part of the document.

Q: What are the major components of a technical concept?

A: Purpose, risks and assumptions, functional specification, processes, user roles and interfaces to other systems

Summary

Requirements Management is the umbrella term for all requirements-related tasks and responsibilities. An important part is the analysis of requirements. All tasks related to analyzing, specifying and documenting requirements are called requirements engineering (RE). Most RE-related tasks are located in the very beginning of a project.

Business analytics is a process that precedes the project and most Requirements Management activities. The discipline formalizes the path from the identification of a need for change and development all the way to the initiation of the project and beyond. Business analysis focuses on the business needs and the project from a holistic point of view.

In order to specify requirements in a way that not only creates a functioning system, but a system that actually supports a client’s business goal, we need to understand the hierarchy of needs. The steps of survival, business goals, business needs and requirements should be understood and connected to each other.

There are various tools, such as business analytics or requirements engineering, that manage the process from the client’s need to survive all the way down to requirements.

The specification sheet is central to any requirements management process. It is central in a way, that all early analysis tasks work towards completing the specification sheet and most later activities work towards realizing what has been specified in the document.

The technical concept (often referred to as the functional specification document) is a first draft of how the system will look like, which functions it will have and how it needs to be integrated into the operational environment of the client’s organization. While this document can reach higher levels of detail, it is only the starting point for any requirements-process.

Self-check questions

How are requirements engineering and requirements management relating to each other?

How are business analytics and requirements management relating to each other?

What is the purpose and what are the main characteristics of the specification sheet?

What is the purpose and what are the main characteristics of the technical concept?

# 3. Requirements Management Tasks

**Study Goals**

On completion of this unit, you will be able to …

… understand and describe the central tasks and responsibilities of Requirements Management throughout the project

… understand all aspects of management and control of requirements

… know the different aspects of requirements administration

… understand requirements-related risks and know typical ways to mitigate those risks

… describe the elements of the requirements implementation model and explain the interrelation between those elements

… understand the responsibilities of the change control board and how requirements can be changed throughout the course of the project

## Introduction

Now, that we have talked about requirements and their role in any project, it has become apparent, that management of requirements is a delicate task. Any well-managed project – high or low volume, short- of long-term, high or low complexity – needs to find a dedicated person, who deals with managing requirements. The larger and more complex a project becomes, the more likely it is, to install a role, exclusively tasked with Requirements Management. But regardless, if this position exists or not, there are several requirements-related tasks, that need to be managed in *any* project.

**Advice for students:** The requirements-related tasks are often very structured, they follow clear guidelines and templates, are (a lot) more textbook-based than other project tasks – and therefore learnable. Other project-related tasks require more experience and sensitivity towards elements that might not be obvious to less experienced employees. Smaller projects are a great way for younger employees to proactively come forward and ask for taking charge of requirements management. While this might not be your only task in the project, requirements management is a great way to show that you are able to handle responsibility. If you do not want to steer your career on a requirements path, you can just ask for other responsibilities after successfully managing requirements once or twice. We are not (necessarily) recommending becoming a Requirements Management professional – but with some dedication, accuracy and personal drive, Requirements Management is a great way to prove, you are generally worthy of being trusted with project responsibilities. If you decide to take this route, you should work with the IREB literature referenced in this course book (e.g. Pohl & Rupp, 2021). Don’t be shy to have their books on your desk – the literature is far from theoretical. It is trusted by thousands of requirements managers around the globe and many consulting firms, clients and project firms require IREB-based certifications from their employees.

## 3.1 Management and Control of Requirements

We start with the assumptions, that the process of developing project requirements is dependent on a number of factors, that limit the overall project organization’s ability to self-organize requirements development:

1. Precision and commonly agreed-upon structures in requirements definition
2. A highly complex and interrelated network of stakeholder interests
3. A high criticality for a completion of the project in a way that satisfies both, the client and the customer

Against this backdrop, it cannot be expected, that all stakeholders just hand in their requirements in a way, that sums up to a solid requirements specification sheet.

Management and Control of requirements is the task of bringing order into the chaos of the multitude of requirements in the project. These tasks are amongst the key differentiators between successful and unsuccessful Requirements Management and will, therefore, be elaborated on in due detail.

### 3.1.1 Basics in management and control

Management and Control related tasks have two main purposes in an overall Requirements Management context. The need for these purposes emerges right after the definition of requirements and is often seen as part of Requirements Engineering tasks (Rupp, 2014):

1. Controlling defined quality criteria
2. Dissolve conflicts between different stakeholder (interpersonal)
3. Dissolve conflicts between different requirements (technical)

By safeguarding quality criteria and dissolving conflicts, Requirements Management decreases the likelihood of additional costs in later project stages. This is critical as defects in requirements definition, that remain unresolved, potentially impede on all later project activities. Failing to meet (and address) insufficiencies in quality and failing to solve conflicts almost inevitable leads to higher costs and the maximization of risks at some point in the project.

#### Mitigation of risk to legal liability

Since requirements are legally binding specifications for the system, that is being developed in the project, compiling a list of inquired requirements is not enough.

If the whole of requirements are not managed and controlled, the contractor faces serious exposure to conflicts that, often enough, lead to lengthy legal disputes. These do not only lead to project stops, possible exclusion and premature termination but also to significant damage to your company’s reputation and possible career disadvantages if you are in the center of managing requirements activities.

#### Generation of acceptance for the new system

Conflicting requirements are usually the result of conflicts between the interests of stakeholders. These conflicts can be open and hidden:

* *Open conflicts*: In open conflicts, stakeholders know their conflicting interests and may – more or less – cooperatively work on a solution. The increase of cooperation in this process is the responsibility of management and control tasks in Requirement Management.
* *Hidden conflicts*: Conflicts, which are hidden, are usually more unpredictable. Requirements Managers have fewer ways to project the degree to which the technical conflict can become an interpersonal one. Yet, it is a critical task and a duty of anyone involved in requirements management to mitigate these unpredictable hidden conflicts and employ skills on both the technical *and* interpersonal level in these situations.

This section is targeted at familiarizing you with how to manage and control requirements in a way that creates a commonly shared understanding of the requirements for the system that is being developed.

### 3.1.2 Quality aspects in managing and controlling requirements

When controlling requirements, it is key to set clear standards, regarding which quality criteria requirements are controlled. Requirements managers have successfully applied three main quality criteria for requirements controlling (Rupp, 2014).

*Fig. X: Main quality criteria for requirements controlling*

Hereafter, we will go through these criteria one by one and provide a list on what to pay attention to, when controlling each individual criterion.

#### Controlling of the quality-element *content*

Content-related defects and deficits in requirements are often procrastinated through the entire project lifecycle.

Risks of procrastinated defects and deficits are project decisions, which lead to a dead end in the particular project stream; the costs for the correction of errors rise with increasing project progress. Furthermore, any project task is built on assumptions. These assumptions relate to questions, such as whether the resources are sufficient, organizational and financial support is given and, especially, whether the specified requirements are correct and a mirror of the customer’s actual requirements.

The goal of content control is to analyze the requirements towards content-related errors, defects, and conflicts. There are a number of factors, which need to be considered in management and control of requirements’ content.

|  |  |  |
| --- | --- | --- |
| Task | Question |  |
| Control Completeness | Regarding the sum of all requirements: Examine, if all relevant requirements analyzed and specified | ☑ |
| Verify, if all specified requirement contain exactly those information necessary to implement the system | ☑ |
| Control solution-neutrality | Check, if the requirements preemptively imply technical design decisions for the system | ☑ |
| Be mindful, that requirements always need to be solution-neutral | ☑ |
| Control verifiability | Verify, if measurable criteria for successful implementation can be unambiguously derived | ☑ |
| Replace relative or vague quality criteria, such as *good* with specific numeric or other absolute quality criteria | ☑ |
| Control integrity | Double-check, if all requirements actually reflect the needs and desires of the stakeholders | ☑ |
| Control consistency | Examine the document for contradictions between different requirements | ☑ |
| Verify, that all requirements can be realized in *one* system | ☑ |
| Control necessity | Control the direct and indirect connection between any requirement and the business goal of the project | ☑ |
| Interface with business analytics, if necessary | ☑ |

*Table X: Content-related criteria for controlling requirements (based on Rupp, 2014).*

#### Controlling of the quality-element *documentation*

The third essential element of managing and controlling requirements is the control of documentation. An accurate documentation of requirements is essential to any successful project. If documentation is not done right, confusion during the implementation phase is almost inevitable.

It is therefore part of requirements control to not only examine the content-related aspects of all requirements, but also the way they are documented.

Risks of non-compliance with the statutory provisions of requirements:

* + Interruptions during the implementation phase
  + Confusion on the original intention of requirements
  + Lack of completeness in the specification sheet
  + Specified requirement may be overlooked

Central tasks and focus in this exercise are:

|  |  |  |
| --- | --- | --- |
| Task | Question |  |
| Control document format | Is the documentation of requirements compliant with the agreed upon format? | ☑ |
| Is the documentation following the template restrictions? | ☑ |
| Is the documentation conforming to the agreed-upon modeling-language? | ☑ |
| Control document structure | Is the structure in accordance with the defined structure of the document? | ☑ |
| Are all information stated in the right section in the document? | ☑ |
| Control rules for documentation | Identify implicit design decisions (regarding the formal layout of the document) that were made without prior approval | ☑ |
| Verify, if the agreed-upon modelling language was used as a standard throughout all documents | ☑ |
| Control ambiguities | Make sure, the documentation leaves no room for multiple interpretation | ☑ |
| Check for clear language and defined terms | ☑ |

*Table X: Documentation-related criteria for controlling requirements (based on Rupp, 2014)*

#### Controlling of the quality-element *reconciliation*

All requirements must be reconciled with all parties involved. If decisions on certain requirements are made without the involvement of all affected stakeholders, future conflicts during the implementation phase can hardly be avoided. A lack of reconciliation during the analysis, definition and specification of requirements therefore leads to an increase in project costs and an increase in consolidation of requirements, which slow down the entire project process.

This does not necessarily mean, all parties need to be in agreement. However, even in conflicts, all requirements need to have gone through a process of scrutiny by all affected stakeholders. Oftentimes, it is impossible to avoid compromises or even reach decisions that leave all parties with some level of open conflict. Still, it is important to verify, discussions have happened and led to transparent decisions.

|  |  |  |
| --- | --- | --- |
| Task | Question |  |
| Control agreement on requirements | Check, if all stakeholders, involved in a requirement have agreed to the specification | ☑ |
| Control agreement on changes | Verify, if requirement changes are in agreement with all stakeholders, who were involved in the original version of the specification | ☑ |
| Control, if all conflicts are resolved | Double-check all requirements, which were subject to some sort of conflict | ☑ |
| Note the sort of agreement, that was reached in the decision-making process | ☑ |

*Table X: Reconciliation-related criteria for controlling requirements (based on Rupp, 2014)*

Controlling requirements on a level, that actually preemptively eliminates later conflicts, can be challenging. Still, it is strongly advised to insist on enough time, as errors and deficits may cause even more time later on in the project.

### 3.1.3 Principles controlling requirements

As Management and Control of requirements has a central role in the overall requirements discipline, we want to elaborate a bit deeper beyond checklists. There are six principles to be applied when managing and controlling requirements

*Fig X: Principles when managing and controlling requirements (based on Rupp (2014) and Young (2006))*

#### Principle 1: Involve the right controller

The controlling process is dependent on the involvement of requirements controllers. Without the right controller, blind spots will not be made visible and the purpose of management and control will not be fulfilled.

The controller should be independent. Even the most self-critical author of requirements should not take the role of the controller. Authors of requirements are often unable to identify their own deficits as they intuitively recognize the meaning in specifications, that are unintelligible for others.

Appoint an internal controller. It is always necessary to appoint an internal controller who is familiar with the project and the specifics of the system, as well as the client industry. If the controller is not a qualified requirements specialist, they can take over a preliminary technical evaluation.

Possibly appoint an external controller. Even though it may take some effort to hire an external consultant, it is recommended in projects beyond a certain level of complexity. In order to safeguard a clean and organized controlling process, external controllers have shown significant value for the implementation of most projects.

**-> Managerial imperative: Appoint an internal (mandatory) and/or external (optional) controller who is familiar with the subject matter and Requirements Management**

#### Principle 2: Control from different perspectives

When controlling requirements, the identification of errors needs to be separated from the correction of the errors. When identification and correction of errors are done in the same moment the correction often adds additional errors in the process.

Controllers have reported clearer focus on *one* task at the time, instead of switching back and forth between two very different cognitive challenges. Furthermore, corrections may be connected to structural changes in the document; these can only be made based on a comprehensive understanding of all errors.

**-> Managerial imperative: Identify and mark errors first, correct in a separate effort.**

#### Principle 3: Change perspectives

Any evaluation is intuitively made from a personal perspective. In order to leave the controller perspective, you need to actively change your perspective into roles of different stakeholders.

Depending on the respective requirements, you can apply the perspective of operator, maintenance, finance, technical management, IT management, customer etc.

**-> Managerial imperative: Keep in mind, that a controller’s goal is to improve requirements for the stakeholders – perform the controlling process from their perspective!**

#### Principle 4: Adjust documentation style

In some instances, it makes sense to change the form of documentation. When realizing, textual language is too complicated for a clear and simple specification, change to graphic models. Stick to the application of formalized graphic languages, such as UML, to avoid unclear graphics. If an existing graphic seems low in informative value, consider changing from graphic to textual language.

