Course Book

REQUIREMENTS MANAGEMENT

DLMPRERM01

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INTERNATIONAL
UNIVERSITY OF
APPLIED SCIENCES

LEARNING OBJECTIVES

Projects are always created with new systems that are developed for operations that have not been carried out before. In contrast to the serial production of technical systems, projects have no precedents, but rather are developed without previous examples. The novelty lies in the unique mix of the desired function of the system, the environment of corporate structures, processes, strategic business needs, and the 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 the client's needs.

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

Requirements are highly specific statements of what a client expects from a system that is being developed in the context of a project. These statements are legally binding instructions that facilitate a seamless project life cycle and minimize errors due to misunderstanding.

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

This course book is intended to familiarize you with the requirements discipline for you to understand the role and importance of requirements in real-life projects. It will also show you the tasks and responsibilities of requirements management for you to know the scope of your work and when you are responsible for these tasks. The course book will additionally provide you with tools to apply when working with requirements of a project during your career. Finally, it will demonstrate the requirements management in different industries for you to learn to apply your understanding and the tools to your own professional environment.

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

UNIT 1

BASICS AND DRIVERS OF REQUIREMENTS MANAGEMENT

STUDY GOALS

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

- understand the 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.

1. BASICS AND DRIVERS OF REQUIREMENTS MANAGEMENT

Introduction

“No two projects are alike” is a common proverb. “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 this sense, are usually the creation of something that has never been created before (Rattay, 2013, p. 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, whose goal is to create a unique product, service, or result (Wuttke et al. 2014, p. 21). Based on this definition, we are directly confronted with a major challenge that is unknown to many individuals operating in a non-time-limited ongoing business: Two parties, the client and the contractor, must 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 the 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 of the requirements presumes a set of unrealistic statements:

- The client is capable of identifying all individuals, departments, and additional 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 everyone involved.
- The client will rationally document and prioritize these requirements.
- The contractor will understand every detail of the requirements.
- The contractor will correctly implement the requirements into project deliverables as planned.
- No changes are 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 with a degree of precision that left no further questions regarding the equally precise implementation by the contractor.
- We assure you, these assumptions have never been true in any project above the simplest 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 life cycle.

A survey by Joseph Carr attributes only 40 percent of significant mistakes in a project to those made in the realization phase, while 60 percent of all mistakes are attributed to the analysis phase. Carr also analyzed the cost of fixing errors depending on when the fix is made. 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 fixed in the operational phase, the costs can be multiplied by 100. Getting the analysis right and understanding early on what the customer really needs are investments 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.
- a lack of compatibility with other technical systems, not just those that are IT related.
- challenges in integration into processes of operation and maintenance.

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

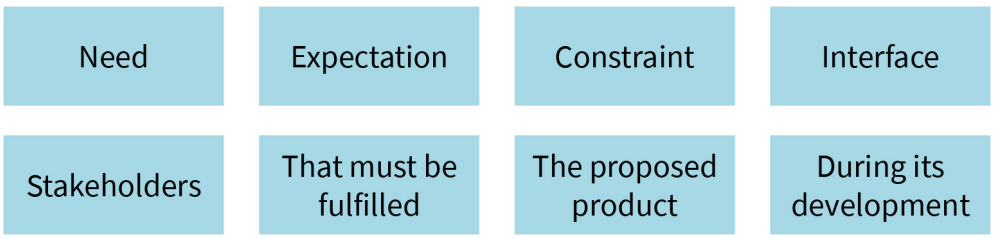
1.1 Definition of Requirements and Management

Requirements management accommodates three terms: (1) requirements, (2) management, and (3) requirements management.

Definition of Requirements

A precise definition of the concept of requirements in the context of requirements management is necessary; according to Chemuturi (2012), “a requirement is a need, expectation, constraint or interface of any stakeholders that must be fulfilled by the proposed […] product during its development” (p. 3).

Figure 1: Elements of Requirements Management



Source: Author (2023), based on Chemuturi (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 fulfilling the need.

Constraints

Needs and expectations can be satisfied in multiple ways. In real-life projects, the way to fulfill needs is always limited by constraints. While time and budget are among the most common constraints, they can extend to all aspects of the project. Thus, constraints are limiting conditions for the realization of a project's needs and expectations.

Interface

Any system that is 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 of the challenges that requirements management must deal with. Therefore, the stakeholder concept is central to the entire requirements discipline.

That what must be fulfilled

Needs are transformed into expectations so that they can be fulfilled. Requirements are high expectations that have been processed by requirements management and 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 at the center of the project effort. In this context, we call the object of the project "the system." While projects often produce technical systems (buildings, machines, information technology [IT]), many industries 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

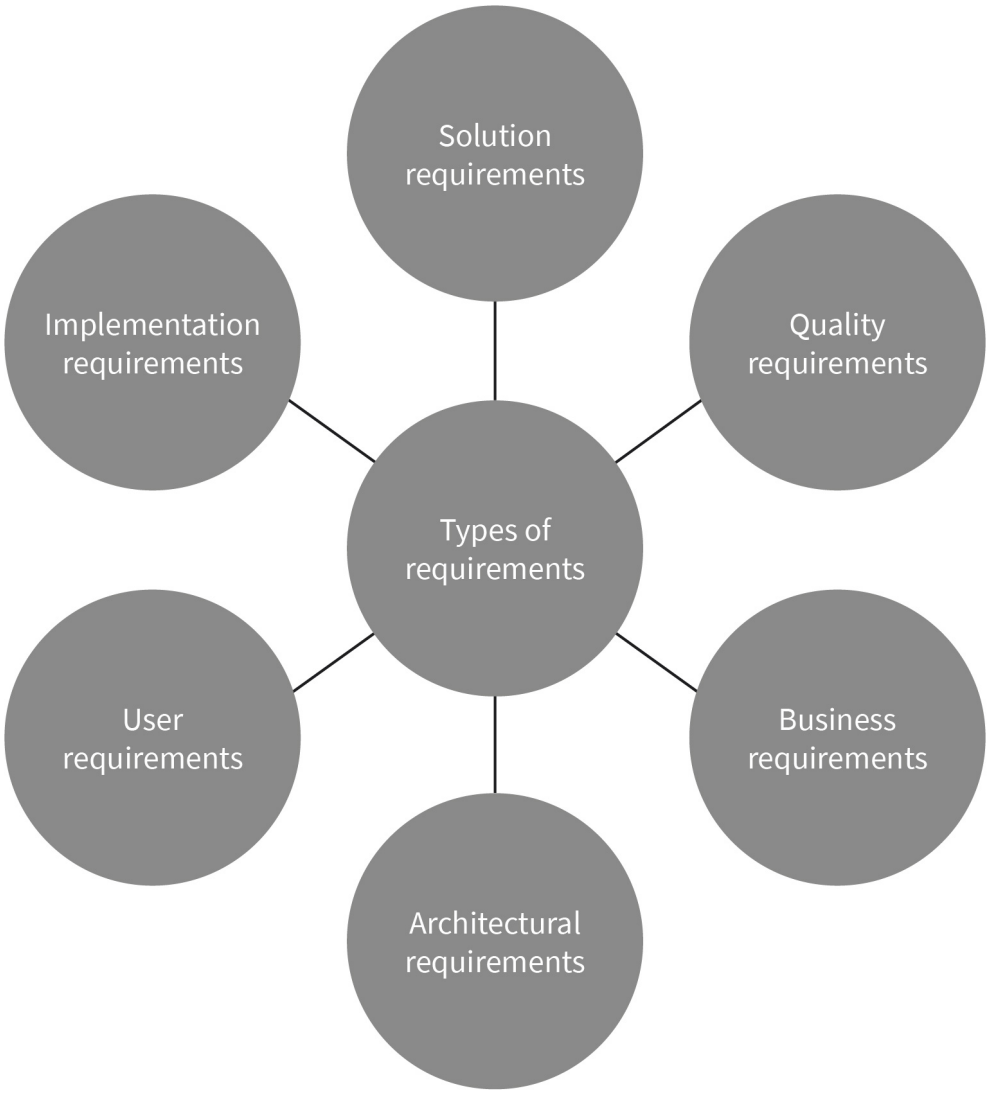
Requirements are parts of any business transaction. They are, however, more easily specified when products are produced in an ongoing production process, as is the case with most consumer goods. Whenever something is being developed from the ground up without much previous experience and with new conditions, requirements become much more important. The development of new systems always takes place over a limited time period, which generally starts with the analysis of requirements and ends with the final approval and acknowledgment by 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 basic distinction between different types of requirements is functional versus nonfunctional (Hruschka, 2019). While functional requirements specify all activities a system must perform (its functions), nonfunctional requirements cover all additional requirements, for example, requirements regarding quality, legal conditions, project management, and user interface (Hood et al., 2007).

Figure 2: Different Types of Requirements



Source: Author (2023), based on Berry & Franch (2011); Gareis & Gareis (2018); Hood et al. (2007); Laplante & Kassab, (2022); Pohl & Rupp (2021); Prakash & Prakash (2018); and Sutcliffe (2012).

Solution requirements

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

- activities that the system can perform independently,
- characteristics of the interface with a user or with another system, and
- further functional agreements.

Examples are the precise temperature to which an air conditioning system can cool down a large office space to, the weight an elevator must carry, and 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 must 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 must operate 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 to ensure these business goals are 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 to increase the line's throughput by 20 percent, this will be stated in the business requirements.

Architectural requirements

Any technical system is placed into an environment of other technical systems with which it must interact. 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 must ensure that the new system is seamlessly integrated into data processes. The construction of a chemical plant must safeguard compatibility with the company's maintenance and repair network and a modern office building must connect to utilities and telecommunications.

User requirements

Requirements management is the art of mitigating customer requirements in a way that leads to the most beneficial system deliverable (Sutcliffe, 2012). The customer, however, is not just represented by the company's solution architect. Anyone who works with the system is a potential source of. Users are operators of machines, facility managers in buildings, applicants of an IT system, and maintenance personnel, among others. These stakeholders are able to provide unique perspectives on what design perks would increase the benefit of the new system (Laplante & Kassab, 2022; Prakash & Prakash, 2018).

Implementation requirements

Projects are often the cause for major transitions in a company's operational routines. Therefore, in many cases, just building a system will not satisfy the client. The personnel responsible for operations and maintenance must be educated, data must be migrated, processes must be redesigned, etc. Sales departments have often used these additional services in the sales process to convince the client that the main system would not differ much from the competitor systems. Recently, however, there has been a trend toward an expectation on the clients' side to include these services in the project scope. To manage expectations, there is a mutual interest in specifying the requirements before dealing with different expectations later.

In the practical reality of most systems, they are sufficient. Keep in mind that this selection is not exhaustive and might be extended in the case of individual projects that you might encounter during the lifetime of your career.

Definition Management

The purpose of discussing the term "management" in a context that is mainly targeted at master's-level business students overlaps with the purpose of establishing a structure of requirements. To ensure an understanding between the reader and the author that reaches further than a surface-level understanding, there is a need to agree upon the very particular definition of what we are talking about when we use terms like management.

The essence of the term "management" that best describes the way we will understand it in this course book was defined by Leontiades (1982) as coping with change and adopting the company to new conditions by making decisions for the benefit of the organization.