**-> Managerial imperative: Change documentation format in ways that are most valuable in clearly communicating the point of a requirement!**

#### Principle 5: Review multiple times

As stated earlier, controlling of requirements is an ongoing task. While the main effort is situated between the finalization of requirements specification and the approval of the steering committee, there should be agreed-upon dates, the reviews are repeated. These dates should be relative to certain milestones in the project implementation process. There is no generalized recommendation, when and how often the review process should be repeated. Indicators for a higher frequency of repetitions are

* high level of innovative elements to the project
* project is scheduled for a longer time period
* controlling process started early in the process
* low level of subject matter expertise on all sides

**-> Managerial imperative: Do not fully trust one-time reviews and set fix dates for repetition of review process.**

### 3.1.4 How to control requirements?

There is a number of tools, that have proven to be effective when managing and controlling project requirements. Most experiences project managers who are involved in management and control of requirements tweak these tools to their appropriate context. In this spirit, we are providing you with archetypes of tools; you can benefit from these by applying them as a framework that can be adjusted and refined in a real-life project context. Keep in mind, that the general idea of these tools are commonly known and applied in the Requirements Management community; so regardless of the particular context, they serve teams as a commonly agreed upon starting point for further refinement.

There are two groups of techniques for management and control of requirements:

1. *Structural tools*: Methods to organizationally structure the review process; review tools provide a framework, which roles partake in controlling requirements and how the process is structured.
2. *Individual tools*: Methods to individually control requirements; development tools can be applied by reviewers, once tasked with controlling the documents. They are usually applied in some sort of combination with review tools.

Fig. X: Structural and individual review tools

#### Structural Tool 1: Third Party Statement

Many requirements managers consult third parties in order to control requirements. It is implicit in the logic of controlling (in general), to separate the roles of development and control. Controlling of requirements is, therefore, often executed by colleagues from other projects. Occasionally, clients issue concerns on expertise of third parties, who are not fully involved in the project. While the legitimacy of these concerns need to be assessed on a case-by-case basis, the question, whether the requirements are specified according to the general rules of requirements specification, can be answered by most experienced requirements- and/or project-professionals.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Process of *third party statement*** | |  | **Controlling requirements in *third party statement*** | |
| *Preparation* | Appoint an agreed-upon requirements controller |  | *Roles* | *Author:* Person in charge of formal creation of requirements specification sheet  *Controller*: Person formally tasked with verification of correctness |
| Document handover |  |
| *Review* | Controller verifies requirements regarding quality deficiencies |  |
| Informal comments are documented and handed over |  |

Third party statement is a lightweight and rather informal tool that is often applied in smaller projects with effective informal communication between contractor and client.

#### Structural Tool 2: Walkthrough

Another review-tool, that is relatively easy and effective in it’s application is the walkthrough. “A structured walkthrough is a working session where invited participants review discuss a set of requirements” (IIBA, 2009). The author elaborates on any detail of the requirements specification sheet, in order to create a common understanding and a consolidated view on the document. As opposed to the third party statement, this method allows for immediate discussion and solution between the author and the controller. The method thereby accommodates the involvement of controllers who are not directly involved in the project. If the controller’s critique is merely caused by lack of involvement, the details can be discussed on the spot.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Process of *walkthrough*** | |  | **Controlling requirements in *walkthrough*** | |
| *Preparation* | Handout of requirements documents (esp. specification sheet) to participants |  | *Roles* | *Author:* Person in charge of formal creation of requirements specification sheet  *Controller*: Person formally tasked with verification of correctness  *Recorder*: Verbal discussions need to be documented for integrity  *Moderator*: Content-related moderation (optional role, often used in larger projects) |
| Preliminary controlling by controller |  |
|  |
| *Walkthrough-Session* | Joint walkthrough in formal walkthrough session |  |
|  |
| Review and discussion of critical aspects |  |
| Formal recognition of deficits |  |

The walkthrough is not to be confused with the review- and approval-process of the steering committee of the project. Smaller and technically more trivial projects seldomly decide on a formal walkthrough-process. In more complex projects, however, this method can be an important part of the approval process, demanded by the steering committee.

#### Structural Tool 3: Inspection

The inspection is the most formal of the three review-methods, we are discussing in this course book. Some projects require highly formalized controlling processes as part of a strict and systematic controlling system. So why burdening a project with complex controlling processes? Oftentimes, the VUCA-world (see chapter 1.3) confronts project professionals with the highest level of complexity, meaning, the *cause-and-effect relationships* in and around the project can hardly be rationalized. In other words: The effects of decisions in general, and requirements in particular, can hardly be foreseen. So in order to accommodate the environmental complexity of requirements specification, the project needs to raise its internal structural complexity.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Process of *inspection*** | |  | **Controlling requirements in an *inspection*** | |
| *Planning* | Define details of inspection   * Goals * Object (which documents?) * Appointment of controllers * Means of execution * Roles and participants |  | *Roles* | *Author:* Persons in charge of the requirements specification sheet  *Controller*: Person formally tasked with the inspection  *Recorder*: Verbal discussions need to be documented for integrity  *Moderator*: Person moderating the discussion on a content-related level (often neutral party)  *Organizer*: Person in charge of the inspection process |
|  |
| *Walk-through* | Creation of common understanding |  |
| Author walks participants through the document |  |
| *Planning* | Controllers inspect the documents and document possible errors and deficits |  |
|  |
| *Planning* | Errors and deficits are consolidated and edited for all participants |  |
| Controllers eliminate non-errors |  |

Inspections are often applied in larger projects with a high level of professionalism and a need for strict organization of complex elements.

*Interim conclusion:*

Review methods can generally be categorized alongside a continuum of complexity: Looking back at the drivers for Requirements Management in chapter 1.4, a high manifestation of the drivers creates the need for more formalized inspection, while a low manifestation implies less formal approach to managing and controlling requirements at the interface of Requirements Engineering and ongoing tasks of Requirements Management.

Quick reminder: Individual tools are methods to help individuals controlling quality aspects, namely *content*, *documentation*, and *reconciliation* of requirements documents (esp. the requirements specification sheet) as part of the management and control aspect of Requirements Management. These techniques supplement the structural tools, which merely structure the controlling process and provide little guidance to the individual task of controlling by whoever is tasked with the actual controlling-work. Still, individual review- and controlling tools can be prescribed by the steering committee, as well.

#### Individual Tool 1: Perspective analysis

The perspective analysis is intended to liberate the controller from their own perspective as a project-/requirements-professional. The controller is provided with a list of perspectives, from which they are supposed to read the requirements. These perspectives can be roles in the project or in the client’s organization or quality-based perspectives.

|  |  |  |
| --- | --- | --- |
| **Role-based perspectives** |  | **Quality-based perspectives** |
| * User-perspective * Customer-perspective * Supplier-perspective * Service personnel-perspective * Tester-perspective * Solution Architect-perspective |  | * Content-perspective * Documentation-perspective * Reconciliation-perspective   (see chapter 3.1.2 quality aspects in managing and controlling requirements) |
|  |
|  |
|  |
|  |
|  |

When choosing perspective analysis as a tool for the controller, precise instructions on the perspectives need to be provided. Experience has shown, that this most perspective analyses require elaboration in meetings; which is why there is normally some need for coordination after completing the analysis.

#### Individual Tool 2: Prototypes

Prototypes are a very effective, but costly way to control and consolidate requirements. Prototypes are developed and handed over to the controller, who spends some time and effort verifying system behavior and usability. This task, of course, requires in-dept knowledge of the systems usage, as the controlling process needs to be performed in the early stages of the development process (IIBA, 2009). While it may not be the recommended technique for large-scale industrial manufacturing projects, prototypes are often used to control requirements in IT-projects. In order to match the complexity of the controlling process with the available resources, controllers can be tasked to only test critical elements of the system.

#### Individual Tool 3: Checklists

The most common controlling tool is the application of checklist. These can be prescribed by the steering committee when the project’s complexity makes it unlikely for the controller to consider any technical and organizational aspect. Oftentimes, controllers are tasked to complete checklists in the process. The elements, that need to be subject to controlling need to be formulated as precisely as possible.

### 3.1.5 Managing adjustments and conflicts

Most tasks and responsibilities of *managing and controlling requirements* are targeted towards identifying errors and deficits. While this is an ongoing task in Requirements Management, the controlling effort needs to be (preliminarily) completed *before* the project moves into the implementation phase. Unresolved errors and conflicts need to be eliminated as much as possible, *before* they manifest themselves as more serious threats to project success in later stages of the project (Malik et al., 2022). So what happens, when errors and deficits are identified? There are basically two possibilities:

1. There is no conflict within the deficit; in this case an adjustment is made by the Requirements Manager.
2. As described above, conflicts between the interests of stakeholders are often the cause for deficits – *in this case, conflict management is a key responsibility of any project manager involved in Requirements Management.*

This is true not only for the managing adjustments of requirements but an ongoing responsibility throughout the project. Conflict management is a critical aspects of Requirements Management and the related skills are core-elements of any requirements manager’s skillset. This mainly comprises four stages:

|  |  |
| --- | --- |
| Aspect | Task |
| Identification of conflicts | Understand conflicts between interests of stakeholders and identify how these interests translate to conflicting requirements. |
| Analysis of conflicts | Analyze any conflict that cannot be solved on the spot; classify the conflict based on types of conflicts (see below). |
| Conflict resolution | Bring stakeholders together and resolve the conflict on the respective level of the conflict type |
| Documentation of resolution | Document resolution in order for more effective controlling and in order to avoid ongoing discussions in later stages |

*Table X: Process of resolution of conflicts in Requirements Management*

There are different types of conflicts. Knowing the most typical types of disagreement supports you in understanding the sources; which is one of the prerequisites for mitigating the conflict (Malik et al., 2022).

* *Conflict of interest*: The most common type of conflict in most requirements Manager’s day-to-day business; whether the disagreements are objective and subjective highly influences the options of a settlement. An example for conflicting interests can be short-term vs. long-term solutions between the owner and the CEO of a client.
* *Functional conflict*: Another highly typical conflict emerges in disagreements on functions of the system. While one stakeholder might argue for additional functionality, another might doubt the feasibility of this function.
* *Relational conflicts*: Conflicts between individuals are more difficult to identify and solve, as they are usually expressed in functional arguments. When individuals are expressing overly strong reservations towards the arguments of a certain other individual, these reservations, while directed at a functional aspect, may actually be targeted towards the individual itself. Many requirements professionals make the mistake to try to resolve the problem on a functional basis, while the functional discussion is merely a cover for the inter-personal conflict.
* *Structural conflict*: Similar to interpersonal conflicts are structural conflicts. Ideas and proposals are often rejected, not because they lack value, but because they come from a different unit or a lower hierarchical layer.
* *Conflict of values*: Oftentimes, especially in culturally diverse global corporations, value conflicts emerge. These can manifest themselves between individuals who value following rules and instructions and individuals who value effectiveness and efficiency.

Oftentimes, conflicts contain more than one element of this list. It is crucial for requirements managers to be able to identify the real source of the conflict. It is, for example, pointless to resolve an interpersonal conflict on a rational level, based on the arguments that cover the conflict. An interpersonal conflict requires an interpersonal solution.

There are a number of basic techniques you should be aware of. While this seems very basic, the International Requirements Engineering Board insists on these techniques in their curriculum for requirements engineering/management professionals (Glinz et al., 2022). As always, a common terminology and a common understanding of tools and techniques is key to any organized and collaborative Requirements Management effort.

|  |  |
| --- | --- |
| Technique | Mechanism |
| Settlement | Conflicting stakeholders negotiate a resolution   * Formal discussion on different available options * Accelerated through strong moderation skills |
| Compromise | Conflicting stakeholders develop new alternative   * Next option if stakeholders cannot settle on available solution * Develop new alternative that accommodates both interests |
| Vote | Conflict resolution by democratic vote   * Widely accepted, if all available options are feasible and valuable * Check with steering committee, if method acceptable |
| Creation of variations | Implementation of both/all alternatives   * If options are not irreconcilable, both/all can be implemented * Mostly applied with functional requirements |
| Deployment of authority | Decision made by highest-ranking manager   * Typical solution with further conflict potential * Should only be applied after due consideration |
| Contributing factors | Consideration of influencing factors and impact   * All obvious factors are gathered and prioritized * Impacts of each option is analyzed * Decision is made via different forms of trivial calculation |
| Decision matrix | Conflict resolution through more complex calculation   * Criteria that influence the decision are defined * Criteria can be valued based on importance or impact * Both numbers are calculated for each available option * The solution with the highest score is chosen |

*Table X: Basic conflict resolution techniques*

These techniques should be applied based on rational judgement considering the current practical situation and local factors, especially corporate culture.

**Self-check questions**

Q: Which techniques qualify for the resolution of conflicts?

A: Settlement, compromise, vote, creation of variations, deployment of authority, contributing factors, decision matrix

Q: What is the difference between structural and functional conflicts?

A: Structural conflicts stem from rivalries in between structural elements of the department – they are non-subject matter related. Functional conflicts, on the other hand, stem from conflicts on the subject matter related functions of the system.

## 3.2 Administration of Requirements

Once requirements are analyzed, reviewed and agreed upon by all relevant stakeholders, they are ready to serve as guidance in the project implementation process. The requirements documents, however, remain and object of ongoing managerial tasks – one of these being administration of requirements. Administration of requirements refers to the formal handling of all requirements in a matter that makes them accessible to exactly *the right people* at exactly *the right moment* in exactly *the right format*. In order to safeguard this level of accessibility, requirements managers need to…

* administer requirements attributes
* prioritize requirements and
* administer versions of requirements documents.

Further tasks, which are often summed up under the label requirements administration, such as implementation management or modification management, are elaborated upon in a separate chapter.

### 3.2.1 Administration of requirements attributes

Besides specified requirements, any requirement needs to be amended with further attributes. Amending requirements with further information allows for a clear separation of the specific requirement and further information (Project Management Institute, 2016). If there was no room for amendments, critical information would need to be squeezed into the specification of the requirement which otherwise would need to be part of the requirement.

Consequently, any documented requirement contains the requirement specification as key object, and further requirement attributes based on project-specific needs. Typical examples based on experience are:

* + *ID*: Number to clearly identify any requirement
  + *Keywords*: Terms to find and relate requirements
  + *Version*: Indicator to identify possible changes and change history
  + *Status*: Information on position in development process
  + *Priority*: Indication on importance to client and project
  + *Author*: Refers to the author for further information

Further attributes may contain *requirement type, sources, release number, responsible stakeholders, references to other requirements* or the *legally binding nature of the requirement*.

Any project has different needs for requirement attributes. It is, therefore, not a reasonable solution, to add additional attributes *just to be on the safe side*. Requirements Managers usually decide the composition of attributes based on specifics of the project, guidelines provided by the client, experiences from projects with a similar use case or conditions implied by the characteristics of the development process.

### 3.2.2 Prioritization of requirements

Prioritizing requirements has a tremendous influence on success and failure of any project. It is rare, that all requirements can be implemented as specified in the early stages of a project. The more complex a project, the more likely is the project experiencing situations, in which managers need to agree upon prioritizing the implementation of some requirements over others (Firesmith, 2004). Modern project management techniques, such as SCRUM, are set up in a way that specifically addresses this issue. Despite intense requirements engineering, you can barely expect everything going as planned (see chapter 1.3 on the VUCA conditions). Clients tend to generally accept these conditions, especially since possible complications might be actively caused by the clients themselves (Firesmith, 2004).

It is therefore important for project managers to know the difference between highly relevant requirements and requirements of less relevance. Consequently, one of the administrative tasks of Requirements Management is to rank requirements in their importance to the project. It is key to requirements management to understand the criteria, based on which requirements are prioritized.

#### Steps to prioritize requirements

There are usually four steps in the prioritization process:

*Step 1*: Identify and define the goals of prioritization based on project goals. Is the primary goal of a certain function to increase the user friendliness of a system or is the goal to increase maintainability?

*Step 2*: Set criteria, based on which requirements will be prioritized. Depending on goals, different criteria apply. These can be

* + costs and risks of implementation
  + impact of implementation/non-implementation
  + required time for implementation

*Step 3*: Identify stakeholders, that are connected to each requirement. Organizational complexities may require prioritizing the opinions of some stakeholders over others. Formal hierarchy comes into play since Requirements Management cannot operate completely outside of the realm of office politics. Furthermore, the vicinity of stakeholders to the respective requirement implies prioritization. All things considered, the requirements of the head of operations of the unit in charge of the system should have more clout regarding user requirements, than the ideas of the CFO (regarding user requirements).

*Step 4*: Choose approaches for prioritizing requirements. The application of different approaches almost inevitably delivers different results. It is therefore important to choose consciously, based on what makes sense and not purely based on simplicity.

Let’s dive into these different approaches for prioritization.

#### Approaches to prioritize requirements

When prioritizing requirements, you can choose different approaches which mainly vary in their degrees of complexity and effort. The low-effort approaches can be separated in spontaneous and analytic approaches.

|  |  |
| --- | --- |
| Spontaneous techniques | |
| Ranking | * Appoint stakeholders to take over prioritization * Let them rank requirements based of their judgement |
| Top-Ten | * Define an amount of top-n requirements (often 10/50/100) * Choose requirements important enough to fit into the top-ranking * Rank these top requirements from 1-10/50/100/n |
| One-criteria | * Build classes of priority based on the relevance for the system   + Mandatory: absolutely necessary for successful implementation   + Optional: not fully necessary but important to some stakeholders   + Nice-to-have: not critical for successful operation of system |
| Priorization matrix | * Build an excel sheet with the following columns   + Requirement code (as identifier)   + Relative value (to stakeholders and system)   + Relative disadvantage (time, effort, conflicts)   + Relative costs (points relative to each other)   + Relative risk (points relative to each other) * Give points 1-10 to each requirement in each category * Create another column for each category and calculate the relative value in % (relative compared to the rest of the column) * Consolidate in a priority column (value should be between 0 and 1) * Rank accordingly from 1-n based on priority column |

It is important to keep the prioritization up to date throughout the entire process. If new requirements are added, instantly add them to the priority ranking. In professional Requirements Management dedicated software applications are applied. These will remind you of prioritizing, whenever you add a new requirement or whenever existing requirements are changed.

### 3.2.3 Versioning of requirements

It may have become clear by this point, that a large part of Requirements Management after the approval of the requirements specification sheet (and other requirements documents) is concerned with changing requirements.

Practical experience has shown, that different versions of requirements documents are quick to emerge in the process. It is the responsibility of Requirements Management, specifically requirements administration, to safeguard that anyone is always working with the latest version of the respective document (Hood et al., 2007).

#### Configuration of requirements

A requirements configuration is a set of requirements that is valid at a defined point in time. If requirements that are closely related to each other, they cannot easily be changed, without considering the effect on the entire configuration. It is therefore important to recognize that any requirement is only allowed to appear once in any particular version of the specification sheet. Configurations are preliminary states of the set of requirements, that are pending approval by the respective board. Oftentimes, the approval board (steering committee in most cases) needs to approve a change of the entire configuration.

It is the requirements manager’s task to build these configurations as part of requirements administration.

#### Requirements baselining

Once approved by the board, these sets of requirements are turned into requirements baselines. Baselines can be regarded as solid foundations for project implementation. Baselines need to be…

* accessible to the entire project team
* a precise orientation for the delivery of parts of the project based on milestones/sprints/releases
* a foundation for a realistic assessment of time, costs and resources
* a basis for comparison with alternative solutions

As implied: requirements baselines are often consolidating requirements not only based on their technical relation with each other, but also based on what needs to be delivered towards a certain milestone, sprint or release in the project.

**Self-check questions**

Q: Based on which criteria can requirements be prioritized?

A: 1) costs and risks of implementation, 2) impact of implementation or non-implementation, 3) required time for implementation

Q: What is the purpose of version management?

A: Everyone in the project needs to work with the lates version of requirements documents at all time.

## 3.3 Risk Management

Most activities related to the mitigation of project risks are usually outside of the scope of Requirements Management. In most cases, this excludes risks stemming from the system itself. Requirements risks are risks immanent to requirements regarding potential harm on multiple levels:

* Requirements could claim more financial, human and time resources in their implementation, than expected
* Volatility and uncertainty in the business environment of the project may cause changes that invalidate the requirement in various ways
* Requirements can be dependent on certain behaviors of users, which cannot realistically be expected
* Requirements may depend on systems, that are part of the technical configuration momentarily, but may change over time

These risks can seriously impact any project implementation process; consequently, they need to be assessed and mitigated properly.

### 3.3.1 Requirements assessment

The requirements risk assessment process usually works in three steps:

*Step 1*: Develop a requirement baseline with stakeholders. Requirements risks management is a continuous task, however, it makes sense to start with a risk workshop in the beginning of the project. It should take place some before the final approval, to allow changes without having to address the change committee. Participants of the workshop should be selected based on their subject matter expertise in the respective domain, their understanding of the entire technical structure of the client’s organization and the client industry.

*Step 2*: Identify risks by asking the question “what happens, if…”. Ask, what happens, if the provided assumptions fail to occur as expected. Assumptions can refer to specific behaviors of people, related systems, elements in the corporate environment. Ask, what happens, if these behaviors change.

*Step 3*: Calculate risks scores and rank risks. Consolidate all risks in one list. Provide a score from 1-10 to each risk regarding two factors: a) what is the likelihood of the event to occur and b) how significant is the impact of that occurrence? Add both numbers to calculate the risk score.

*Step 4*: Build classes based on own judgement. It is often recommended to classify into classes, such as risks that need to be eliminated, risks that need to be watched and risks that can be neglected. Set thresholds for each class, e.g. 1-3 neglectable, 4-6 watchlist, 7-10 elimination.

Requirements risks are associated with unexpected occurrences in the project and the environment. Naturally, these cannot be predicted in a project assessment session during the requirements engineering process. While this session is necessary to find a risk baseline to start with requirements risk management is mainly continuous a task throughout the project.

### 3.3.2 Risk mitigation

The most valuable risk mitigation tool is a high level of alertness throughout the project. It is important to understand not only the identified risks, but also the system, its environment and the client industry (incl. current developments).

Active risk mitigation is based on a number of principles. These seem self-evident, but experience shows, that some aspects cannot be pointed out too clearly:

*Principle 1*: Involve the relevant stakeholders. Keep communication with key stakeholders going throughout the project. Discuss current developments and their impact on project implementation.

*Principle 2*: Validate requirements in each phase of the project. Developments, which impact the risk level of certain requirements may have happened without being obvious to you, but very present to others.

*Principle 3*: Maintain a risk log. Document requirements in a requirements risk log. If you are using a Requirements Management application without this function, create a well-structured document, post it prominently and maintain it at least on a weekly basis. Communicate actively and inform relevant participants on new developments.

If maintained with care and vigilance, most risks, associated with requirements can be kept under control effectively.

**Self-check questions**

Q: Is class building always based on fix criteria or is it flexible to personal judgement?

A: Class building can be left the informed judgement of the requirements manager

Q: When is the validation of requirements completed from a risk management perspective?

A: The validation continues up to the full completion of the project.

## 3.4 Implementation Management

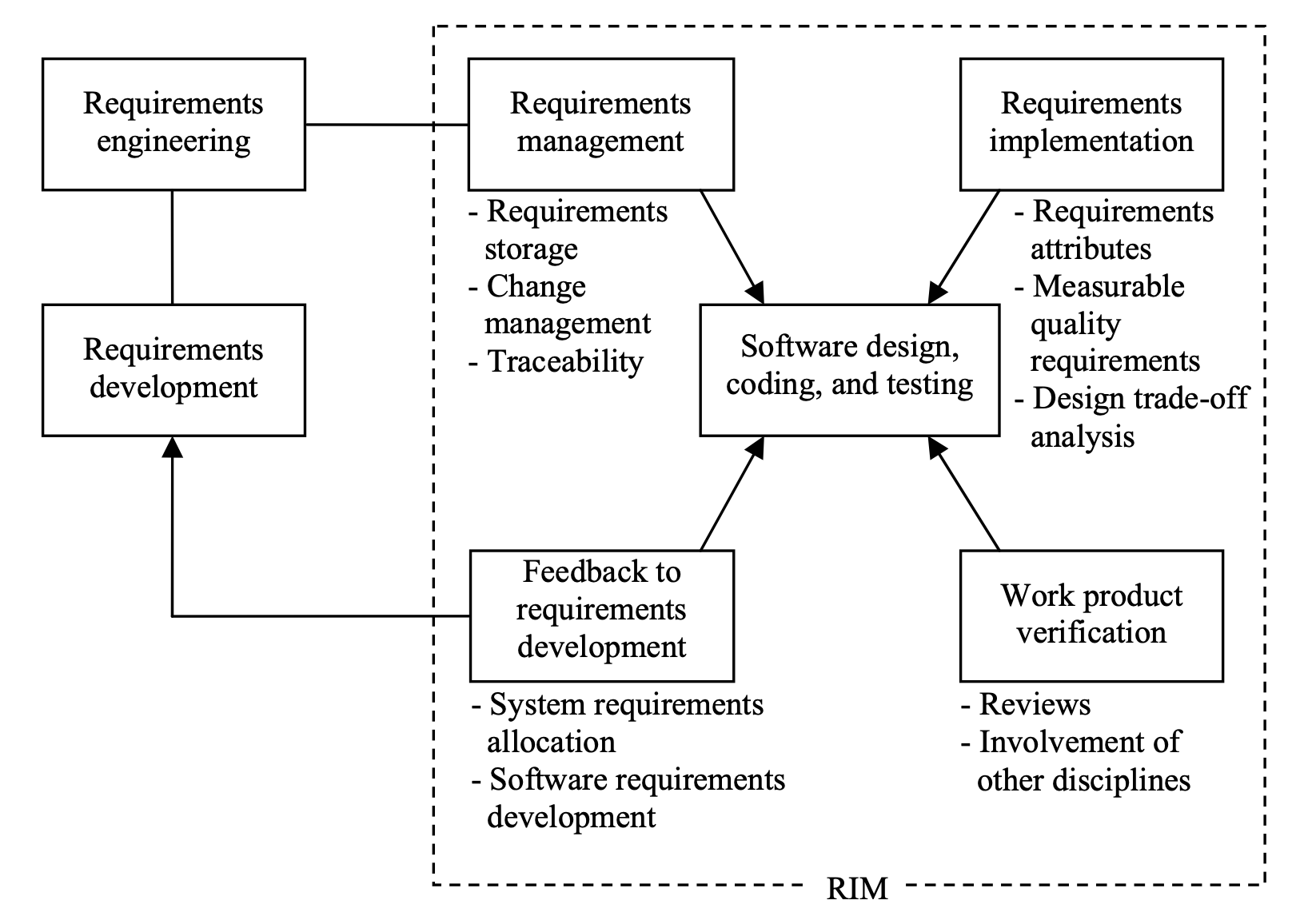
Once again, Requirements Management does not stop after the approval of the requirements specification sheet by the steering committee. It is critical for the success of the project to actually implement requirements – and overseeing the implementation of requirements throughout the project life cycle is part of this responsibility. The logical questions, at this point is: “*Why is this necessary? After all, requirements were defined so the implementation process can be managed alongside very specific instructions on what the client requires in their system*?” While this statement is generally true, the project organization constitutes a self-organizing social system that has the tendencies to self-guide itself in a direction that might create a favorable development from a system perspective – but shifts away from the system as defined in the project requirements (Lindstrom, 1993). While the project manager may have a stronger focus on how far the system generally works and if the system is generally coherent, requirements managers need to focus on the requirements and trace them through the entire project lifecycle. *The central goal is to keep the project team on track and not spend too much time on features which might make sense for the system in general but are not specified as requirements* (Pohl, 2010).