Figure 3: Elements of the Management Definition

Source: Author (2023), 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 are 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 must be changed in a way that enables successful execution. Besides matching our understanding of a changing world, the applied definition perfectly caters to 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 enables the further creation of the system that is the object of the project. Thus, 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 and the project matches the adoption element of the term management.

Requirements and management as coping with change

Changes – in contrast to transformation – refer to internal measures that represent a deviation from previously maintained processes, structures, practices, etc., and can usually be associated with a reaction to changes in the project or company environment. 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.

Requirements Management Definition

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 basically fixed set of requirement-related tasks. Most of the time and effort is often attributed to the analysis of requirements. This discipline (and all tasks related to the analysis) is referred to as **requirements engineering** (RE). Once the requirements are defined and agreed upon, there is a set of additional tasks related to them, such as administration, adding further requirements, mitigating conflicts, and managing the requirements change process. These extra tasks are usually referred to as requirements administration. Hood et al. (2007) follow this thinking as they define requirements management as “the sum of all activities in connection with requirements that take place after the requirements have been developed or engineered” (p. 59).

Requirements discipline
the science and art of engineering and managing requirements

Requirements engineering
the art and science of analyzing and formalizing requirements

In this course book, we are applying a comprehensive view of requirements management. Consequently, we do not separate tasks into requirements engineering and requirements administration, but into ongoing, sequential tasks of the entire requirements discipline.

Ongoing tasks are those that are necessary during the entire project process. This includes, among other things, the administration of requirements or the management of change requests. 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. This includes requirements elicitation, which is essentially located at the beginning of the

project and usually becomes necessary only selectively in the further course. Based on our holistic understanding of requirements management, we identify eight major tasks and locate them in the ongoing or sequential parts of the entire requirements discipline.

Table 1: Tasks of Requirements Management

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	Additional attributes are necessary to integrate each requirement into a wider set and context of requirements. These attributes support implementing filters to make sure the right requirements are visible to the right roles in the project.
Prioritization management	These is often a difference between the priorities of the client and what makes sense from a project management perspective. Sometimes, the client needs a "quick win" to win the hearts and minds of their employees. Managing these questions is also part of requirements management.
Traceability management	There is always a certain likelihood that a requirement will get lost over the project life cycle. To make sure no requirement vanishes in the complications and complexities of the implementation phase, requirements management is tasked with tracing the requirements throughout the entire life cycle.
Modification management	Whenever changes must be made in the specification sheet, a certain level of care is required to secure the agreement of stakeholders on both sides on any changes. This is usually done by requirements management.
Version management	In most projects, there will be many necessary changes. These changes create new versions of different documents. Requirements management is tasked with the challenge of ensuring everyone is working with the most recent version.

Source: Author (2023), based on Glinz et al. (2022).

1.2 Requirements Management as an Answer to the VUCA World

Even though projects have always had a need for the specification of requirements, the discipline of requirement management emerged in the late 1970s in the context of the **silent revolution**. This is largely attributed to social, economic, and technological developments that have shaped the world in an ongoing developmental process. These developments, which influence any aspect of our professional and personal realities, are often conceptualized in the high-level framework of the volatile, uncertain, complex and ambiguous (VUCA) world (Lin & Huang, 2020; Mack et al., 2015; Tulder et al., 2019).

VUCA has proven itself a solid concept to derive key insights on a wide variety of practical issues. 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 following elements:

Silent revolution re-orientation of companies after a severe economic crisis in the 1970s that resulted in a massive push for globalization in the 1980s

- volatility: Changes in the economic and technological environment happen with accelerated speed and frequency.
- ambiguity: Cause-and-effect relationships are more difficult to rationalize than they were before.
- uncertainty: Future events can barely be foreseen and can happen with greater suddenness.
- complexity: The number of elements that cause an event is rising exponentially.

To familiarize yourself with the challenges that await 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 concept of high-level VUCA and personal experiences.

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 of the causes and consequences of developments. The practical problem is caused by velocity and the number of change occurrences (Tulder et al., 2019). Volatility describes the following:

- rapidity of change: Changes occur faster.
- frequency of change: Changes occur in quicker succession.
- 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 life cycle is planned 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 forms. While it makes a certain amount of sense to analyze as many requirements as possible in the beginning of a project, the specification sheet should not be considered a fixed document. Changes in the client's environment can occur very rapidly, which may change the client's requirements in the project. Keep in mind that this is not necessarily an expression of "flip-flopping" on the client's part but rather an expression of a capability to react to a volatile environment quickly and responsibly. It is a strength of any requirements manager to understand the necessity for quick reactions to requirement changes and integrate them responsibly into the entire network of project requirements.

Uncertainty: Lack of Stable Assumptions Regarding the Future

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

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

Uncertainty has a major impact on project and requirements management. First, external shocks can lead to dramatic changes in project requirements and even the most bizarre causes cannot be excluded (see volatility). More specific to uncertainty 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 of whether something works or not is always dependent on a chaotic variety of external influences. These are never the same, even with clients that operate in the same industry. Those external influences might be current trends in the client's industry, specifics of the technical structure, or even related to different organizational cultures. All this strongly suggests that one should never overestimate judgments based on previous experience and never underestimate clear and unprejudiced assessments of any new project environment (Tulder et al., 2019).

Complexity: Incomputable Causes of Effects and Effects for Causes

Complexity, in general, describes a chaotic relationship between causes and effects (Baraldi et al., 1999; Mainzer, 2012; Luhmann, 1987). The business world in general is dominated by causal relationships – after all, there must 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; 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 to find an effective and sustainable solution, knowledge of the causes is crucial to the process of finding a solution. You may imagine any management context as a network of interrelated occurrences. This leads to several insights on this network:

1. When you must solve a practical problem, there is a complex number of causes (e.g., decisions by other departments and project streams).
2. These causes are often hidden, and it is not obvious how they interact together in the causation of the problem.
3. Whenever you make a decision, this decision can become a hidden cause for further problems.
4. The effects of your decision-making – whether they may have a positive or negative effect – are often unknown to you, 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, in two departments, for example. In a VUCA world, these investigations must be made to effectively solve a problem (Mack et al., 2015). It is critical to understand that 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 that have a solution that works. Perfectionism and the 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.

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 of 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 and says, and what the interviewer will understand. This condition is impeded by the growing increase in functional differentiation even in smaller more focused companies and projects. What an interviewee thinks about requirements and the way they verbalize them is strongly dependent on their function in the company and their educational and professional socialization.

In the same logic, interpretation on the part of the interviewer is influenced by their 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 in the situational context complicate a precise understanding even further. The techniques of RE (the analytical steps in the beginning of each requirements process) were specifically developed to overcome this gap.

1.3 External and Internal Drivers of Requirements Management

Requirements management emerged in the 1970s 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 is necessary. While we can derive some implications for practical project management, from the VUCA perspective, a discussion on the drivers of requirements management will help you better understand the practical challenges of project and requirements management.

Driver 1: Technical and Social Systems Have Become More Fragmented

The first, and one of the most important, drivers of requirements 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 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 1950s, 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 this 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 of the most specific details. These details, however, are understood only by very specific employees. All individual employees combine these skills in a system that is more than just the sum of its parts. In this thinking it is not a given that the client fully understands the complexity of a system you may be tasked to build in a project. Consequently, you cannot simply rely on the client to know all the details of what they really want. This has strong implications for project management and requirements management:

- The greater the fragmentation into little, highly specific tasks that require specialized knowledge, the greater the number of technical experts needed to complete the entire project.
- The more fragmented the systems become, the more subcontractors tend to be involved; thus, the contractors are increasingly limited in their ability to understand the input of their subcontractors.
- The more fragmented and specialized elements of the system and the projects are, the less oversight on the part of project management there is regarding what must be done.

To sum this up: More fragmentation results in less clarity in how the different technical and organizational components interact with one another. The trend of fragmentation in highly specialized project tasks and systems is a major driver of the development and application of requirements management tasks and techniques. Requirements management was made to relieve projects of the burden of nobody really knowing what is supposed to be done.

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 its mark on mass customization in ongoing industrial manufacturing. While Henry Ford manufactured only one edition of his first automobiles

(Olson, 2015), today's customers can order an infinite number of customizations that match their exact requirements. The social development of individualization extends upward in the supply chain, not only to the highly customized product manufacturing line – which is, of course, the result of a project that was characterized by requirements, that no other car manufacturer had. To complete this project, the supplier that was contracted to manufacture Volkswagens also needed to formulate highly specific and individualized requirements to the next supplier up the supply chain (Slamanig, 2010).

While the proverb "no two projects are alike" 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, it had to adjust for different geological and thermal conditions when the company started targeting global markets in Latin America and Africa. Today, projects are not just characterized by a greater number of technological and organizational elements, but these elements also vary from project to project. The implications for requirements management are as follows:

- The more individualized the needs of clients are, the less knowledge of the project the contractor has.
- The more individual the customer's business needs are, the more difficult it becomes to communicate them to the contractor.
- The more individualized the needs, the less contractors can rely on previous experience in similar projects.

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

Driver 3: Projects Have Become More Time Intensive

As global competition has intensified, western companies have not been able to secure their global dominance against countries with low-cost labor, 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 must 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 than a system from a German competitor. Time, however, has become a crucial resource in the competition for new projects in the following contexts (Rüegg-Stürm, 2003):

- Customers greatly emphasize time efficiency. Every day the handover of a system is delayed can be financially measured. High-priced 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 on schedule.
- The delays can largely be attributed to situations during the implementation where project managers have worked with the wrong assumptions about what the client requires. Assumptions, in this sense, are the opposite of a specified requirement.

Well-performed requirements management can, therefore, be a critical resource in project negotiation and in securing a stable position in global markets.

Driver 4: Projects Have Become More Globalized

Communication between the 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 milieu more efficient (Dellner, 2010). Working abroad requires a higher emphasis on the mutual understanding of what should be the result of a project. The 1970s were shaped by the globalization wave that created multinational networks of corporations, in which individuals from all cultural backgrounds came together to perform increasingly complex projects (Butler, 2021). There are multiple examples and experiences in which projects were threatened by managers who relied on intuitive communication. What does globalization mean for multinational projects? There are two consequences:

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

Requirements management (and especially RE) was designed as a new language that can be understood by anyone across different cultural environments. Managers realized it was not enough to just agree on English (or any other language) to enable successful communication in multinational projects. Requirements management entails a code for how to use English (or any other language) to minimize the need for culturally varying interpretations (Pohl & Rupp, 2021).

Driver 5: The Number of Stakeholders and Perceptions of the Project's Goal Has Increased

Stakeholders are groups (or individuals) who have some sort of interest in the project goal. In a more elementary organizational environment, there is asingle point of contact in the client organization who can be addressed regarding requirements. In a more basic technological environment, the client will be able to name all the requirements of the project subject. The increased organizational and technological complexity, which we have seen since the 1970s, has forced project managers to put more emphasis on integrating a multilayered network of project stakeholders (Pohl, 2010; Pohl & Rupp, 2021). In larger corporations, there can be multitudes of organizational entities that might be (even unknowingly) affected by the way in which the project will be designed and implemented. A more diverse set of individuals will be affected, as companies become more complex and intertwined, and as increased interorganizational linkages and dependencies create further stakeholders and administrative bodies of respective governments, environmental groups, unions and the client's customers (Pohl, 2010). Furthermore, these stakeholders

may have conflicting interests regarding characteristics, budget, and time constraints. How is the number of stakeholders driving the demand for requirements management? There are two main consequences:

1. The more stakeholders are involved in a project, the greater the number of communication relationships in the project and thus the greater the communicative control effort for the project manager.
2. The more stakeholders with particular needs, the greater the likelihood of conflicting interests regarding project requirements.

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

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 must be pointed out, however, that companies sometimes see no need for requirements management departments 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 project management office (PMO) companies, it is often 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; Ebert, 2019; Pohl & Rupp, 2021).

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

SUMMARY

Clients have unique requirements on technological, structural, processual, and interpersonal (stakeholder) levels. When performing a project for a client, it is necessary to bridge the communication 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 that are mostly executed in the early stages of the project: requirements analysis, specification, and documentation. These are the prerequisites for a successful start to 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 the 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 sociocultural 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.

UNIT 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 and business analytics.
- explain the different layers of desire from a company's survival to requirements.
- understand the importance of the specification sheet.
- Discuss the importance of the technical concept in the context of requirements management.

2. CLASSIFICATION AND TERMS 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 refers to managing all project and system-related communication with the goal of maximizing clarity on both sides. Clarity in communication at 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 (RE) are often applied synonymously. Even when both terms are used separately, there is no consensus on how both terms relate to each other. We advise you, whenever necessary, to openly ask for clarification at the beginning of each project. Different understandings of terms is a common issue, caused by varying uses in the literature and science. Most projects recognize this, and most project plans contain a section with definitions that guarantees a common understanding of all terms (Project Management Institute, 2021).

For the sake of clarity, we will provide a contextualization of both requirements management and engineering that suits the purpose of this course book. Even though there are varying opinions on the question of which term subsumes all other subdisciplines, the fundamental idea is to separate the subdisciplines into the following:

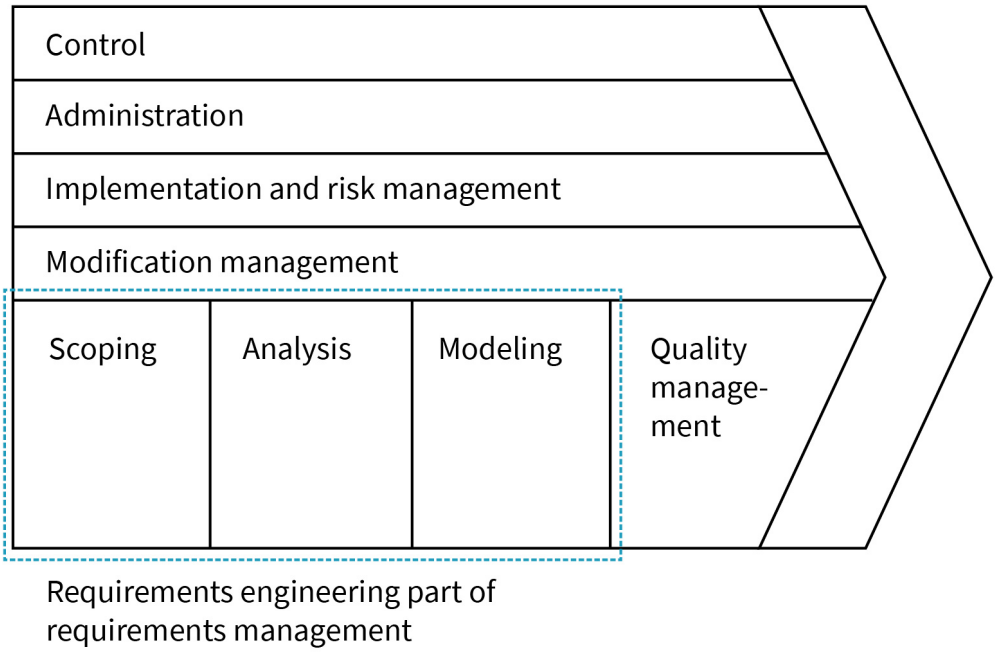
- the task of analyzing requirements at the beginning of the project
- the task of managing the requirements throughout the project

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

RE refers to the analysis, development, and gathering of requirements from the project's stakeholders. While RE must not to be misunderstood as requiring 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. RE 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 must be dealt with in any project.

Figure 4: Requirements Engineering and Requirements Management



Source: Author (2023).

2.2 Requirements Management in Relation to Business Analytics

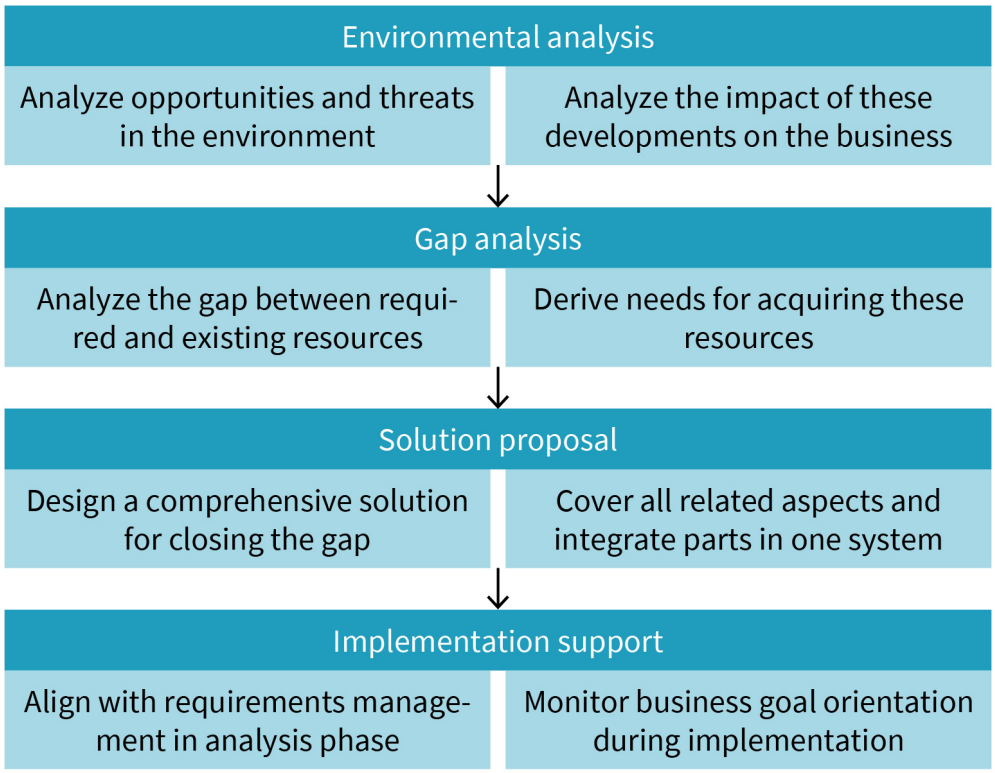
Any project starts with a business need; without a clearly defined business need, projects are devoid of any purpose. Oftentimes, it is not at all easy to define the business need. Requirements management without dedicated business analysis tends to focus on the solution (i.e., the system) for an undefined 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. Thus, business analysis can 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 book focuses mainly on requirements management, we must 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 that must be accounted for in any project – either 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 performed in business analysis?

Figure 5: Tasks of Business Analysis



Source: Author (2023).

Environmental Analysis

The root cause of all business needs lies in the developments in the company's environment. These changes can lead to existential threats and major chances (which, if not taken, can also lead to existential threats). These developments can be of an economic, technological, ecological, or social nature. An analysis of these external developments helps tackle the challenge more consciously. The telecommunications technology manufacturer Nokia failed to take advantage of the opportunities, which led to its downfall during the emergence of smartphone technology. Business analysis oversees the analyzing of 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 the ways in which a 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 for 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 differences in the 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 nonfunctional 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 its broadest sense. In contrast to requirements management, this stage establishes a business-oriented picture of the inner workings of the solution with an 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, and 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 must be recognized by requirements management. However, it should be completed before a project team enters the stage.

Implementation support

At the interface of business analysis and requirements management, both responsible individuals/teams must communicate for successful implementation. Requirements management must target the business needs of a project by starting where business analysis' responsibilities end: the design of requirements for a technical solution that is identified within the project scope. Still, individuals/teams in charge of business analysis must 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 must withstand the critical judgment of business analysts, as must 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 the 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.

Table 2: Differences Between Requirements Management and Business Analysis

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 return on investment (ROI)	Functioning system

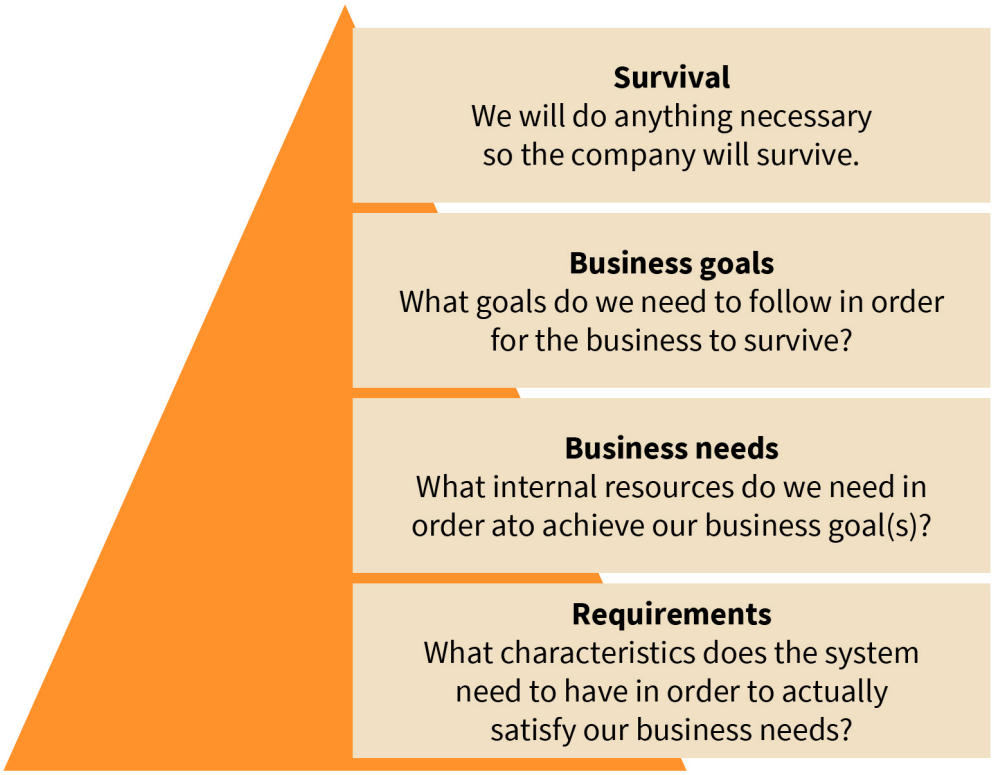
Source: Author (2023).