Furthermore, the reality of project implementation is made of constant changes and developments in the client’s business environment, the client’s organization and consequently in the project, as well. The requirements were defined for a reality that might have been accurate for the time of the Requirements Engineering process, and most of the aspects of this reality will remain stable – but in most projects, changes will occur. In cases where changes seem to force the project managers to adjust the planned implementation, requirements managers need to ensure the accommodation of all previously defined requirements. This may seem a bit inflexible but requirements are usually legally binding features of the system which cannot be changed on a verbal basis. While requirements can be adjusted to new realities, if really necessary, most of the time these new realities can accommodate the previously defined requirements. The effort, to ensure exactly this, is part of the requirements manager’s responsibility in Implementation Management.

In this section we will elaborate on goals and the specific purpose of Requirements Management in the implementation process, the different measures to be taken during implementation and how to carry out the implementation.

### 3.4.1 The Requirements Implementation Model

In order to understand the challenges and pitfalls of Requirements Implementation, we need to clarify a number of elements that are necessary for a solid implementation process. Jäälinoja and Oivo (2004) holistically formalized these elements in a reference model.

 <- Original image as comparison

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*Fig. X: An integrated reference model for Requirements Implementation Management (based on Jäälinoja & Oivo, 2004).*

The model shows the central elements of successful Implementation Management. These are 1) effective systems engineering, 2) high level of reconciliation in requirements implementation, 3) prototype verification including and effective review process and – of course – all managed by comprehensive Requirements Management.

Side note:

Systems Architecture: Model-based task in developing a system based on experience, expertise and requirements. From a requirements-perspective, System Architecture is the central point of contact for implementation.

### 3.4.2 System engineering

The model puts system engineering in the center of its activities. After all, from a project management perspective, even the most holistic view on requirements is no representation of the system itself. It is the responsibility of systems engineering, to carry out the design and architecture, development, testing and adjustment of the system architecture. Systems engineering is central in the implementation process and the main point of contact for Requirements Management. Please note, that the original version of Jäälinoja and Oivo’s model refers to the specific domain of *software development*, in this particular context.

### 3.4.3 Requirements Implementation

Requirements Implementation is the process of transforming requirements into actual artefacts of the system. These artefacts can be

* code in IT projects
* tangible elements of a technical system (power plant, building etc.)
* intangible elements of a system (prescribed maintenance process etc.).

Requirements management delivers the system characteristics, that are necessary from the customer’s perspective – systems engineering transforms them into the above stated artifacts. All changes in requirements are therefore directed towards systems engineering and *never* the technicians, who practically implement the system. Despite systems engineering being in control of system architecture-related matters, Requirements Managers have the responsibility to insist on their perspective – and systems engineers have the duty to fulfill the requirements as provided by Requirements Management.

### 3.4.4 Work product verification

Especially in software development projects, inconsistencies between the programmer’s work and the requirements may occur (Jäälinoja & Oivo, 2004). With reference to the management & control responsibilities of the requirements manager, this directly overlaps with their responsibilities in Implementation Management.

One way this is usually handled in real-life projects is the development of prototypes by systems engineering (or software design). These prototypes are then evaluated for their compliance with the requirements. There are different methods available that help to verify, to what extent requirements are fulfilled in a system. The Architecture Tradeoff Analysis Method (ATAM) “is a method for evaluating architecture-level designs that considers multiple quality attributes such as modifiability, performance, reliability, and security in gaining insight as to whether the fully fleshed out incarnation of the architecture will meet its requirements” (Kazman et al., 1998). Although designed for early software development, ATAM is applied in various industries and recommended for simple and effective practical use.

### 3.4.5 Feedback loops to Systems Engineering and the Requirements Engineering phases

Even in non-agile projects, feedback loops to the initial Requirements Engineering phases are critical. “Successful requirements development requires a constant flow of information from the actual developers […] to the requirements analysts” (Jäälinoja & Oivo, 2004). This feedback loop is two-directional: Requirements Management needs to provide feedback to Systems Engineering and Systems Engineering needs to provide feedback to Requirements Management. Even in later stages, Requirements Management needs to go back to the engineering-phases and make adjustments, if agreed upon by the steering committee (ref. section 3.5).

This interaction needs to happen both formally and informally. On an informal level, project managers, system engineers and ground-level technicians need to regularly communicate with the requirements manager. Requirements managers themselves need to proactively involve themselves in the implementation process. On a formal level this usually means, involving the requirements manager in all technical planning activities – and making this the communicative default.

**Self-check questions**

Q: Please make a statement on the following proposition: “It is the primary goal of the requirements manager in the implementation process to ensure the development a coherent and functional system”

A: This statement, while being desirable, is wrong: The primary goal is to ensure the correct implementation of all requirements. The coherence of the system is the main responsibility of the project manager.

## 3.5 Modification Management

Over the previous chapters of this course book, we have emphasized multiple times, how requirements change over time and what occurrences might trigger these changes. Section 3.5 is dedicated to familiarizing you with the practical challenges and most common procedures of this Requirements Management task.

### 3.5.1 Tasks of Modification Management

Modification Management takes charge of all matters, related to changing requirements after the implementation of the project has already started. This task comprises (Bhatti et al., 2010; O’Neal & Carver, 2001; Strens & Sugden, 1996)

Side note:

Change request: Formal approval for the change of a previously agreed-upon characteristic in a project.

* *Collection of changes*: Requirements Managers are the single point of contact for all change requests; while communication usually starts in the project team, the formal process starts with issuing a change request to the requirements manager.
* *Documentation according to right format*: It is common, nowadays, to manage requirements in an integrated IT system; these systems allow for prescribed formats, which need to be followed by the proposer. If information is missing, the requirements manager needs to follow up on the request.
* *Mitigation of change requests*: Changes can never be made in a vacuum as they may cause chain reactions throughout the project. New conflicts may emerge and even a simple change can lead to conflicts with stakeholders, who insist on the originally agreed-upon requirement. These conflicts need to be mitigated by the requirements manager.
* *Management of approval process*: Once a change request is handed in correctly, the request follows a defined formal process. Following this process is the responsibility of the requirements manager.
* *Implementation of changes*: Not everyone in a project may organically get notice of the change – so in order to avoid different statuses in different work streams in the project, requirements managers need to make sure, everyone who’s work might be affected by the change, proceeds their work accordingly.

This is just a brief summary based on personal experience. The three main challenges of modification management are 1) communication with the change control board, 2) Issuing change requests and 3) analyzing the impact of changes. These challenges will be elaborated upon in the following sub-sections.

### 3.5.2 Dealing with the Change Control Board

Changes in requirements are a delicate topic. Requirements specification sheets are legally binding documents and both parties generally need to stick with implementing the project as agreed. Changes can cause issues, such as budget expansions, further changes in functionality etc., which can only be decided on a high level. Projects, therefore implement a change control board, which incorporates representatives of the most relevant stakeholders.

Next to the client and the contractor, change control boards can be made of change managers, product managers, systems architects, configuration managers, quality assurance managers or stakeholders which fit into this line of representatives.

There are several responsibilities, any change control board should have (Strens & Sugden, 1996):

* *Expense analysis*: The board needs to assess expenses and effort of a change that was handed in from inside the project.
* *Assessment of requests*: The board needs to evaluate and assess all change requests based on criteria relevant to the client (and the contractor). They can assess, for example, the benefit of changing one requirement that would necessarily lead to the cancellation of a number of other requirements.
* *Approval/denial of requests*: The board decides upon the approval or denial of change requests.
* *Priorization of requests*: If multiple changes requests are approved around the same time, their implementation needs to be prioritized. In case they cannot be implemented at the same time and in case the order of implementation is of relevance, the change control board prioritizes the implementation of requests.

While it makes sense to separate the role of the requirements manager from the change control board, in reality, they are often structurally connected (e.g. through membership of the requirements manager). Being member of the change control board might seem like an ideal position for the requirements manager, it puts a lot of responsibility and power into their hands. Once again, the suitability of this needs to be assessed on a case-by-case basis.

### 3.5.3 Managing Change Requests

The change request is the final crucial element of Modification Management. It is a formal document (or form in a respective IT-system) that contains all information needed for consideration of approval.

Managing change requests basically comes down to classifying them and triggering/accompanying the following change process.

There are three options available, when classifying a change request:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Type | Trigger for request | Source of problem | Impact |
| 1. | Bugs or errors | Malfunction in system | Faulty implementation of requirements | No impact on requirements |
| 2. | Corrective changes | Malfunction in system | Insufficiency or error in requirements | Requirements change necessary |
| 3. | Adaptive changes | New requirements of stakeholders | Changes in business environment of stakeholders | Requirements change necessary |

*Table X: Three types of changes in classification of change requests (based on Project Management Institute, 2016)*

Once classified, the change requests follows an adjustable process of an analysis of impact that a change might cause, an evaluation of the change request in itself, a decision on approval or denial, and, if approved, priorization as well as an allocation of responsibilities for implementation on part of the project team (see responsibilities of the change control board).

Bear in mind, that the main responsibility lies on the shoulders of the change control board – however, the board needs to be guided by the requirements manager in terms of complete and transparent information, as well as guidance in the change process.

**Self-check questions**

Q: What are the responsibilities of the change control board?

A: 1) Expense analysis, 2) assessment of requests, 3) approval or denial of requests, 4) priorization of requests

Q: To whom are change requests addressed?

A: Change requests are always handed over to the requirements manager. They will hand them over to the change control board.

Summary

There are two kinds of Requirements Management Responsibilities: Ongoing and sequential tasks. In this chapter of the course book, we have elaborated on ongoing tasks, that you will face, when involved in Requirements Management.

Management and control of requirements safeguards the quality of requirements and requirements documents throughout the project lifecycle. There are three elements, that need controlling:

1. Content of requirements
2. Documentation of requirements
3. Reconciliation of conflicts in requirements management

These tasks can be performed with different methods, such as third party statements, walkthroughs, inspections, perspective analysis, prototypes or checklists. An important challenge is conflict resolution.

The administration of requirements refers to administrative tasks throughout the project process. Requirements need to be prioritized based on agreed-upon criteria and versions need to be managed, in order for all employees working with the latest version at all times.

The mitigation of requirements related risks is another key challenge. Requirements could claim more resources in their implementation, than expected; volatility and uncertainty may cause changes that invalidate the requirement in various ways. Furthermore requirements can be dependent on certain behaviors of users and the may depend on systems, that are part of the technical configuration momentarily, but may change over time.

Implementation Management is the final ongoing task. We elaborated on a model that puts systems engineering in the center of the implementation process and connects it to prototype verification, feedback loops requirements management and requirements implementation.

# 4. Methods and Quality of Requirements Management

**Study Goals**

On completion of this unit, you will be able to …

## Introduction

Besides the ongoing tasks in Requirements Management, there are a number of sequential tasks to be completed in any project. Projects themselves are sequential processes, that can be compartmentalized into different steps. This is not to say, that tasks from early steps are not repeated in later stages – specification of requirements, for example, needs to be done primarily in the early stages of the project. Assuming, most requirements are completed, once approved, new requirements have to be specified later on and existing requirements need re-specification. Yet, the bulk of specification work is being completed in the beginning and therefore part of a sequence.

## 4.1 Scoping

Technically, scoping is a project management responsibility that defines the extent of services delivered by the contractor. Since all actions of the contractor are targeted towards completing the project in a way that satisfies the requirements of the client, scoping becomes highly relevant for Requirements Management (Kelepouris et al., 2006).

Side note:

Project Scope:

Defined amount of tasks to be fulfilled by a contractor in order to complete a project. Traditionally, the scope serves as basis for the organization of tasks in the project plan.

### 4.1.1 Scoping system, context and irrelevant context

The main challenge of scoping is to separate what elements of the project are really necessary from what is unnecessary (Haley et al., 2006). Scoping is often the first step in projects, and thereby becomes the fundament for further requirements definition.

We can separate the scoping idea into three elements, the irrelevant environment, the system context and the system (Haley et al., 2006).

*Fig. X: Main elements of scoping from a Requirements Management perspective*

In order to actively contribute to scoping from a Requirements Management perspective, these four elements need to be understood by anyone involved in Project- and Requirements Management. In the scoping process, there are four main tasks that are often attributed to Requirements Management:

*Definition of system*: The definition of the system defines all elements, that are supposed to be part of the system. This can be technical components, but also functions, these components are supposed to deliver to ooperators.

*Definition of system context*: Generally speaking, the system context is made of all elements in the system’s environment, that are relevant for the system itself. By defining these elements during the scoping process right in the beginning, further Requirements Management efforts become more transparent. The fundamental elements are:

* Stakeholder
* Technical systems
* Technical documents
* Processes and structures

During scoping, it is the requirements manager’s job to identify these elements and analyze their interaction with the system, that is being developed in the project.

*Definition of system boundaries*: System boundaries define the border between the system and its environment. As they define an area, within which the contractor can do their work, the system border defines a clear and specified distinction between where the project ends.

While this may seem obvious in many situations, let’s imagine the development of a cement plant. A cement plant is a technical system of multiple parts – and it is rare, that all parts of this system are produced by the same contractor. A conveyor belt, that delivers the minerals into the plant, for example is part of the technical system. But oftentimes, it is built by other contractors, or it is already existing in the plant. In this case, the boundary needs to be drawn between the conveyor and the plant.

*Definition of context boundaries*: The context boundary separates the relevant environment from the irrelevant environment. The previously mentioned conveyor belt delivers raw material to the plant and is, therefore, part of the system environment. A controlling system, that measures the efficiency of the entire company, including plant efficiency, might be on the inner side of the context boundary, as well. A payroll system that transfers salaries to the employees, operating the plant, might not be on the outer side of the boundary, as there is no direct interaction with the plant.

Only when system, system context and irrelevant environment are clearly defined and a mutual agreement between client and contractor has been reached, can the project move into the next phase.

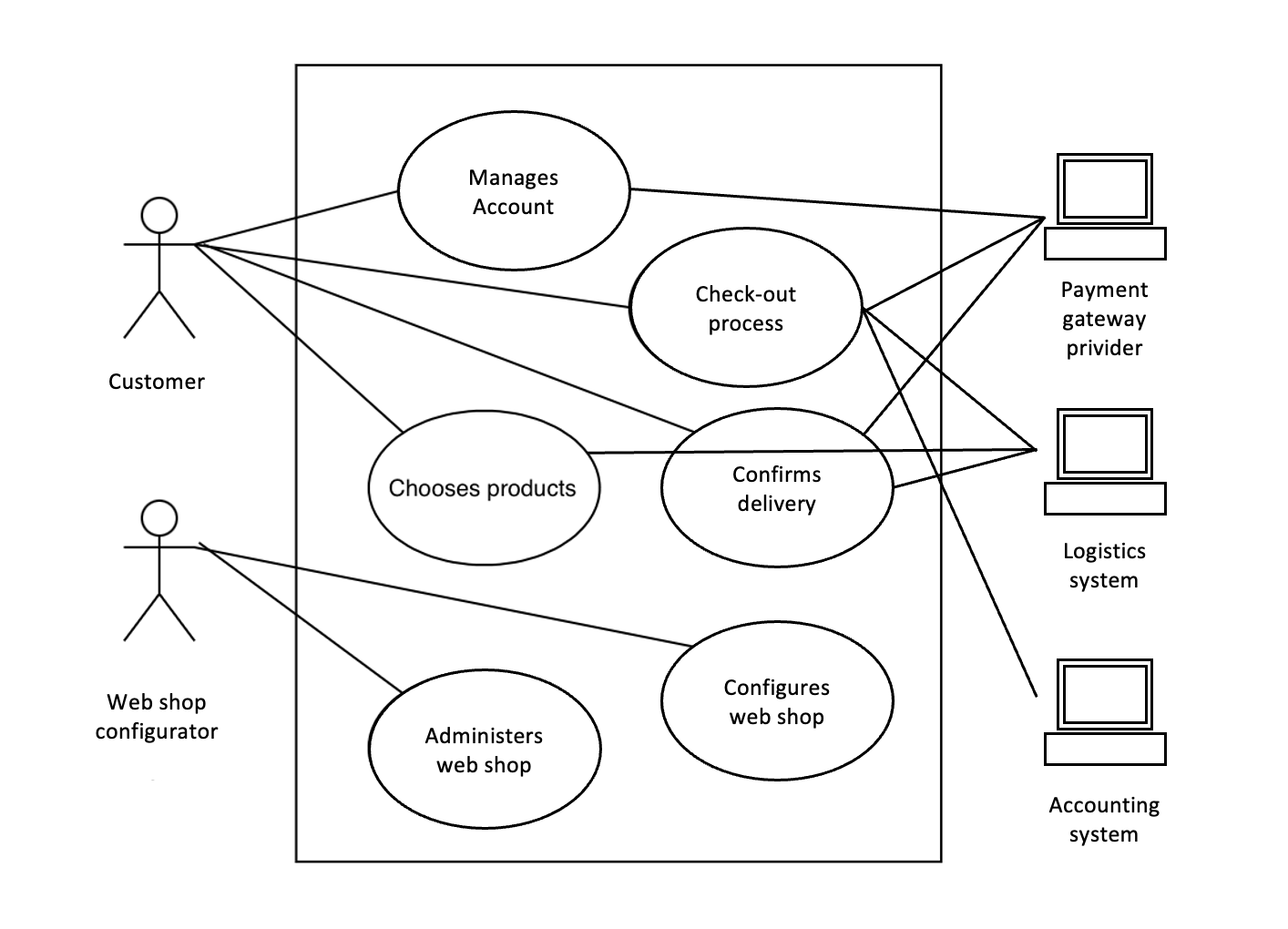
### 4.1.2 Documentation of system scope

As always in Requirements Management, documentation is essential for the scoping process. In this case, however, we are talking about a high-level overview of all following system characteristics and subsequent project activities.

But even for the high-level overview provided by the scope, precision is key. A solidly documented scope provides a common understanding of all stakeholders and delivers transparency towards further steps. Whenever complexity and confusion are taking over, project teams can go back to a well documented scope.

There are several ways to document the scope – the most widely used of which is the unified modeling language (UML) (Maciaszek, 2001). UML is a graphical language that contains clear definitions for the different graphical elements.

Let’s take a look at an example designed in UML. In this example an retail entrepreneur has tasked a project company to build a web shop to expand their business. This is, how a simple scope could look like.



*Fig. X: Example of the scope of a simple web shop in UML*

In the rectangle, you see the system and the system boundaries. On the left side, you can see the stakeholders using and operating the system. On the right side you see the IT systems interacting with the system in the center. In the system itself (rounded shapes) you see functions the system needs to perform. And through the lines you can see the how the system is interacting with the stakeholders and the IT systems in its relevant environment.

As you can see, UML is not made to win design awards, but to find a unified language to graphically document systems in a way that is clear and universally understood.

**Self-check questions**

Q: Name a central requirements-related advantage of UML

A: Opt. 1) UML is a unified language that unambiguous in its symbolism. Opt. 2) UML simplifies complicated relationships between elements into simple graphs.

Q: What are the central elements of the system context?

A: Stakeholder, technical systems, technical documents and processes and structures

## 4.2 Requirements Analysis and Requirements Specification

One of the major challenges in Requirements Management is the analysis and the specification of the analyzed requirements. These tasks, usually referred to as Requirements Engineering, are performed and completed in the early stages of the project process. At this stage of the course book, you should be familiar with the idea, that more analytical work is to be done in later stages of the project, as requirements documents are often more dynamic due to dynamics in the project and the project environment.

It is the goal of requirements analysis to collect all requirements from all stakeholders and specify them in a way that they are understood by everyone involved (Haley et al., 2006)

To understand the task, you need to become familiarized with three subjects:

* Sources for requirements analysis
* Category building
* Techniques for analyzing requirements

We will go through these subjects one by one in this section.

### 4.2.1 Sources for Requirements Analysis

In order to define all discussed types of requirements, requirements manager need to find the right sources in order to ensure the most comprehensive coverage of requirements throughout the client’s organization.

#### Human sources

Most requirements will be provided by human sources. The task of a requirement manager is more than collecting requirements, which are actively provided by the client. Due to the human factor, this part of the analysis can be challenging and constitutes one of the key bottlenecks for requirements engineering (Mahmoud & Carver, 2015). Requirements manager need to actively investigate possible stakeholders and include them in the analytical process.

*Procurement managers:*Due to their responsibility of managing the process of selecting the right system and the right contractor to complete the project, procurement managers are among the most crucial stakeholders. Based on the internal processes that led to the project, procurement managers are usually familiar at least with basic requirements of a project.

*Operators:* Operators, as well as maintenance and repair personnel are invaluable assets of any requirements analysis. Naturally, they should be involved in the definition of user requirements, but also solution requirements. Be mindful to safeguard as much buy-in as possible, as users have significant influence in any change process.

*Subject matter experts:* Any larger company has a limited number of highly experienced experts in a certain domain. There is no unified identifier, but usually, their status is well known in each organization. Involving these experts has the obvious advantage of better-quality requirements; another advantage is to get them involved, in case the project is connected to a larger change project.

#### Technical sources

In practice, human sources will oftentimes refer to technical sources. This makes sense, as documents are usually more detailed and reliable than experts can be in a one-hour conversation. The techniques are only formalized to a limited extent; literature on process management requirements deliver some insights on how to theoretically and practically approach this challenge (Pérez-Castillo et al., 2011). Nevertheless, human and technical sources should complement each other. If the technical source requires elaboration or contextualization, requirements managers need to arrange a follow up meeting with the respective human source, that referred them to technical sources.

*Field surveys:* It is a common practice to analyze users while performing their tasks using a system that is similar to the system at hand or the predecessor of the new system. These visits can take time and need to be carefully prepared, but they are usually successful at least to a medium degree.

*Business Proposal:* A second method that can be used to source knowledge on requirements in the client’s organization is the preparation of a business proposal. Once the contractor drafts the business vision in their perceived manner, the client has a basis to work with and a tangible document to adjust to their individual preferences.

*Concept of Operation:*The concept of operation (or CONOPS) is a document that describes the way, a system is operating the context of up- and downstream systems. The document especially emphasizes how employees in their respective roles interact with the system. Concepts of operation can provide solid mid- to high-level information on the project requirements.

*Procedure manuals:*Procedure manuals are detailed description of technical systems written from the perspective of each user/operator. Due to their detailed nature they can be large documents that require time and expertise. Oftentimes there is no way around the endeavor to examine these manuals.

*Proposal for new system:*When you start a project for a client, there is always some sort of history that can be examined. The regular way to get a project started is a business proposal. If you are looking for the purpose of the project and need to investigate the details of why the previous solution was not capable enough, proposals are usually the first place you should look for answers.

### 4.2.2 Building categories for requirements

When approaching requirements analysis, keep in mind, that stakeholders’ cognition does not differ from the cognition of any other human being. Expressing the desire for a certain function in a system, stakeholders need to activate their competencies on the requirements-related subject. Neurotypical humans, however, can barely access all their competencies on the spot. This imposes a challenge on the requirements manager when analyzing requirement.

* *Stakeholders only implicitly know about requirements*: What if stakeholders require a function but implicitly presume the function is available? This implicit knowledge might not be shared by the contractor. Imagine, buying a new smartphone – would you specifically ask for Bluetooth functionality? Most younger people would not even get the idea to ask. Still, if you bought a phone without asking for Bluetooth and it would turn out, this function is missing, you would find this unacceptable.

Side note:

Implicit knowledge: Knowledge that exists but cannot be activated on the spot. Implicit knowledge guides humans by serving as a fundament for all decisions. Most knowledge from your studies at IU will serve you as implicit knowledge throughout your career.

* *Stakeholders do not know about requirements*: What if stakeholders lack expertise in a certain matter – but if they would possess this knowledge, they will most certainly formulate very specific requirements based on this additional information. In our smartphone example, picture a built-in VPN that allows customers to connect to the internet around the world in order to avoid tracking by advertisers, access cheaper regional subscription plans for streaming services etc. If more customers would know about tracking by advertiser and this option to avoid it (that is not existing as a built-in function), they might opt for a smartphone model that delivers this function.

Usually, only known *explicit requirements* are brought forward by the stakeholders in requirements analysis. Requirements managers need to be aware that it cannot be expected of stakeholders to activate implicit knowledge and formulate requirements for which they lack the knowledge. It is the requirements manager’s duty to support the stakeholders in a way that enables a manifestation of implicit and unknown requirements.

So before entering an interview in the context of requirements analysis, requirements managers need to be aware of three different categories of requirements. One of the most widely applied models in requirements analysis is the Kano-Model (Madzík, 2018). The model distinguishes between a) threshold attributes, b) performance attributes and c) excitement attributes.

*Fig. X: Classification of attributes based on the Kano Model*

#### Threshold attributes (must-be):

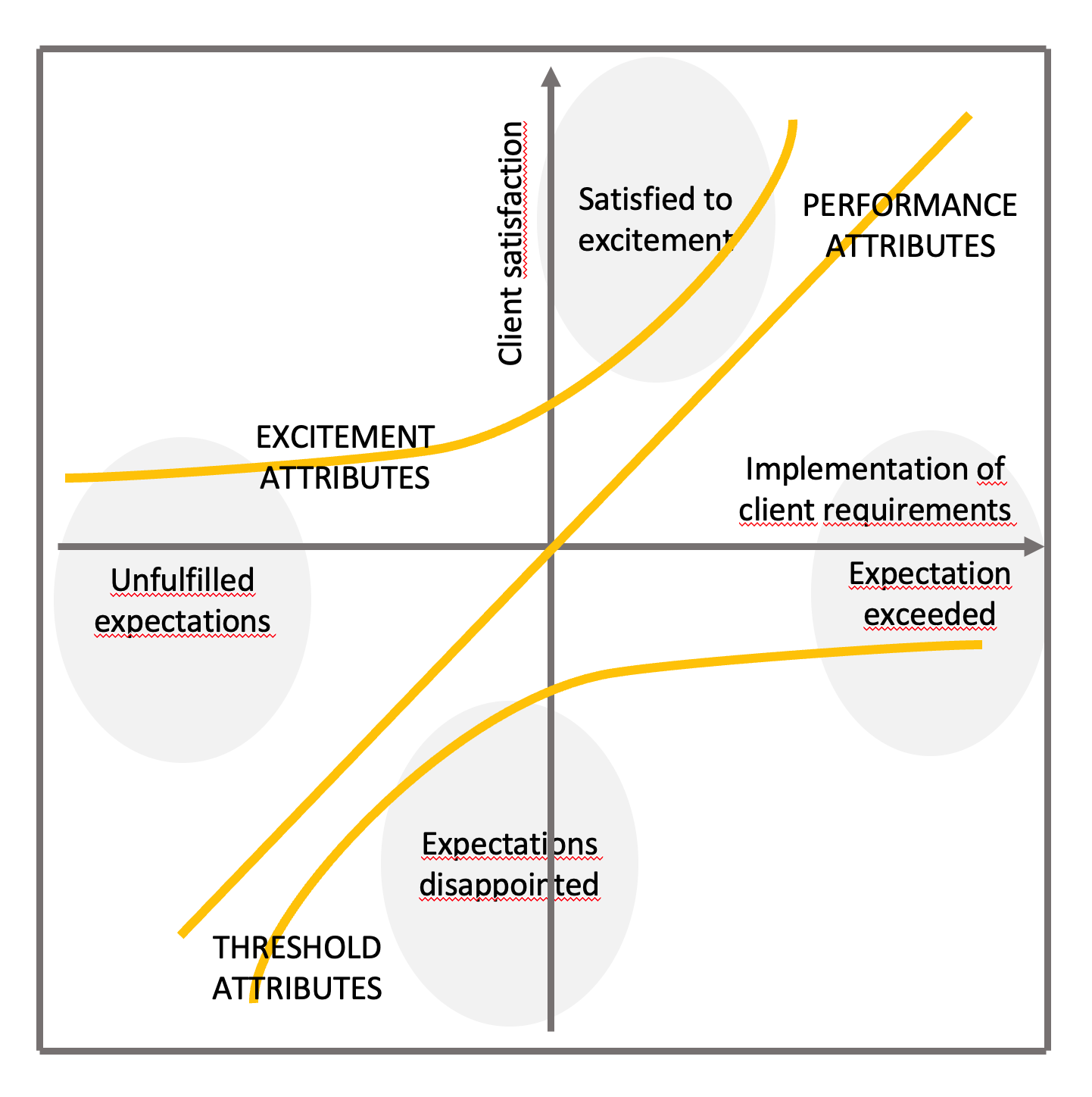
Characteristics that refer to implicit knowledge on requirements on the part of the stakeholders. Must-be requirements “should be met automatically but meeting only these requirements does not lead to satisfaction of the customer” (Madzík et al., 2019). Stakeholders might be too deeply involved in specifics, that they are unable to access knowledge on requirements that are self-evident to them. If they are not fulfilled, however, contractors cannot refer to the documentation of the interview. While it may not be considered too much of a success to gather threshold requirements, failing to gather and implement them will almost definitely become cause for customer dissatisfaction.