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 and who are often responsible for leading change programs. In smaller corporations but with larger projects, these tasks are often performed by external consultants or by internal employees with varying roles. Roles that match the tasks connected to business analysis are often labeled as business or enterprise architect or business-systems, data or process analyst (Hruschka, 2019). Internal roles that typically qualify for business analysis are product manager, project/program manager or in-house consultant.

2.3 From Customer Needs to the Specification of Requirements

Any business transaction, especially a complicated one such as a project, starts with some sort of customer need. To differentiate between requirements and customer needs, we can deduce these terms from a hierarchy of desires that all companies have.

Figure 6: Hierarchy of Company Desires



Source: Author (2023).

Survival of the Company

At the top of the hierarchy is a business' desire to survive. Safeguarding its own existence is the fundamental goal of any company that supersedes all other goals, including 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 need to have an immediate existential threat at hand to justify a project. Just keep in mind that key performance indicators (KPIs), such as revenue, profit, and growth, are never the highest priorities, as some companies consciously operate contrary to these KPIs – so long as it serves their survival.

THE MANAGERIAL PERSPECTIVE
We will do anything necessary for the company to survive.

Business Goals

Business goals are designed to serve a company's primary desire of survival. Business goals can be both positive and negative: growth and downsizing, investment and divestment, or 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; for example, profitability can be served by very different secondary business goals, such as more efficient processes or an increase in sales (to scale more effectively).

THE MANAGERIAL PERSPECTIVE

What goals must be followed for the business to survive?

Business Needs

Business needs (often used synonymously with customer needs) specifically refer to company-internal resources that 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 identify 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 to achieve the business goal. In practical terms, these needs are usually the product of any project.

THE MANAGERIAL PERSPECTIVE

What internal resources do we need to achieve our business goal(s)?

Requirement

Requirements are characteristics of the resources that a system must 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 that will serve the business goals and sustain the company's existence over time. A few hypothetical examples illustrate the difference between goals, needs, and requirements, as shown in the following table.

THE MANAGERIAL PERSPECTIVE

What characteristics must the system have to actually satisfy our business needs?

Table 3: Examples for the Hierarchy of Desires of the Company

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	Investors pressure for higher stock value Breaking up into two smaller companies	Economies of scale in administration through new target groups New operative area will be established	Increase in stock price through… … higher profitability … increased output
Business need	Massive restructuring/ 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 toward technical, operational and service-related integration into the existing system

Source: Author (2023).

Practical example

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

Example of survival

The firm's 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 toward China. Chinese companies have attempted to acquire European competitors, 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 of business goal

To defend the company from a hostile takeover, the company must obtain high stock prices. This goal can be achieved by increasing the distribution of profits to the shareholders. There are different possibilities for achieving this goal; the company decides to increase overall profitability through increased production, sales, and greater economies of scale.

Example of 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 will generate economies of scale.

Example of requirements

To meet business needs, the plant must have very particular characteristics. The managers identify three key elements for the generation of economies of scale:

1. Economies of scale for operations: Operational staff can operate the new plant just like the other plants.
2. Economies of scale for administration: The interfaces to the digital control systems of the company seamlessly integrate into the digital structure.
3. Economies of scale in repair and maintenance: 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 greater endeavor to define these requirements as they understand that knowledge of the specifics is distributed across the organization. In this spirit, they opt to involve a project contractor with experience in requirements management.

2.4 The Specification Sheet and Its Significance

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

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, object, and result of the project are supposed to be designed and implemented. Thus, it provides detailed guidance to the contractor and assures the client that their needs will be satisfied by the tasked project. Furthermore, the specification sheet is 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 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 refers to the transformation of the requirement as a generalized desire by a stakeholder into the language of requirements management, which will make the requirement 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.

Content of the Specification Sheet

Most specification sheets comprise two major components: business and system. The business section introduces the context of the project and provides information that is 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.

Table 4: Components of a Typical Specification Sheet

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, that are not understood?
	1.2 Glossary	Define all terms regarding the project, requirements and the system and agree on a common understanding
	1.3 Stakeholders	Who must 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

Section	Structure	Description
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 operates?
	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 its desired environment
	2.4 Main exclusions	List all technical aspects and elements, that are not part of the system
	3. Subsystem I	In case of more complex systems, separate into different subsystems (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 Nonfunctional requirements	Specify the nonfunctional requirements
	4. Subsystem II-n	Repeat as often as necessary to specify each subsystem
	Appendices	Add further information, technical descriptions, and graphics that you can refer to in the specification.

Source: Author (2023).

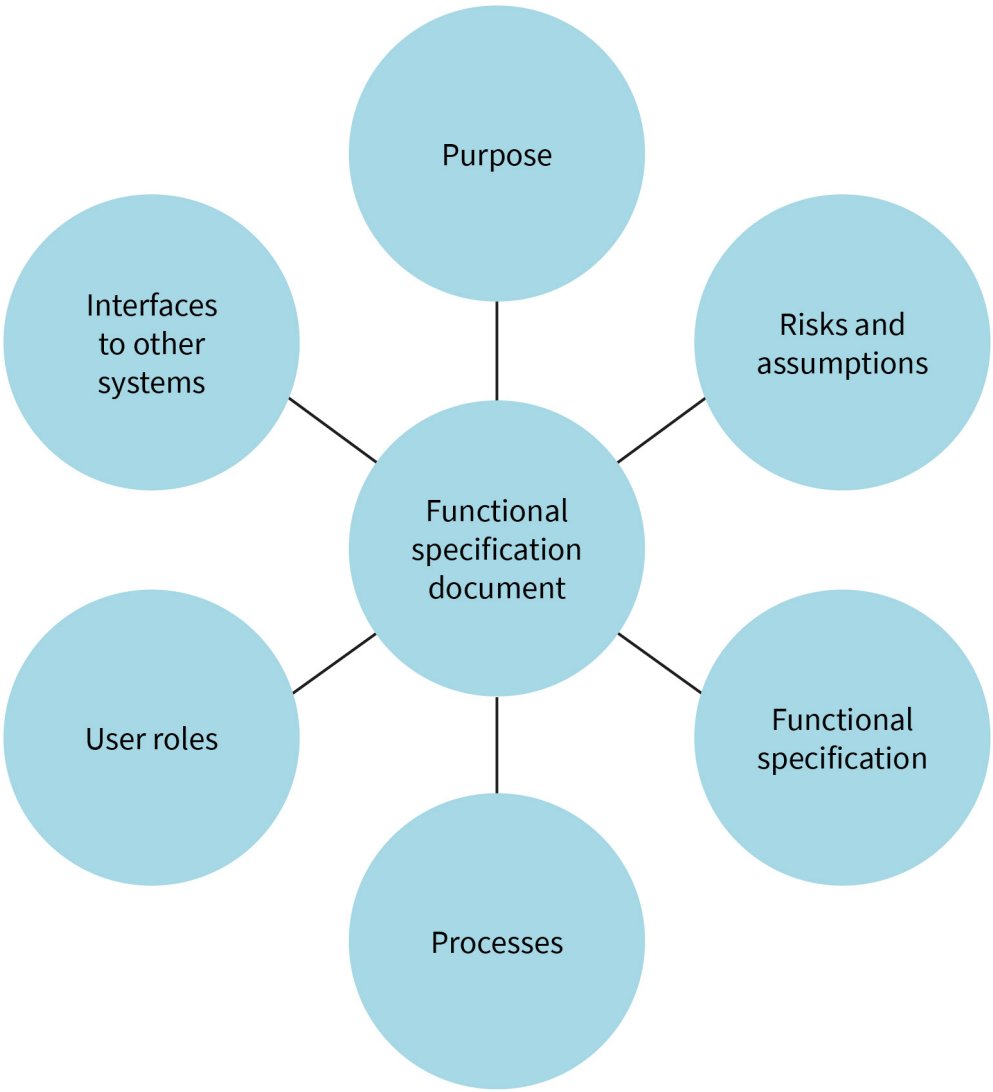
2.5 The Importance of Functional Specifications and Technical Concept

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 at the center of attention for most requirements managers (Ebert, 2019). To create consensus on functionalities of a system (that are being developed and built into a project), requirement managers usually work with an additional document that not only specifies the functionality of the system but delivers a holistic view of the function and **use case**, of which the system will be capable. The technical concept (often synonymous with functional specification document) is typically compared with a detailed user manual that was written before the system was developed. There are varying schools of thought on what must be part of the technical concept, depending on

industries and companies, as well as size, complexity, and the nature of the project (Adams, 2015; Baumgartner et al., 2021; Haberfellner et al., 2019). The most general (but not necessarily exhaustive) list of elements are shown in the figure below.

Figure 7: Elements of the Technical Concept



Source: Author (2023).

Let's take a closer look at each element of the technical specification. Keep in mind that these elements (in some form or another) are also relevant for projects outside of the technical and IT spectrum, such as events 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 of how the system benefits the client and, thereby, creates a bridge between the technical, operational, and business concerns.

Risks and Assumptions

Merely specifying what must 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 by the contractor (Adams, 2015). So, it makes sense for any client to use their subject matter expertise to refer to technology- and industry-specific risks that must 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 have a negative impact on the functional design.

Functional Specification

The specification of all functions of a system in the technical concept is still different from the specification of the 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 affirmation normally refers to the system's integration into other technical systems (last aspect in this list), it is particularly true for operational processes. 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 role from this particular perspective must be described and understood.

User Roles

User roles specifically explain the interaction of users with the system. These roles must 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 from the 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. A key element is the question of 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 information technology (IT) environment, but naturally also reaches as far as construction, industrial manufacturing, and 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 developments throughout most project life cycles. However, it provides all parties with a precise image of what the system will look like from a functional perspective.

SUMMARY

Requirements management is the umbrella term for all requirement-related tasks and responsibilities. An important aspect is the analysis of requirements. All tasks related to analyzing, specifying, and documenting requirements are called RE. Most RE-related tasks occur at 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.

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 must 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 RE, that manage the process 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 toward completing the specification sheet and most later activities work toward realizing what has been specified in the document.

The technical concept (often referred to as the functional specification document) is a first draft of what the system will look like, what functions it will have, and how it must 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.

UNIT 3

REQUIREMENTS MANAGEMENT TASKS

STUDY GOALS

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

- describe the central tasks and responsibilities of requirements management throughout the project.
- discuss all aspects of management, control of requirements, and requirements administration.
- analyze requirements-related risks and know typical ways to mitigate those risks.
- explain the elements of the requirements implementation model and the interrelation between them.
- understand the responsibilities of the change control board and how requirements can be changed throughout the course of the project.

3. REQUIREMENTS MANAGEMENT TASKS

Introduction

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 with a high or low volume, short or long-term, of high or low complexity, must find a dedicated person who deals with managing requirements. The larger and more complex a project becomes, the more likely it is to install an individual exclusively tasked with the function of requirements management. But regardless of whether this position exists or not, there are several requirement-related tasks that must be managed in any project.

ADVICE FOR STUDENTS

The requirements-related tasks are often very structured; they follow clear guidelines and templates and are much more textbook based than other project tasks, and, therefore, learnable. Other project-related tasks require more experience and sensitivity toward 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 to take 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 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 that you are generally worthy of being trusted with project responsibilities. If you decide to take this route, you should work with the International Requirements Engineering Board (IREB) literature referenced in this course book (Pohl & Rupp, 2021). Don't be shy about having IREB 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 assumption that the process of developing project requirements is dependent on several factors that limit the overall project organization's ability to self-organize requirements development. This process includes the following elements:

- precision and commonly agreed structures in requirements definition
- a highly complex and interrelated network of stakeholder interests
- a high criticality for project completion in a way that satisfies both the client and the customer

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

Management and control of requirements is the task of bringing order to the chaos of the multitude of requirements in a project. These tasks are among the key differentiators between successful and unsuccessful requirements management and will, therefore, be elaborated on in detail.

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 the requirements and is often seen as part of requirements engineering (RE) tasks (Rupp, 2014), as follows:

- checking defined quality criteria
- eliminating conflicts between different stakeholder (interpersonal)
- eliminating conflicts between different requirements (technical)

By safeguarding quality criteria and eliminating 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 resolve conflicts almost inevitably 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 the requirements are not managed and controlled, the contractor faces serious exposure to conflicts that, typically, 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 at the center of managing requirements activities.

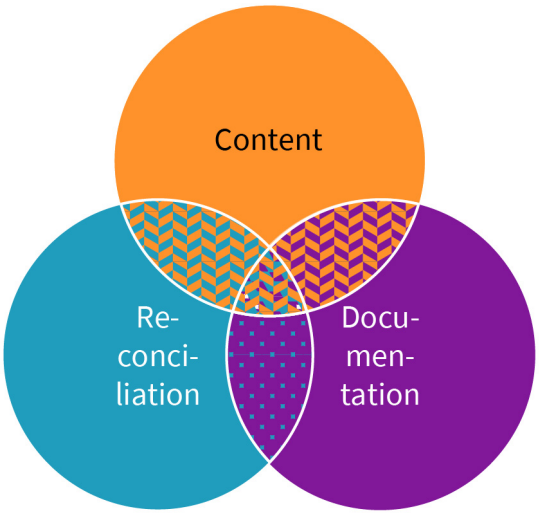
Generation of acceptance for the new system

Conflicting requirements are usually the result of conflicts between the interests of stakeholders. These conflicts can be open or hidden: In open conflicts, stakeholders know their conflicting interests and may cooperatively work on a solution. The increase of cooperation in this process is the responsibility of management and control tasks in requirements management. Conflicts that 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.

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 control (Rupp, 2014). Hereafter, we will explore these criteria one by one and provide a list on what to pay attention to when control each individual criterion.

Figure 8: Main Quality Criteria for Requirements Control



Source: Author (2023), based on Rupp (2014).

Control of the quality-element: Content

Content-related defects and deficits in requirements are often delayed through the entire project life cycle. Risks of procrastinated defects and deficits are project decisions, which lead to a dead end in the particular project stream, increasing the costs of correcting errors rise as the project progresses. 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 toward content-related errors, defects, and conflicts. There are several factors that must be considered in management and control of requirements' content.

Table 5: Content-Related Criteria for Controlling Requirements

Task	Considerations	
Control completeness	Regarding the sum of all requirements; examine if all relevant requirements have been analyzed and specified.	☑
	Verify, if all specified requirements contain exactly the information necessary to implement the system.	☑
Control solution neutrality	Check if the requirements preemptively imply technical design decisions for the system.	☑
	Be mindful that the requirements are always 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 that 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.	☑

Source: Author (2023), based on Rupp (2014).

Control 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

practically 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 noncompliance with the statutory provisions of requirements include

- interruptions during the implementation phase,
- confusion on the original intention of requirements,
- lack of completeness in the specification sheet, and
- overlooking specified requirements.

The central tasks and focus of this exercise are shown in the table below.

Table 6: Documentation-Related Criteria for Controlling Requirements

Task	Questions and considerations	
Control document format	Does the requirements documentation comply with the agreed upon format?	☑
	Does the documentation follow the template restrictions?	☑
	Does the documentation meet the agreed-upon modeling language?	☑
Control document structure	Is the structure in accordance with the defined structure of the document?	☑
	Is 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 interpretations.	☑
	Check for clear language and defined terms.	☑

Source: Author (2023), based on Rupp (2014).

Control 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 slows down the entire project process.

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

Table 7: Reconciliation-Related Criteria for Controlling Requirements

Task	Considerations	
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 agreed to by all stakeholders who were involved in the original version of the specification.	☑
Control if all conflicts are resolved	Double check all requirements, which were involved some sort of conflict.	☑
	Note the sort of agreement that was reached in the decision-making process.	☑

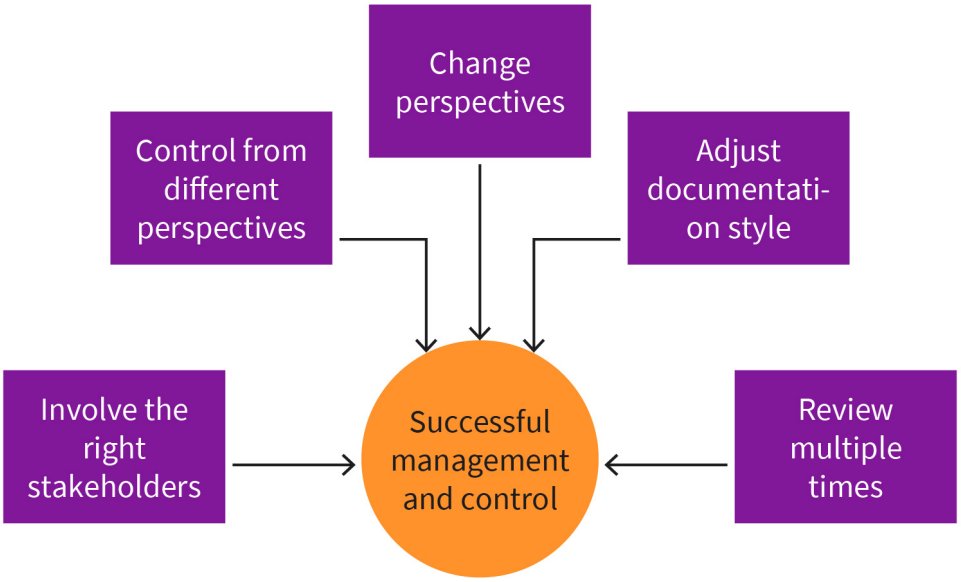
Source: Author (2023), based on Rupp (2014).

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

Principles of Control 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, as shown in the following figure and explained below.

Figure 9: Principles When Managing and Controlling Requirements



Source: Author (2023), based on Rupp (2014); Young (2006).

Principle 1: Involve the right controller

The control 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 conduct 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. To safeguard a clean and organized control 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 must 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 a clearer focus on one task at a 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, then correct in a separate effort.

Principle 3: Change perspectives

Any evaluation is intuitively made from a personal perspective. To leave the controller perspective, you must actively change your perspective to the roles of different stakeholders. Depending on the respective requirements, you can apply the perspective of operator, maintenance, finance, technical management, IT management, customers, etc.

MANAGERIAL IMPERATIVE

Keep in mind, that a controller's goal is to improve requirements for the stakeholders – perform the control 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 the requirements is an ongoing task. While the main effort is situated between the finalization of the requirements specification and the approval of the steering committee, there should be agreed-upon dates and the reviews are repeated. These dates should be relative to certain milestones in the project implementation process. There is no generalized recommendation as to when and how often the review process should be repeated. Indicators for a higher frequency of repetitions are as follows:

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

MANAGERIAL IMPERATIVE

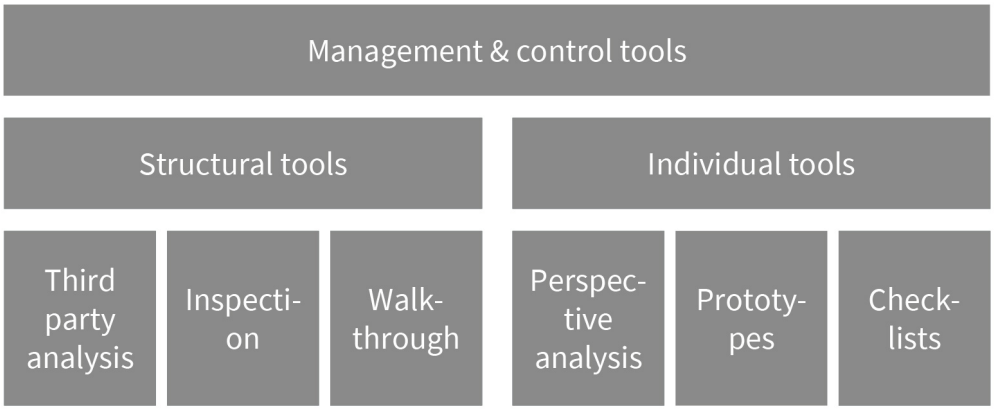
Do not fully trust one-time reviews and set dates for repetition of review process.

How to Control Requirements?

Several tools have proven to be effective when managing and controlling project requirements. Most experienced project managers who are involved in the 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 ideas of these tools are commonly known and applied in the requirements management community; so regardless of the 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, as follows:

1. Structural tools: These are methods to organizationally structure the review process. Review tools provide a framework for which roles to assume in the control requirements and how the process is structured.
2. Individual tools: These are methods to individually control requirements. Development tools can be applied by reviewers once they are tasked with controlling the documents. They are usually applied in some sort of combination with review tools.

Figure 10: Structural and Individual Review Tools



Source: Author (2023).

Structural tool 1: Third-party statement

Many requirements managers consult third parties to control requirements. It is implicit in the logic of control (in general), to separate the roles of development and control. Controlling requirements is, therefore, often executed by colleagues from other projects. Occasionally, clients issue concerns about the expertise of third parties who are not fully involved in the project. While the legitimacy of these concerns must be assessed on a case-by-case basis, the question of whether the requirements are specified according to the general rules of requirements specification, can be answered by most experienced requirements and/or project professionals. A third-party statement is a light and rather informal tool that is often applied in smaller projects with effective informal communication between contractor and client.

Table 8: Third-Party Statement

Process of third-party statement		**Control 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		

Source: Author (2023), based on International Institute of Business Analysis (IIBA; 2009).

Structural tool 2: Walk-through

Another review tool that is relatively easy and effective in its application is the structured walk-through, which is "a working session where invited participants review discuss a set of requirements" (IIBA, 2009). 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.

Table 9: Walk-through

Process of walkthrough		**Control 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 must be documented for integrity Moderator: Content-related moderation (optional role, often used in larger projects)
	Preliminary control by controller		
Walk-through session	Joint walkthrough in formal walk-through session		
	Review and discussion of critical aspects		
	Formal recognition of deficits		

Source: Author (2023), based on IIBA (2009).

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

Structural Tool 3: Inspection

The inspection is the most formal of the three review methods that we discuss in this course book. Some projects require highly formalized control processes as part of a strict and systematic control system. So why burden a project with complex control processes? Oftentimes, the volatile, uncertain, complex, and ambiguous (VUCA) world 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, to accommodate the environmental complexity of requirements specification, the project must raise its internal structural complexity.