#### Excitement attributes (attractive):

Characteristics of the system that refer to unknown requirements. Again, the stakeholder may not know about certain features that are possible to implement in the system. In contrast to Madzik et al.’s representation, experience has shown, that this type of requirement goes beyond extra features that raise *enthusiasm* and *satisfaction* (2019). When hiring a contractor for a project, there is always an implicit expectation to hire subject matter expertise. This includes coming up with solutions, which at least includes the industry standards, if not new ideas. Stakeholders usually show some level of excitement or gratitude to the contractor, if familiarized with these ideas. The Kano model shows how the absence of excitement factors does not harm the client’s satisfaction – uncovering unknown requirements, on the other hand, and turning them into excitement factors exponentially increases the client’s satisfaction.

#### Performance attributes (one-dimensional):

The easiest part of the requirements analysis is the gathering of requirements that are present in the stakeholder’s mind. Gathering so called *one-dimensional attributes* is relatively simple, as “the customer is able to define them even before using the product or service” (Madzík et al., 2019). Meeting these requirements will increase client satisfaction, failing to meet them, on the other hand, will lead to increasing dissatisfaction.



*Fig. X: The Kano Model for client satisfaction (based on (Madzík et al., 2019)*

The model shows, how the different categories of requirements raise satisfaction, once implemented. In order to avoid disappointment, threshold attributes and performance attributes need primary attention. To raise the satisfaction to a higher level, excitement factors can contribute. Experience has shown, that clients tend to approach contractors with the expectation of contributing subject matter expertise – so be mindful not to disregarding considerations on excitement attributes as optional add-ons. The Kano Model has been subject to further development (Madzík, 2018) – the base model, however, still serves as a solid tool to approach requirements analysis.

### 4.2.3 Techniques for analyzing requirements

In the previous sub-section, we have implied the interview of the stakeholder by the requirements manager as a primary method for requirements analysis. While this is not incorrect, the interview is only one of many techniques to analyze requirements.

*Fig. X: Summary of techniques provided by IREB (Glinz et al., 2022)*

The international Board of Requirements Engineering (IREB) recommends a number of techniques (Glinz et al., 2022) that will serve as the basis for this chapter.

#### Interview

Interviews are meetings with stakeholders with the declared target of analyzing requirements (Glinz et al., 2022). If more than one stakeholder of the same kind is present, the likelihood to uncover blind spots increases. As always in meetings, however, too many people actively contributing can harm the effectiveness of the analysis.

*Advantages*: The interviewer can fully focus on one (or ideally two to three) person(s) and their insights and desires. In contrast to questionnaires, the conversational back and forth can alleviate misunderstandings and allows for elaborating on complicated questions.

*Disadvantages*: In case there are a higher number of stakeholders involved, interviewing any of them might be time consuming. Furthermore, success depends on the expertise and the social skills of the individual interviewer.

#### Questionnaire

Questionnaires are a common tool to gather requirements from a high number of stakeholders. The most typical methods are via paper, email or web form (Glinz et al., 2022). They need to be standardized to some extent, even though different questionnaires can be made for different stakeholder groups.

*Advantages*: Questionnaires work if a high number of stakeholders need to be questioned in a short time, over long distances and with little effort. Stakeholders who are not equipped to answer questions on the spot might feel more comfortable with the time and chance to consider or to discuss with colleagues.

*Disadvantages*: Questionnaires only deliver explicit requirements and there is little chance that unknown or implicit knowledge can be activated. Furthermore, the designers of the questionnaire need to be very precise in their questions. Oftentimes, stakeholders don’t answer questions they do not fully understand.

#### Brainstorming

Brainstorming is used as a creativity technique in requirements analysis. It serves to generate new ideas in as little time as possible (Saha et al., 2012). Requirements managers meet stakeholders of the same domain (e.g. operators) and gather ideas in a semi-structured discussion.

*Advantages*: Brainstorming freely generates ideas that can be developed in a team effort. Participants are liberated from their own limitations as their contributions are picked up by their peers – which, in itself triggers creativity.

*Disadvantages*: Brainstorming requires positive dynamics in a team. The technique can be counterproductive in case the corporate culture of the client rewards negativity and spontaneous rejection of new ideas.

#### Persona-based analysis

When working with stakeholders who are mainly involved in the design of the system (e.g. system architects), the conversation lacks the perspective of other stakeholders (e.g. users, operators, maintenance) (Glinz et al., 2022). In these cases, meetings can be structured along viewing the system from the perspective of a defined list of stakeholders.

*Advantages*: Perspective-based analysis extends the advantages of brainstorming into a more structured communicative system. This structure forces the participants to leave their own professional bubble and allows for the creation of new requirements profiles.

*Disadvantages*: Experience has shown increasing resistance with level of isolated subject matter expertise. Some degree of openness is required in this analytical technique.

#### System-archeology

We now move on to the documentation techniques. Object of the analytical process are not stakeholders per se, but systems and documents. System archeology refers to gathering requirements from analyzing older or similar systems (Kluge & Schlör, 2016). If a function seems crucial in the older system, it is worth considering it for the new system, as well.

*Advantages*: This can lead to a very complete set of requirements, which includes implicit requirements. Stakeholders might be used to a function that it does not seem worth mentioning – system archeology will uncover these functions one by one. Furthermore, this technique helps the requirements manager to understand the big picture, including reasons, why a new system is necessary.

*Disadvantages*: Speaking from experience, system archeology can be tough and exhausting for the requirements manager. In order to avoid a copy/paste approach, the documents need to be fully understood. If this is not the case, the analysis bears the risk of just improving older/other systems, while a coherently new approach would be the best solution.

#### Re-use

Re-using requirements and other technical documents is close to the idea of system archeology. If a contractor is specialized in leading the implementation of new emergency control systems for police and fire departments, different communities might not have too different requirements. Requirements are usually saved and archived by contractors, to re-use them in similar projects (Kluge & Schlör, 2016).

*Advantages*: If carefully applied, storing and re-using requirements can simplify the analytical process. This can accelerate the process and usually leads to more complete requirements.

*Disadvantages*: Re-use bears the risk of implementing faulty or insufficient requirements. Each project is different to some degree – to determine this particular degree is an additional challenge in the analytical process.

#### Field survey

Field surveys can start small by just observing the day-to-day application of an existing system. In larger projects, field surveys can take weeks or months and require larger teams to visit and analyze the sites, the where the system will have some relevance.

*Advantages*: Workflows and processes that are hard to describe can be observed in real-life. This can lead to an elimination of the cognitive barriers between stakeholders and requirements managers. Especially in situations, where these barriers are obvious, field surveys should be considered as a viable option in requirements analysis.

*Disadvantages*: Humans regularly give their best, when they are under some sort of observation; this can distort the insights of the requirements manager. Furthermore, in case of a complete “revolutionary” approach of the new system, insights in the old system have limited usefulness.

#### Apprenticing

A slightly unconventional approach, but nevertheless recommended by the IREB is the apprenticeship (Glinz et al., 2022; Kluge & Schlör, 2016). Requirements managers actively participate in the role of different stakeholders in order to experience their biggest system-related challenges.

*Advantages*: This technique has the same benefits as the field survey. However, it delivers more insights into implicit and unknown requirements, as the technique allows the requirements manager to develop their own ideas how to improve the system.

*Disadvantages*: This technique, of course, is high in time and resource consumption. Also, many applications do not allow for untrained personnel to get involved in their operations. If there is the slightest risk of any kind of harmful outcome of a requirements manager getting involved into the daily operations of systems, this technique should be avoided.

### 4.2.4 How to choose the right technique?

Across the list of analytical techniques, we have implied where techniques may be applicable and where to avoid certain tools. The question depends on a multitude of hard and soft factors – so any definite recommendation would deliver nothing more than a false sense of comfort.

Nevertheless, before closing the analysis-section, we want to provide a list with factors, requirements managers usually consider, when choosing an analytical technique for requirements analysis.

|  |  |
| --- | --- |
| Type of knowledge | Supporting question |
| Explicit / implicit | What kind of requirements (see 4.2.2) do you want to analyze? Implicit requirements need different tools than explicit ones. |
| Functional / non-functional | Is the current part of the analysis targeted at functional or non-functional requirements? |
| Level of detail | Is the analysis in the early stages and are high-level insights sufficient? Or do you need to go deeper? |
| Personal experience | Is the requirements manager experienced in more suptle techniques, such as interviews? |
| Project environment | How fitting are the different techniques to the corporate structure, cultural elements and traditions in the client’s organization? |

*Table X: Elements to consider when choosing analytical tools*

This list is a great starting point to consider – but is by no means conclusive. When becoming involved in Requirements Management, try to avoid pushing towards your direction against the stakeholders’ opinions. Brainstorming might be a great technique, for example, but some more experienced participants may reject it for its lack of structure. When agreeing on a suitable technique, however, it is recommended to follow a structured application.

**Self-check questions**

Q: Based on the Kano Model, what is to be expected, if threshold attributes are not implemented

A: The client is most likely to experience disappointment in the lack of system understanding and proactiveness in the requirements interviews.

Q: Would an apprenticeship be an appropriate tool for analyzing requirements of flight control systems?

A: Flight control systems are usually part of critical infrastructure. The result of human errors are dramatic and leave no room for untrained personnel on the premise. Therefore it is strongly recommended to use other methods in this scenario.

## 4.3 Requirements Modeling and Review

During requirements analysis, requirements are gathered as an *idea*. An idea, in this context, is the requirement itself, regardless of the form in which it is documented. It goes without saying, that this is only the very first step. Requirements need to be drafted in a way, that makes them easily comprehensible by everyone involved in the project. Writing a list with sentences that describe the requirement seems like the obvious idea – and this is always part of the process. Sentences, however, can quickly become ambiguous and hard to understand for the reader, when it comes to more complex requirements and their relation to each other. This is why the discipline of Requirements Management has incorporated the concept of models (Glinz et al., 2022).

### 4.3.1 Requirements models

The general purpose of models is to create a pragmatic and simplified representation of a real-life context. In Requirements Management this real-life context (in terms of the system) is not yet existing – the requirements for the system are already in existence. Requirements models bring order into the chaos auf singular requirements and display more in less words, than written sentences could.

Requirements Management usually applies graphical models, that are qualified to represent the sum of all requirements in a defined scope (Glinz et al., 2022). These graphical models are based on the aforementioned modeling languages, e.g. the unified modeling language. Again, modeling languages are graphic systems which attribute very specific meaning to a wide range of graphical elements. Much like in text-based language, this makes it easy to unambiguously understand, what a certain word means. If, for example, the interrelation between a server and a computer is supposed to be illustrated, there are generally multiple icons, that *could* represent a server and a computer. In UML, there is only *one* symbol for server and *one* for computer. Even the ways, to elements interact with each other (interfaces, operation etc.), or how elements are grouped (system, team etc.) is restricted by defined modeling language (Kluge & Schlör, 2016).

In order to keep the application of the modeling language (and the models themselves) simple, these symbols are supplemented with text. There are, for example, no dedicated symbols for customer and operator. Instead, both are illustrated as a person – this person is then labeled as *customer* or *operator* with text. Furthermore it needs to be stated, that requirements should always be documented with both, natural language *and* models.

Modeling languages are easy to learn and once learned, they are widely understood without the challenges related to textual and oral communication. It should be obvious by now, that these conditions perfectly match the use case of Requirements Management in terms of documenting requirements.

In this sub-section we will introduce you to the modeling of the most typically modeled elements in requirements documents: goals and use cases.