Table 10: Inspection

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 must 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 nonerrors		

Source: Author (2023), based on IIBA (2009).

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

Interim conclusion

Review methods can generally be categorized alongside a continuum of complexity: a high manifestation of the drivers creates the need for more formalized inspection, while a low manifestation implies a less formal approach to managing and controlling the requirements at the interface of RE and the ongoing tasks of requirements management.

QUICK REMINDER

Individual tools are methods to help individuals control quality aspects, such as content, documentation, and reconciliation of requirements documents (especially 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 control process and provide little guidance to the individual control task by whoever is tasked with the actual control work. Still, individual review and control 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 his or her 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.

Table 11: Perspective Analysis

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

Source: Author (2023), based on IIBA (2009).

When choosing perspective analysis as a tool for the controller, precise instructions on the perspectives must be provided. Experience has shown that 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-depth knowledge of the systems usage, as the control process must 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. To match the complexity of the control process with the available resources, controllers can be tasked to only test critical elements of the system.

Individual tool 3: Checklists

The most common control tool is the application of a 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. Controllers are often tasked with completing checklists in the process. The elements that are subject to control must be formulated as precisely as possible.

Managing Adjustments and Conflicts

Most tasks and responsibilities of managing and controlling requirements are targeted toward identifying errors and deficits. While this is an ongoing task in Requirements Management, the control effort must be (preliminarily) completed before the project moves

into the implementation phase. Unresolved errors and conflicts must 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). What happens when errors and deficits are identified? There are 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 of deficits. In this case, conflict management is the key responsibility of any project manager involved in requirements management.

This is true not only for managing adjustments of requirements but is an ongoing responsibility throughout the project. Conflict management is a critical aspect of requirements management and the related skills are core elements of any requirements manager's skillset. This mainly comprises four stages, as shown in the following table.

Table 12: Process of Conflict Resolution in Requirements Management

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 control and to avoid ongoing discussions in later stages

Source: Author (2023), based on Malik et al. (2022).

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). The following are the most common types of conflict:

- conflict of interest: This is 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 of conflicting interests can be short-term versus long-term solutions between the owner and the chief executive officer (CEO) of a client.
- functional conflict: Another highly typical conflict emerges in disagreements about the functions of the system. While one stakeholder might argue for additional functionality, another might doubt the feasibility of this function.
- relational conflict: Conflicts between individuals are more difficult to identify and solve, as they are usually expressed in functional arguments. When individuals express overly strong reservations toward the arguments of other individuals, these reservations, while directed at a functional aspect, may actually be targeted toward the particular

individual. Many requirements professionals make the mistake of trying to resolve the problem on a functional basis, while the functional discussion may be a cover for the inter-personal conflict.
- structural conflict: Like 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: Value conflicts may emerge, especially in culturally diverse global corporations. These can manifest themselves between individuals who value following rules and instructions and individuals who value effectiveness and efficiency.

Conflicts often 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 several basic techniques you should be aware of. The International Requirements Engineering Board (IREB) insists on these techniques in their curriculum for RE/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. These techniques should be applied based on rational judgment considering the current practical situation and local factors, especially corporate culture.

Table 13: Basic Conflict-Resolution Techniques

Technique	Mechanism
Settlement	Conflicting stakeholders negotiate a resolution • Formal discussion on different available options • Accelerated through strong moderation skills
Compromise	Conflicting stakeholders develop new alternatives • 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	Decisions 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 1. All obvious factors are gathered and prioritized 2. Impacts of each option is analyzed 3. Decision is made via different forms of trivial calculation

Technique	Mechanism
Decision matrix	Conflict resolution through more complex calculation 1. Criteria that influence the decision are defined 2. Criteria can be valued based on importance or impact 3. Both numbers are calculated for each available option 4. The solution with the highest score is chosen

Source: Author (2023), based on Glinz et al. (2022).

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 an 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. To safeguard this level of accessibility, requirements managers must

- administer requirements attributes,
- prioritize requirements, and
- administer versions of requirements documents.

Further tasks are often summed up under the label “requirements administration” and include tasks such as implementation management or modification management.

Administration of Requirements Attributes

Besides specified requirements, any requirement can 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 be squeezed into the specification of the requirement, which otherwise would be part of the requirement.

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

- identification: 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.

Prioritization of Requirements

Prioritizing requirements has a tremendous influence on the success and failure of any project. It is rare that all requirements are implemented as specified in the early stages of a project. The more complex a project, the more likely the project is to experience situations in which managers 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 RE, you can hardly expect everything to go as. 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 by their importance to the project. It is key to Requirements management to understand the criteria, based on which requirements are prioritized. There are usually four steps in the prioritization process:

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?
2. Set criteria on which requirements will be prioritized: Depending on goals, different criteria apply. These can be the costs and risks of implementation, the impact of implementation/non-implementation, and the required time for implementation.
3. Identify stakeholders 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 chief financial officer (CFO).
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 what is easiest.

Approaches to prioritizing requirements

When prioritizing requirements, you can choose different approaches that mainly vary in the degree of complexity and effort. The low-effort approaches can be separated into spontaneous and analytic approaches.

Table 14: Spontaneous Prioritization Techniques

Spontaneous techniques	
Ranking	1. Appoint stakeholders to take over prioritization 2. Let them rank requirements based of their judgment
Top-ten	1. Define a number of top-n requirements (often 10/50/100) 2. Choose requirements important enough to fit into the top ranking 3. Rank these top requirements from 1-10/50/100/n
One criterion	1. 1. 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
Prioritization matrix	1. 1. 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) 2. Give points 1–10 to each requirement in each category 3. Create another column for each category and calculate the relative value in percent (relative compared to the rest of the column) 4. Consolidate in a priority column (value should be between 0 and 1) 5. Rank accordingly from 1-n based on priority column

Source: Author (2023).

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.

Versioning of Requirements

It may have become clear by this point that a large part of requirements management deals with changing requirements after the requirements specification sheet (and other requirements documents) is approved. 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 ensure that everyone 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 are closely related to each other, they cannot easily be changed without considering the effect of the modification on the entire configuration. It is, therefore, important to recognize that any requirement is only allowed to appear once in any 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) must 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 and must be as follows:

- 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, requirement baselines consolidate requirements not only based on their technical relation with each other but also based on what must be delivered toward reaching a certain milestone, sprint, or release in the project.

3.3 Risk Management

Most activities related to the mitigation of project risks are usually outside the scope of requirements management. In most cases, this excludes risks stemming from the system itself. Requirement risks are inherent to requirements regarding potential harm on multiple levels (Famuyide, 2017):

- 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 requirements 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 must be assessed and mitigated properly.

Requirements Assessment

The requirements risk assessment process usually works in four steps, as explained hereafter.

Step 1

Develop a requirement baseline with stakeholders. Requirement risks management is a continuous task; however, it makes sense to start with a risk workshop at the beginning of the project. It should take place 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 would happen if the provided assumptions failed to occur as expected. Assumptions can refer to specific behaviors of people, related systems, or elements in the corporate environment. Ask what would happen if these behaviors changed.

Step 3

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

Step 4

Build classes based on your own judgment. It is often recommended to classify risks such as risks that must be eliminated, risks that must be watched, and risks that can be neglected. Set thresholds for each class, for example, 1–3: neglectable, 4–6: watchlist, and 7–10: elimination.

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

Risk Mitigation

In principle – and irrespective of domain, risk type, etc. – risks can be countered with three approaches: Risks can be eliminated through appropriate measures, for example, by repatriating risks of international projects associated with language; risks can be accepted and priced in, for example, by quantifying/qualifying the risks arising from language barriers and recognizing that even if the risk event occurs, the benefits of international positioning outweigh the risks; and risks can be mitigated through appropriate measures.

We will elaborate on the third approach. 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 (including current developments). Active risk mitigation is based on a few principles (Famuyide, 2017). These may 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 that impact the risk level of certain requirements may have happened without your notice, but may be very present to others.

Principle 3

Maintain a risk log. Document requirements in a requirement 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 about new developments. If maintained with care and vigilance, most risks associated with requirements can be effectively kept under control.

3.4 Implementation Management

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 implement the requirements and monitor it throughout the project life cycle is part of this responsibility. The logical question at this point is “Why is this necessary? After all, requirements were defined so the implementation process can be managed alongside very specific instructions about what the client requires in their system.” While this statement is generally true, the project organization constitutes a self-organizing social system that tends 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 it is coherent, requirements managers must focus on the requirements and trace them through the entire project life cycle. The goal is to keep the project team on track and not spend too much time on features that might make sense for the system in general but that are not specified as requirements (Pohl, 2010).

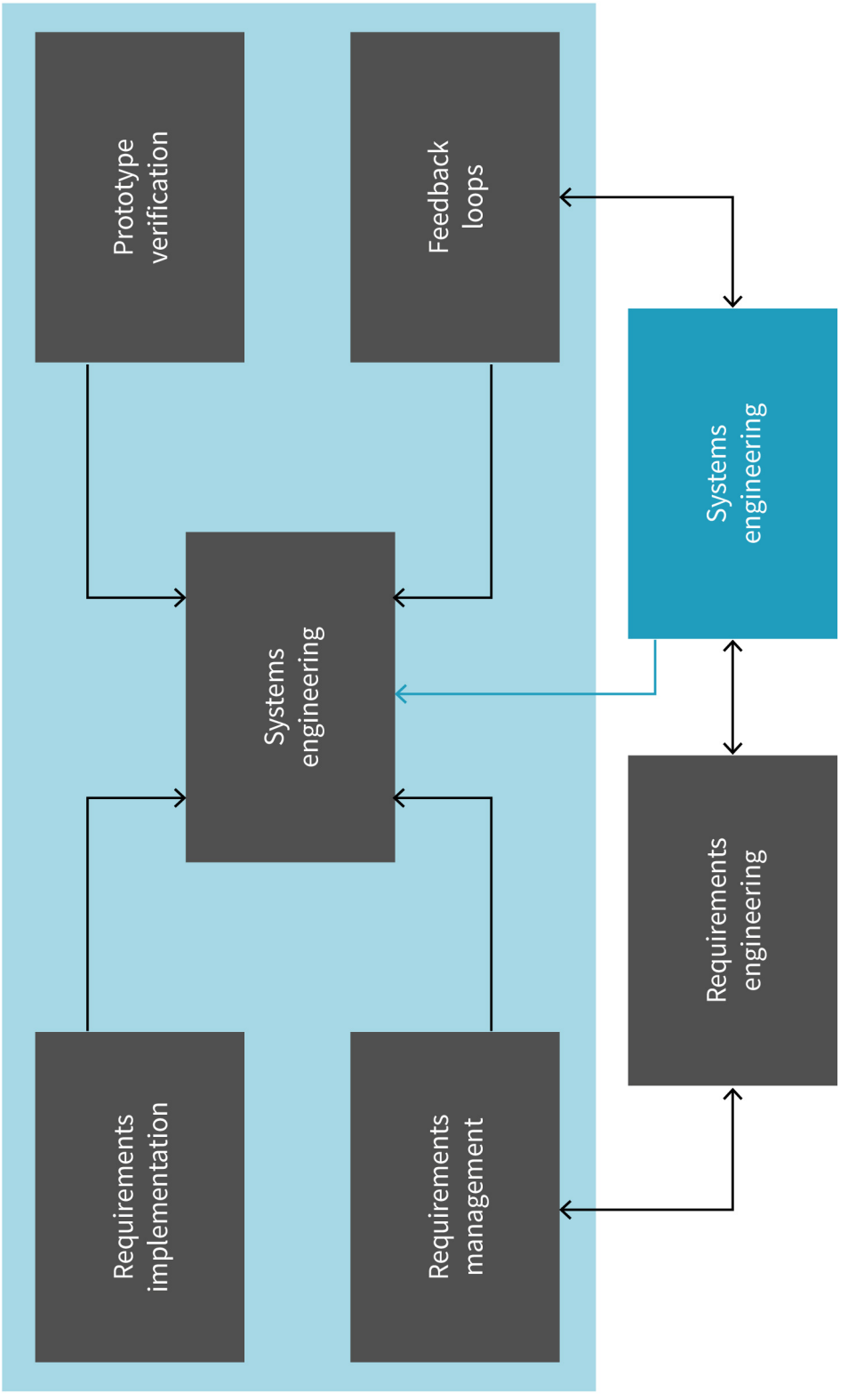
Furthermore, the reality of project implementation is that it is made up of constant changes and developments in the client's business environment, the client's organization, and, consequently, in the project. The requirements were defined for a reality that might have been accurate at the time of the RE process, and most of the aspects of this reality will remain stable; however, in most projects, changes will occur. In cases where changes seem to force the project managers to adjust the planned implementation, requirements managers must ensure the accommodation of all previously defined requirements. This may seem a bit inflexible, but requirements are usually legally binding features of the system that cannot be changed verbally. While requirements can be adjusted to new realities, if 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 the 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.

The Requirements Implementation Model

To understand the challenges and pitfalls of requirements implementation, we must clarify a few elements that are necessary for a solid implementation process. Jäälinoja and Oivo (2004) holistically formalized these elements in a reference model.

Figure 11: An Integrated Reference Model for Requirements Implementation Management



Source: Author (2023), based on Jäälinoja & Oivo (2004).

The model shows the central elements of successful implementation management: effective systems engineering, a high level of reconciliation in requirements implementation, and prototype verification, including an effective review process, all managed by comprehensive requirements management.

Systems Engineering

Systems engineering is the function that is responsible for the conceptual development of a system and also provides support for the entire life cycle from a design perspective. Systems engineering performs the design and architecture, development, testing, and customization of the system architecture. The model puts systems engineering in the center of its activities. After all, from a project management perspective, even the most holistic view of 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 **systems 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 (2004) model refers to the specific domain of software development in this context.

Systems architecture
This is the model-based task in developing a system based on experience, expertise, and requirements. From a requirements perspective, systems architecture is the point of contact for implementation.

Requirements Implementation

Requirements implementation is the process of transforming requirements into actual artifacts of the system. These artifacts can be

- code in IT projects,
- tangible elements of a technical system (e.g., power plant, building), or
- intangible elements of a system (e.g., a prescribed maintenance process).

Requirements management delivers the system characteristics that are necessary from the customer's perspective, while systems engineering transforms them into the above stated artifacts. All changes in requirements are therefore directed toward systems engineering and never the technicians who implement the system from a practical standpoint. Despite systems engineering being in control of system architecture-related matters, requirements managers have the responsibility to insist on their perspective, while systems engineers have the duty to fulfill the requirements as provided by requirements management.

Work-Product Verification

Inconsistencies between the programmer's work and the requirements may occur (Jäälinoja & Oivo, 2004), especially in software development projects. With reference to the management and 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), which are then evaluated for their compliance with the requirements. There are different methods available that help verify the extent to which a system fulfills the requirements. 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, p. 1). Although designed for early software development, ATAM is applied in various industries and recommended for simple and effective practical use.

Feedback Loops to Systems Engineering and the Requirements Engineering Phases

Even in complex projects, feedback loops to the initial RE phases are critical. Jäälinoja and Oivo (2004) posit that “successful requirements development requires a constant flow of information from the actual developers […] to the requirements analysts” (p. 3). This feedback loop is two-directional: Requirements management must provide feedback to systems engineering, which must provide feedback to requirements management. Even in later stages, requirements management must go back to the engineering phases and adjust, if agreed upon by the steering committee.

This interaction must happen both formally and informally. On an informal level, project managers, system engineers, and ground-level technicians must regularly communicate with the requirements manager. Requirements managers themselves must 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.

3.5 Modification Management

Requirements change over time and there are numerous occurrences that might trigger these changes. This section will familiarize you with the practical challenges and most common procedures of this requirements management task. Here, we should point out the distinction between changes and transformation, which has been implied several times. We want to understand change as the transformation in the project and business environment, a passive process that project managers can address both proactively and reactively. By changing expected conditions that were assumed to be stable during requirements elicitation, changes can have a massive impact on project and requirements management. When changes directly impact the project in this way, changes are necessary. We, therefore, want to understand changes as changes to requirements, which are accordingly the subject of change management in the requirements context. It should be added to this that changes are not fundamentally a function of changes, but can have different causes within the project or the customer company.

Tasks of Modification Management

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

- collection of changes: Requirements managers are the single point of contact for all **change requests**; while communication usually starts with the project team, the formal process starts with issuing a change request to the requirements manager.
- documentation according to right format: Today, it is common to manage requirements in an integrated IT system, which allow for prescribed formats that must be followed by the proposer. If information is missing, the requirements manager must 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 must 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 receive notice of the change; thus, to avoid different statuses project work streams, requirements managers must ensure that everyone whose work might be affected by the change proceeds with their work accordingly.

Change requests
A formal request for the approval of the change of a previously agreed-upon characteristic in a project.

This is just a summary based on personal experience. The three main challenges of modification management are (1) communicating 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.

Dealing With the Change Control Board

Changes in requirements are a delicate topic. Requirements specification sheets are legally binding documents and both parties generally must stick with implementing the project as agreed. Changes can cause issues, such as budget expansions and further changes in functionality, which can only be decided at a high level. Therefore, projects 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 up of change managers, product managers, systems architects, configuration managers, quality assurance managers, or stakeholders who fit into this line of representatives. There are several responsibilities that change control boards have, and they can be listed as follows (Strens & Sugden, 1996):

1. Expense analysis: The board must assess expenses and the effort required of a change that was handed in from within the project.
2. Assessment of requests: The board must evaluate and assess all change requests based on criteria relevant to the client (and the contractor); for example, the benefit of changing one requirement that would necessarily lead to the cancellation of other requirements.

3. Approval/denial of requests: The board decides upon the approval or denial of change requests.
4. Prioritization of requests: If multiple change requests are approved at approximately the same time, their implementation must be prioritized. In case they cannot be implemented at the same time or if 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, they are often structurally connected (i.e., through membership of the requirements manager). Being a member of the change control board might seem like an ideal position for the requirements manager, as it puts a lot of responsibility and power into their hands. Once again, the suitability of this must be assessed on a case-by-case basis.

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, as shown in the table below.

Table 15: Three Types of Changes in Classification of Change Requests

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

Source: Author (2023), 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 itself, a decision on approval or denial, and, if approved, prioritization 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 change control board has the main responsibility for changes; however, the board must be guided by the requirements manager in terms of complete and transparent information as well as guidance in the change process.

SUMMARY

There are two types of requirements management responsibilities: ongoing and sequential tasks. In this unit, we have elaborated on the ongoing tasks involved in requirements management that you will face. Management and control of requirements safeguard the quality of requirements and requirements documents throughout the project life cycle. The three elements that require control are the requirement's content, documentation, and the resolution of conflicts. These tasks can be performed with third-party statements, walkthroughs, inspections, perspective analysis, prototypes, or checklists. An important challenge is conflict resolution.

Requirements administration refers to administrative tasks throughout the project process. Requirements must be prioritized based on agreed-upon criteria and versions must be managed to ensure that all employees are always working with the latest version.

Mitigating 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 requirements. Furthermore, requirements may depend on certain behaviors of users; these behaviors may be related to systems that are part of the technical configuration in the moment, but that may change over time.

Managing changes is another challenge of requirements management. A variety of internal and external causes can lead to necessary changes even after the requirements specification has been approved. Here, a clear process must be followed that proposed changes go through until they are approved. Fundamentally, requirements management is responsible for guiding change requests through this process. However, at the end of the process, it is the change control board that decides on each request and does so based on the information provided by requirements management.

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.

UNIT 4

METHODS AND QUALITY OF REQUIREMENTS MANAGEMENT

STUDY GOALS

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

- understand the sequential tasks of requirements management.
- know the importance and application of project scoping in the context of requirements management.
- understand the basics of requirements modeling, the conceptual idea of modeling languages and their use in requirements management.
- discuss and elaborate on quality criteria of requirements.
- know the latest developments of automation and artificial intelligence based on the idea of “requirements smells.”

4. METHODS AND QUALITY OF REQUIREMENTS MANAGEMENT

Introduction

Besides the ongoing tasks in requirements management, there are several 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; the specification of requirements, for example, must 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 the specification work is completed in the beginning and therefore part of a sequence.

4.1 Scoping

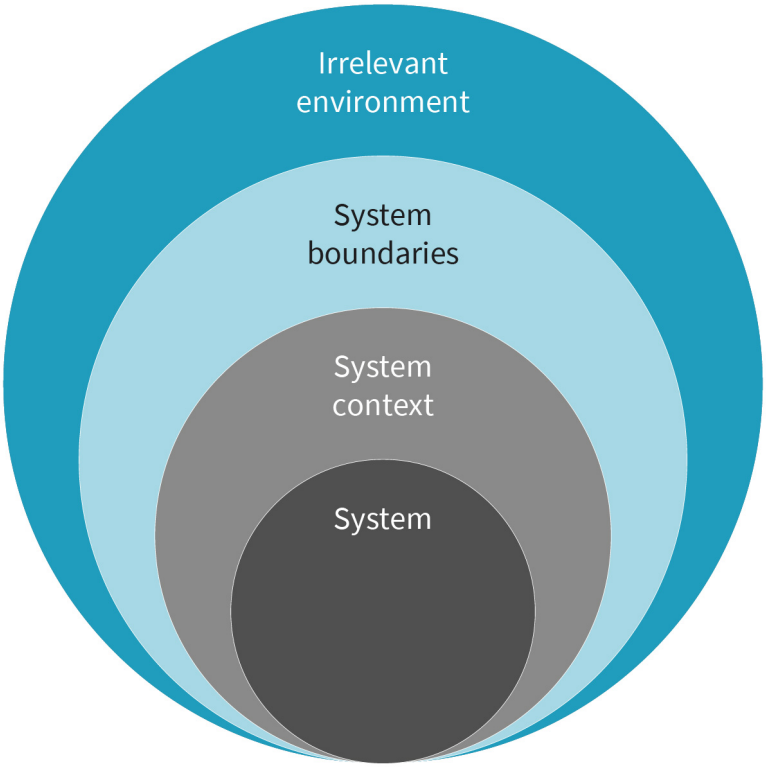
Project scope
This refers to the defined number of tasks to be fulfilled by a contractor to complete a project. Traditionally, the scope serves as basis for the organization of tasks in the project plan.