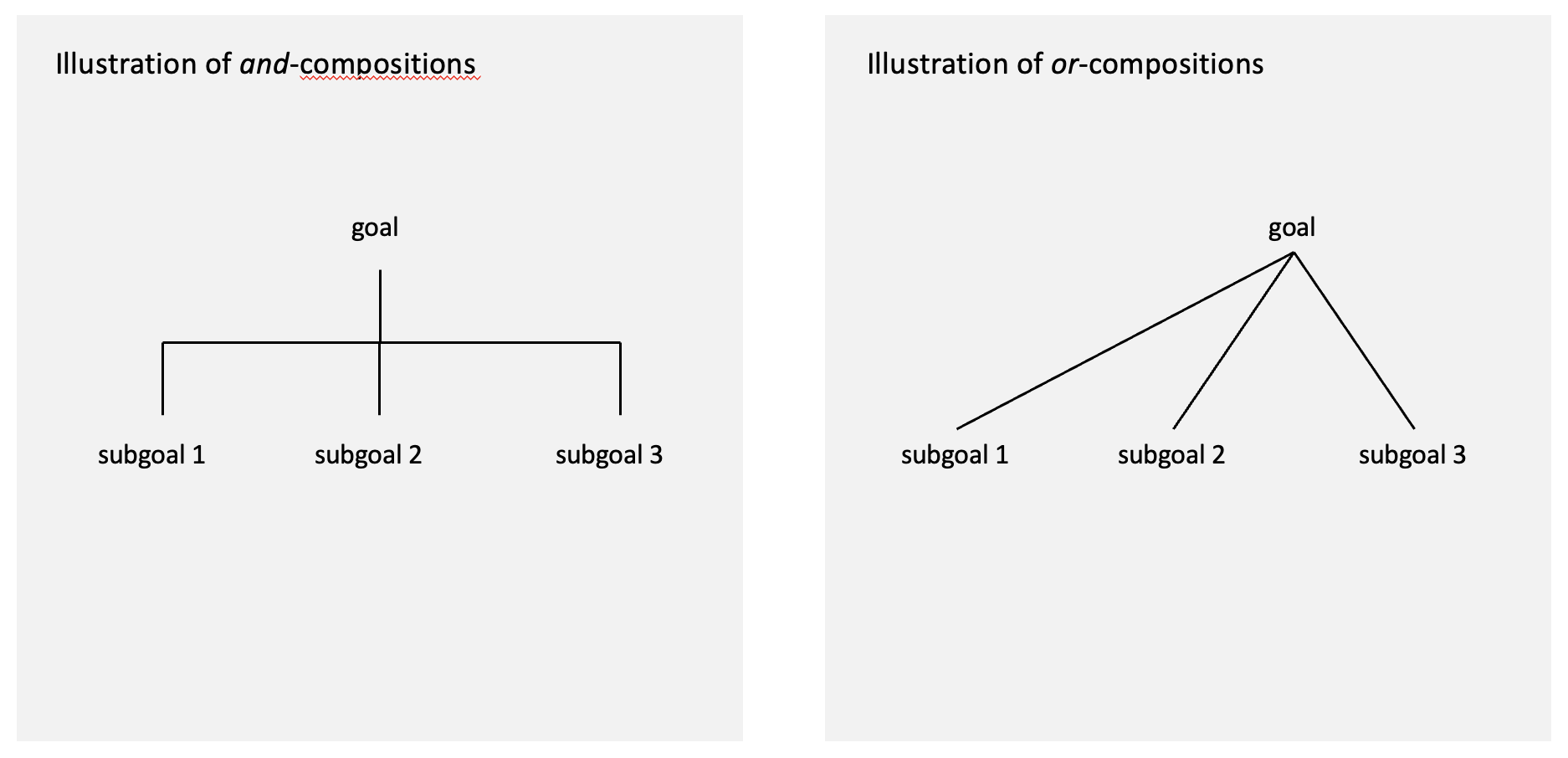
### 4.3.2 Model-based documentation of goals

Goals are an essential aspect of requirements documentation. Even in low-complexity projects, individual requirements can be difficult to interpret without the understanding of a clear goal. It is, therefore, an essential element of any requirements analysis, to collect and document all goals, to which requirements relate.

Goals are usually composed of a set of subgoals; the breakdown of goals into subgoals is a *composition* (Glinz et al., 2022). In Requirements Management, there are specific ways to graphically illustrate goals and subgoals. The most common distinction is made between *and*-compositions and *or*-compositions.

1. *and-composition*: Goals that are reached by a *complete combination* of subgoals
2. *or-composition*: Goals that are reached by *at least one* of different subgoals

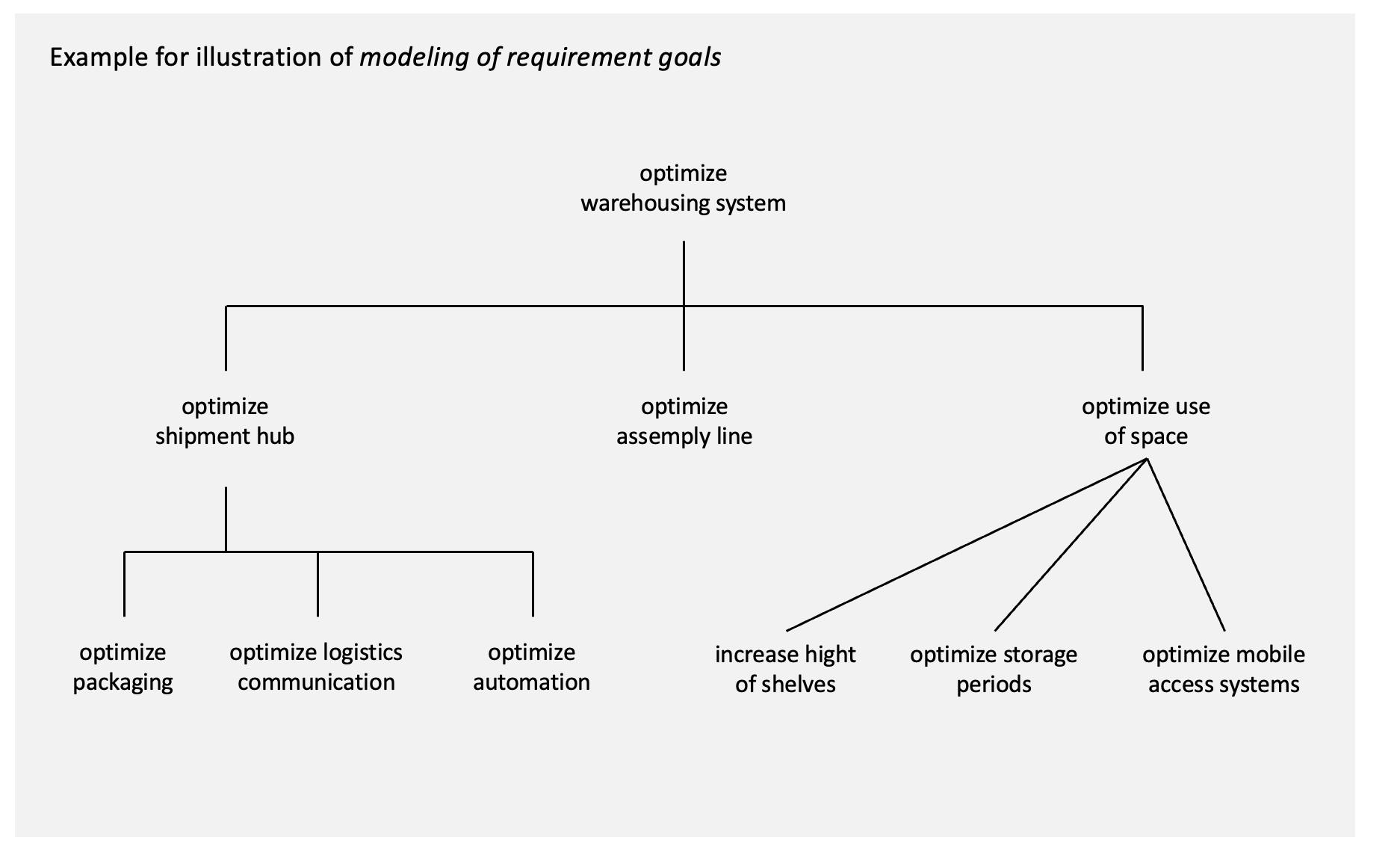
As you can see, two different ways to graphically illustrate goals and their composition based on modeling languages can alleviate the risks of using natural language. Requirements Managers illustrate this distinction as follows.



*Fig. X: UML-based illustration of and/or-compositions (based on (Kluge & Schlör, 2016)*

The decomposition of goals is usually more complex. In section 2.3, we elaborate on the hierarchy of desires, related to any project. In the context of this hierarchy, documentation of goals in the context of requirements analysis creates an interface between requirements and higher levels of the hierarchy, e.g. business needs or business goals.

Let’s illustrate this in a more practical example:



*Fig. X: Example for the UML-based graphic illustration of goals*

The example refers to a hypothetical project of a company, that aims at optimizing their warehouse operation (business goal). Amongst different options, the management staff decides to initiate an optimization of the warehousing system (business need). This goal can only be achieved, if *all three subgoals*, the optimization of the shipment hub, the assembly line and the usage of storage space are optimized. While the same is true for the optimization of the shipment hub (indicated by straight lines), the optimization of the usage of storage space can be achieved with one of this subgoal’s subgoals (indicated by skew lines).

### 4.3.3 Model-based documentation of use cases

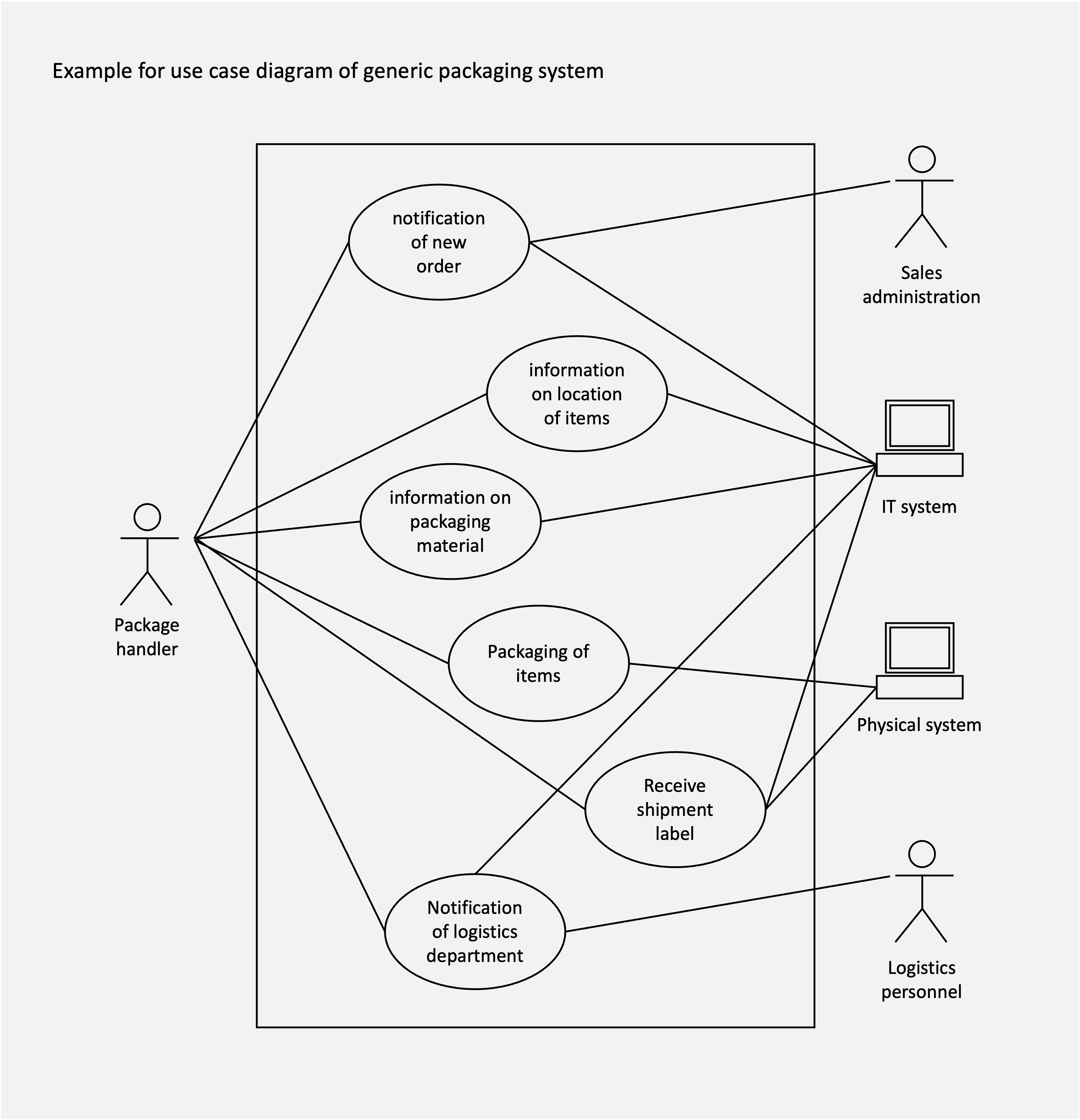
The second most typical situation, within which requirements managers apply modeling techniques, is the use case documentation. Use cases structure the entire system into a combination of functions. These functions are combined in a way that illustrate the real-life purposes of a system.

Keep in mind, that no client *really* wants a new warehousing system – what the client (of our previous example) really wants, is, for example, faster ways for packaging goods (optimized packaging). This business need can be satisfied by a warehousing system that delivers more efficient ways to achieve this goal. The description of all packaging-related functions of the new system would be the *packaging use case*.

In many cases, requirements naturally refer to one or more specific use cases. If this is not given, requirements managers need to connect requirements to specific use cases. In some cases, for example with quality requirements, this is barely possible – these requirements are usually not part of the use case documentation.

#### The use case diagram

The use case diagram is “a common approach for modeling the functional aspects of a system and the system boundaries, along with the system’s interaction with users and other systems” (Glinz et al., 2022). It unambiguously documents, how the system is required to operate. Furthermore, use case diagrams make it easy to connect different use cases with each other. This can deliver insights on the interactions of different parts of the system. Keep in mind, that use case diagrams



*Fig. X: Generic use case diagram for the example of packaging in warehouse optimization*

Keep in mind, that use case diagrams only deliver a picture of the static elements of a system. They are not well-suited are not well-suited for the illustration of processes. Furthermore, requirements modeling has its limits when it comes to details. It should be understood, that models illustrate big pictures – these big pictures, however, are

**Self-check questions**

Q: UML-based requirements specification is a great way to illustrate requirements simply and unambiguously. There are different levels of abstraction necessary, when specifying requirements. Which level is best accommodating the application of UML?

A: UML works well on a high level. Detailed requirements specification should be done in natural written language.

Q: When illustrating goals, which two options are available in UML and how are both options illustrated?

A: Goals can be composed of either *or*-subgoals or *and*-subgoals. Or-subgoals are identifiable by skew lines, and-subgoals are indicated by straight lines.

## 4.4 Quality Criteria of Requirements Management

At this point, we are familiar with the specification of requirements in the form of models for high-level requirements specification. On a more detailed level, specifying requirements in natural language becomes inevitable in most projects. When specifying requirements this way, the quality of the way the requirement is specified becomes decisive.

We have elaborated on quality aspects of requirements in section 3.1. (Management and Control of Requirements), in terms of safeguarding the quality of the *requirements* *documents*. In this section, we will elaborate on the different quality criteria for *individual requirements*. It is the goal of any requirements manager to ensure the specification of requirements in a way that conforms to the unified standards of Requirements Management. This way, they can ensure, that all requirements are specified in a way that allows for a precise understanding of the requirements by the contractor’s personnel and all stakeholders of the client.

*Fig. X: Quality criteria for the specification of individual requirements (based on (Glinz et al., 2022; Kluge & Schlör, 2016; Rupp, 2014)*

In this section, we will walk you through each of these criteria and illustrate their importance with examples.

**Feasibility**

A requirement is feasible, if the implementation in the system is realistically possible. This, of course, can sometimes not be assessed by the requirements manager alone and calls for the involvement of other participants, e.g. system architects.

|  |  |
| --- | --- |
| Unfeasible specification | Feasible specification |
| *REQ1 The excavator shall be fully operated by artificial intelligence.* | *-* |

Fully operating an excavator with artificial intelligence is barely possible as of 2022. There is no way to change the specification here, because the lack of feasibility lies in the core of the requirement itself, not the specification.

**Independence**

Requirements are implemented by different workstreams and different project employees. Ideally, everyone knows all requirements, but this is not a given. Therefore, all requirements need to be comprehensible independent from each other.

|  |  |
| --- | --- |
| Dependent specification | Independent specification |
| *REQ1 The operational reporting of the system needs to include item 1 – n.*  *REQ2 It needs to be made available in English and French language.* | *REQ1 The operational reporting of the system needs to include item 1 – n.*  *REQ2 The operational reporting needs to be made available in English and French language.* |

Even though this makes sense with both requirements combined, both requirements independent from each other are not comprehensible anymore.

**Consistency**

Requirements may not contradict each other. Especially when requirements are analyzed by different managers, contradictions are a regular occurrence. Before this contradiction is uncovered by the requirements controller, contradictions can be solved more easily by directly discussing them.

|  |  |
| --- | --- |
| Inconsistent specification | Consistent specification |
| *REQ1 The operator shall be allowed to remain at their workplace throughout their entire shift*  *Req 2 The operator needs to hand in the printed report at the production manager’s office twice a day* | *REQ1 The operator shall be allowed to remain at their workplace throughout their entire shift*  *Req 2 The operator transfers a digital copy of the report to the production manager’s office twice a day* |

Technically, this is a change in the requirement, not the specification – these cases, however, need to be discussed with the relevant stakeholders.

**Necessity**

When interviewed, stakeholders sometimes tend to issue desires, they do not actually have themselves. This may arise from a perceived expectation to contribute, or from the desire to guess other stakeholder’s requirements.

So it happens, that requirements are added to the list, that are not really required by anyone, and the system would not change its functionality, if they stayed were removed from the list.

|  |  |
| --- | --- |
| Unnecessary specification | Necessary specification |
| *REQ1 The screen in the operator’s cabin shall have mirror flip functionality* | *-* |

Once confirmed, that actually no one desires a functionality that somehow made it to the requirements list, it can be removed.

**Unambiguity**

Eradicating ambiguity from project requirements is one of the key purposes of Requirements Management. Ambiguity refers to room for interpretation when reading a specified requirement. All requirements need to by specified in a way that does not allow for more than one interpretation.

|  |  |
| --- | --- |
| Ambiguous specification | Unambiguous specification |
| *REQ1 The system shall stop operating, if the temperature rises above 65°.* | *REQ1 The system’s failsafe mechanism shall perform a shutdown, if the temperature rises above 65°C.* |

The ambiguous specification leaves open, what shall happen after the temperature limit is reached. The unambiguous example refers to the precise event. The failsafe mechanism itself will be specified in another requirement, as this example is just referring to the trigger. Furthermore, the left example leaves open, if 65° refers to the Fahrenheit or Celsius scale.

**Verifiability**

In order to verify, if a requirement has been implemented or not, it needs to be specified in a way that leaves no questions. This calls for precision in formulation by the stakeholder and specification by the requirements manager.

|  |  |
| --- | --- |
| Unverifiable specification | Verifiable specification |
| *REQ1 The handrails on the maintenance walkway shall have a hight that is safe for walking.* | *REQ1 The handrails on the maintenance walkway shall have a hight of 1,2 meters.* |

The right example specifies the hight as *safe*. It cannot be tested, if this was implemented, as safe is a relative term. If high above ground, safe has a different meaning than just elevated by a few centimeters. Try to apply precise information that can actually be measured.

**Simplicity**

While novels – and even course books – can benefit from additional and seemingly random information, requirements do not. It is recommended to write down the essence and find as few words as possible, to get the meaning across.

|  |  |
| --- | --- |
| Complicated specification | Simple specification |
| *REQ1 Oftentimes, the code will be entered wrongfully multiple times in a row, so if it is done by the homeowner, he/she shall receive an additional phone call by the security company to confirm their identity.* | *REQ1 When wrongfully entering the code three times, the security company shall call the landline phone and confirm the homeowner’s presence in the building.* |

Even though the right example is only slightly shorter than the left one, the intention becomes clearer and the specification is made with more clarity.

**Correctness**

Requirements managers are often no experts in the subject matter, in which they specify requirements. The question, if a requirement contains incorrect elements is often hard to answer. Simpler mistakes can be more easily identified.

|  |  |
| --- | --- |
| Incorrect specification | Correct specification |
| *REQ1 The entrance hall shall have the shape of a 361° circle.* | *REQ1 The entrance hall shall have the shape of a 360° circle.* |

It does not require subject matter expertise to identify the 361° circle as an error that need to be corrected.

**Understandability**

In order to make all involved stakeholders understand all requirements, they need to be specified in simple and correct language.

|  |  |
| --- | --- |
| Hardly understandable specification | Understandable specification |
| *REQ1 The machine’s coating shall withstand thermal climaxing up to -60°C.* | *REQ1 The machine’s coating needs to be certified for temperatures up to -60°C.* |

The right example uses less complicated terminology and allows for an understanding, independent from educational and regional background.

**Non-redundancy**

Oftentimes, two requirements refer to the exact same functionality, even though, they are formulated in a very different way. When confronted with a larger number of requirements, e.g., from questionnaire feedback, this is often overlooked. Redundancies in the specification need to be eliminated, in order to avoid distribution of the same tasks to different workstreams.

|  |  |
| --- | --- |
| Redundant specification | Non-redundant specification |
| *REQ1 The operating system of the machine shall have an interface to the Enterprise Resource Planning System of the company.*  *REQ2 The machine shall be able to exchange information with the SAP Hana system of the company (web-based)* | *REQ1 The operating system of the machine shall have an interface to the Enterprise Resource Planning System of the company.* |

Even though both requirements use different terms, they are referring to the same system interface. If not sure about the technicalities, Requirements Managers need to evaluate with subject matter experts.

These criteria are to be considered, while specifying requirements in natural language. While requirements controlling is a failsafe on this end, there is a limit to any controller’s patience when reviewing requirements. To be a team player, their contribution should not be extended to the complete overhaul of the specification sheet.

**Self-check questions**

Q: Name at least the reason, why requirements need to be verifiable.

A: Requirements documents are legally binding. In order to avoid conflicts on whether a requirement is met, they need to be tested precisely.

Q: Why can two different specifications of the same requirement emerge in a document?

A: Requirements are often analyzed by different analysts and provided by different stakeholders. These might come forward with the same idea in a different formulation.

## 4.5 Identification of Requirements Smells

Article from Margit

In the previous section, we emphasized the relevance of quality assurance of requirements. The increase in complexity of 21st century projects has significantly increased the sophistication of Requirements Management – especially quality assurance of requirements has been taken to a new level. This has a multitude of reasons (Femmer et al., 2016):

* Reading complicated requirements burdens each individual’s resources
* Practice has shown that complicated requirements are ignored more often
* Incomplete requirements can lead to the design and implementation of a system, that is effectively useless to the customer

Traditionally, Requirements Management has utilized manual reviews, supported by quality checklists, such as the one compiled in section 4.4 of this course book. As described, individual requirements managers or controllers evaluate any requirement one by one, implement their changes and either directly change requirements or return the document to the author. While this has proven to be effective, it is anything but efficient:

First of all, the manual review is lengthy and requires a high intensity of resources. Feedback loops take their time to manifest themselves in *actually* improved requirements. Furthermore, requirements managers who are not subject matter experts tend to focus their comments on formal aspects as stated in section 4.4 and fail to uncover errors and inconsistencies related to the content of the requirements. These issues, and the lack of alternatives, call for more efficient ways to quality-check requirements.

### 4.5.1 Automation of requirements quality assurance

There are multiple tools available, that quality-check written natural language. When students write term papers in their text editing software (e.g. Microsoft Word), they are supported by functions to identify spelling errors, grammatical mistakes, interpunctuation and even problematic sentences which are technically correct, but lack semantic elegance.

These tools have inspired both, scientists and practitioners, to start the development of similar tools for the specification of requirements. As of 2022, this is more of a theoretical concept, but multiple surveys have shown great promise of an automated approach to control requirements (Femmer et al., 2014). There are several aspects, that appear to be identifiable with such automated tools (Femmer et al., 2016):

*Fig. X: Problems that allow for automated requirements quality assurance*

None of these problems cannot fully be eradicated automatically. Especially semantic problems call for intense manual scrutiny. The concept of automated real-time support when specifying requirements, would be served, nonetheless.

### 4.5.2 Requirements smells

The idea to identify different kinds of shortcomings in the way, requirements are specified, is based on the presumption, that machines can find these shortcomings based on specific hints. These hints are called *requirements smells*. Picture an IT system, that smells possible errors in requirements. The terms is derived from a comparison with human olfactory organs. The smell of something is just an indicator of a smelling object – but no proof. „A requirement smell is an indicator of a quality problem in a requirements document. A smell in a requirements document is always connected to a specific location in the document and a detection mechanism exists for each type of smell“ (Beer et al., 2017). If a sentence contains an imprecise term, this could be an indicator of an imprecision. If a sentence is specified in passive grammar, this could be an indicator for lack of an actor, etc.

Again, much like autocorrect in Microsoft Word, requirements smells only indicate shortcomings in the requirements specification. If a personal name, for example, is close to the name of an object, Word might suggest a change. It will remain up to the author or the controller of requirements to actually change the specification.

### 4.5.3 Automated ways to detect requirements smells

There are different technical ways to manifest the concept of automatically detecting requirement smells.

#### Key words

The simplest method is to create lists with key word that are supposed to be avoided. This technique picks up on *lexical problems* in requirements specification. It is theoretically possible to close holes in the net of insufficient terms to a certain degree. In practice, there is no guarantee, this will work well enough (again, even autocorrect in Word lacks knowledge of all terms in the English language). Nevertheless, this can become a significant tool to increase requirements quality.

#### Requirements parsing

The automatic screening of formal shortcomings focuses on structural problems. For multiple reasons, requirements documents have a fix structure that needs to be complied to. This is difficult, to control, especially when using flexible software, such as MS Word. Requirements parsing tools can screen those documents based on compliance to a structure, that needs to be defined in the parsing tool. While this works well for use cases, such as identifying missing reference points(Beer et al., 2017), it is redundant, when a project organization is applying Requirements Management software.

#### Natural Language Processing (NLP)

Another technology that offers great potential for the identification of requirements smells is NLP. The technology was mainly developed to analyze natural human language. With some tweaking, NLP can identify sentences, which are correct in a linguistic sense, but cause grammatical problems in a requirements context. Femmer et. al. (2016) emphasize the potential for the identification of passive sentences, that lack an active person or system to participate in a specified functionality.

As of 2022, there is no tool available to unify all available technologies in one system. And even the individual systems themselves need some more development. The emergence of artificial intelligence technologies will certainly accelerate this development and we are positive to see this concept establishing itself over the next years.

**Self-check questions**

Q: What are typical causes for lexical errors?

A: Typical causes are imprecise terms, such as *safe*, *increased* or *sufficient.*

Q: Which problems are qualified to be addressed by NLP technologies?

A: Natural Language Processing mainly addresses semantic problems of requirements.

Summary

In unit 4, we have elaborated on the sequential tasks of requirements management. These are the tasks, that have most of their activities located in a limited phase of the project.

First of all, scoping is decisive for Requirements Management, as the scope build the fundament for requirements specification. Here, the Requirements Manager needs to draw clear distinctions between

* the system
* the system environment and
* the irrelevant environment

The analysis and specification of requirements, usually referred to as Requirements Engineering, contains the analysis and the formulation of requirements. There are different sources available: Human sources are procurement managers, operators or subject matter experts; technical sources are field surveys, business proposal, concept of operation, procedure manuals and proposal for new system. The Kano Model supports this process by differentiating into three types of requirements: excitement factors, performance factors and threshold factors.

There are two ways to document requirements: Natural written language is suitable for detailed specification, whereas graphic models are applicable for high-level specification. The most common graphic system is the Unified Modeling Language (UML).

Quality criteria can be met by manually evaluating the quality – this, however, is time and resource consuming. There are new approaches of technologies to identify so called requirements smells, that can help to automatically identify shortcomings in requirements.

# Appendix 1 – References

Alphabetical order

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