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 toward completing the project in a way that satisfies the requirements of the client, scoping is highly relevant for requirements management (Kelepouris et al., 2006).

Scoping System, Context, and Irrelevant Context

The main challenge of scoping is to separate what elements of the project are necessary from what are unnecessary (Haley et al., 2006). Scoping is often the first step in a project, and thereby becomes the foundation 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).

Figure 12: Main Elements of Scoping From a Requirements Management Perspective



Source: Author (2023), based on Haley et al. (2006).

To actively contribute to scoping from a requirements management perspective, these four elements must 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, as described in the following.

Definition of system

A system is defined as all elements that are supposed to be part of the system. These can be technical components as well as functions that these components are supposed to deliver to cooperators.

Definition of system context

Generally, 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 at the beginning, further requirements management efforts become more transparent. The fundamental elements are stakeholders, technical systems, technical documents, and 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 the required work, the system border clearly delineates 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 it is often built by other contractors, or it already exists in the plant. In this case, the boundary must be drawn between the conveyor and the plant.

Definition of context boundaries

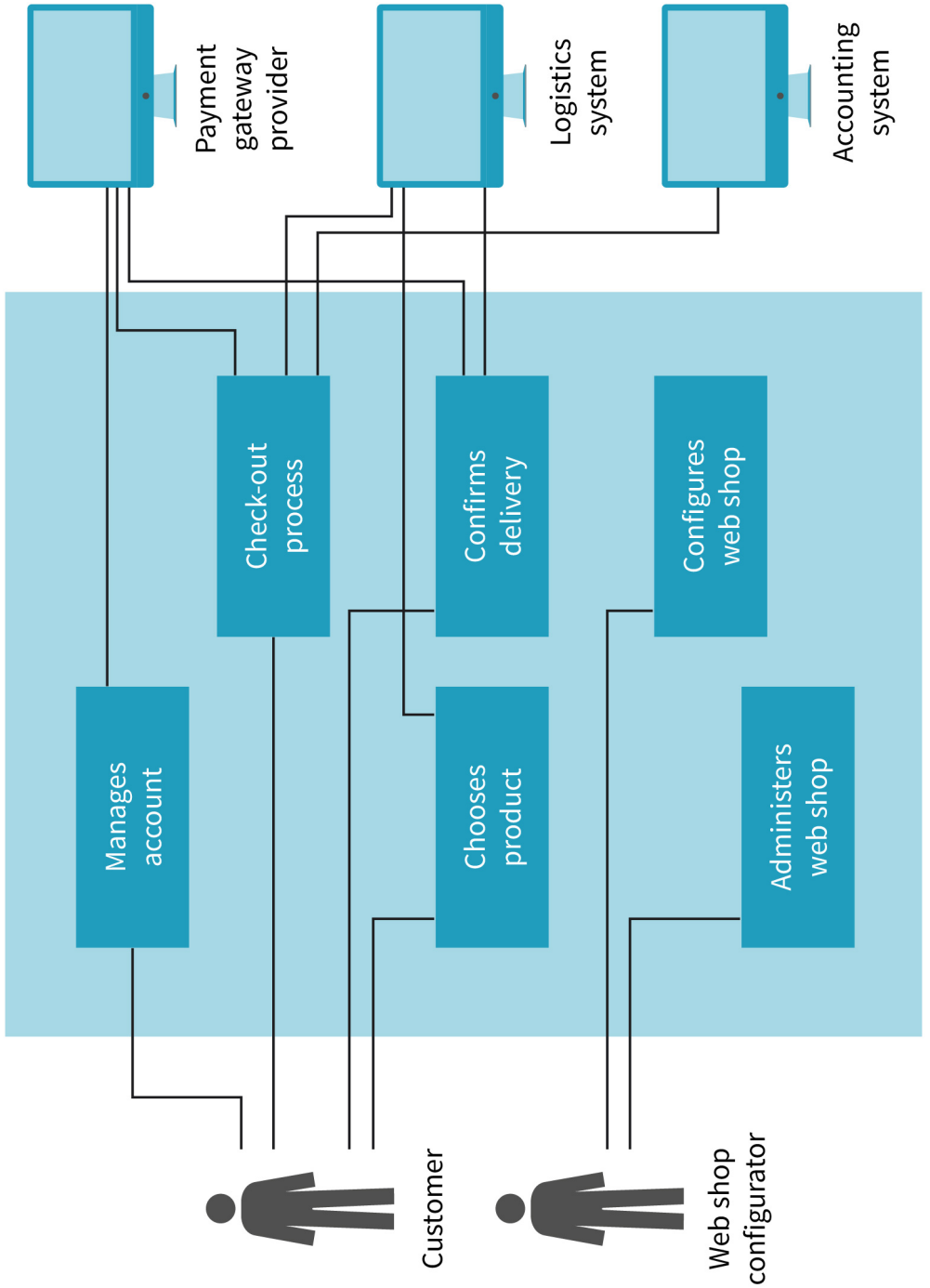
The context boundary separates the relevant environment from the irrelevant environment. The previously mentioned conveyor belt delivers raw material to the plant and is, therefore, part of the system environment. A control system that measures the efficiency of the entire company, including plant efficiency, might be on the inner side of the context boundary as well. A payroll system that transfers salaries to the employees who operate 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 the irrelevant environment are clearly defined and a mutual agreement between client and contractor has been reached, can the project move into the next phase.

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 the 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 for all stakeholders and delivers transparency toward further steps. Whenever complexity and confusion take 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 look at an example designed in UML. Here, a retail entrepreneur has tasked a project company with building a web shop to expand its business. This is what a simple scope might look like.

Figure 13: Example of the Scope of a Simple Web Shop in UML



Source: Author (2023).

In the rectangle, you can 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 are the information technology (IT) systems interacting with the system in the center. In the system itself (rounded shapes) you see functions the system must perform. And through the lines

you can see how the system interacts with the stakeholders and the IT systems in their relevant environments. As you can see, UML is not made to win design awards, but rather to find a unified language to graphically document systems clearly so that it is universally understood.

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 (RE), are performed and completed in the early stages of the project process. More analytical work is done in later stages of the project, as requirements documents are often more dynamic due to changes 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 must become familiar with three subjects:

1. Sources for requirements analysis
2. Category building
3. Techniques for analyzing requirements

We will explore these subjects throughout the section.

Sources for Requirements Analysis

To define all discussed types of requirements, the requirements manager must find the right sources 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 RE (Mahmoud & Carver, 2015). Requirements managers must actively investigate possible stakeholders and include them in the analytical process.

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

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 secure as much buy-in as possible, as users have significant influence in any change process.

Subject matter experts are essential to any larger company that has a limited number of highly experienced experts in a certain domain. There is no unified identifier, but usually, their status is well known within 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 often 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; the literature on process management requirements provide 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 must arrange a follow up meeting with the respective human source that referred them to the technical sources.

It is a common practice to use field surveys 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 must be carefully prepared, but they are usually successful at least to a medium degree. A second method that can be used to source knowledge of 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.

The concept of operation (or CONOPS) is a document that describes the way a system operates in 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 provide detailed descriptions 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 but by examining these manuals.

When you start a project for a client, there is always some sort of history to be examined. The regular way to get a project started is a business proposal. If you are looking at the purpose of the project and must investigate the details of why the previous solution was unsatisfactory, proposals are usually the first place you should look for answers.

Building Categories for Requirements

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

Stakeholders only implicitly understand requirements

Implicit knowledge
This refers to the knowledge that exists but cannot be activated on the spot. Implicit knowledge guides humans by serving as a fundament for all decisions.

What if stakeholders require a function but implicitly presume the function is available? This **implicit knowledge** might not be shared by the contractor. Imagine, when buying a new smartphone, would you specifically ask for Bluetooth functionality? Most younger people would not even think to ask. Still, if you bought a phone without asking for Bluetooth and it turned out that this function was missing, you would find this unacceptable.

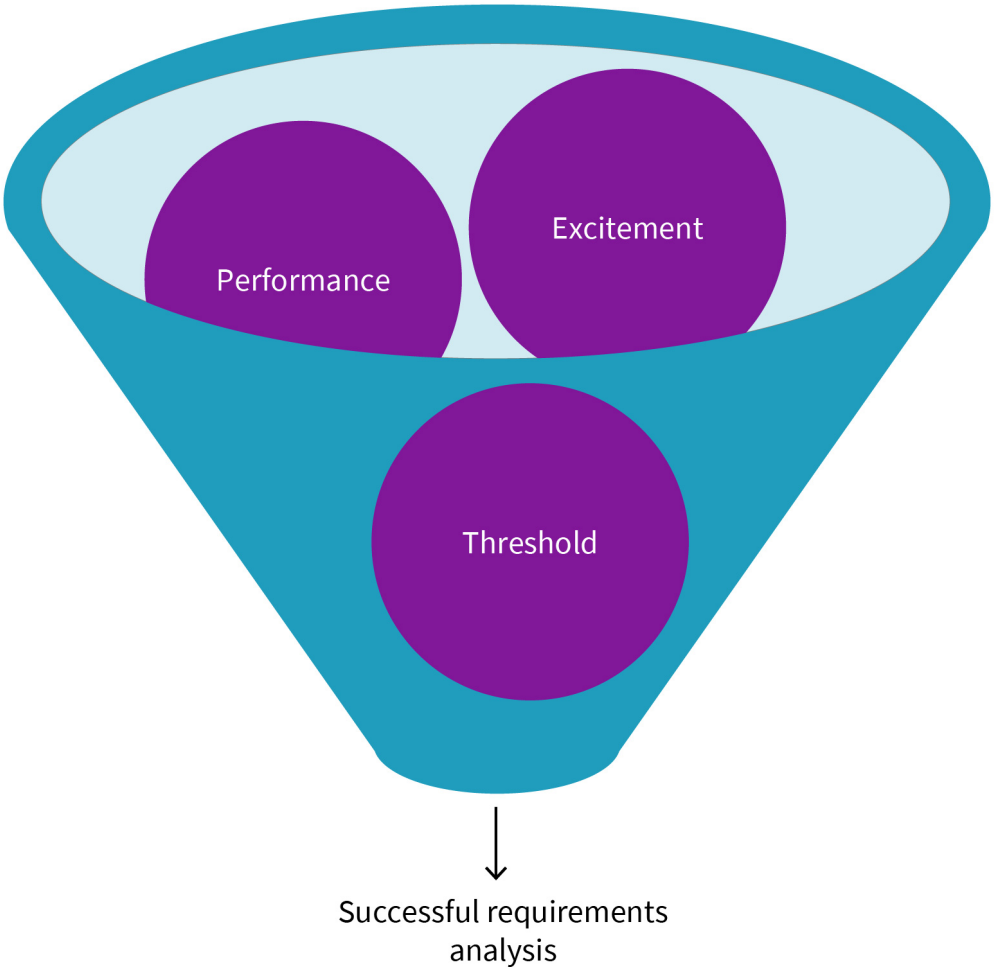
Stakeholders do not know about requirements

What if stakeholders lack expertise in certain subject matter, but if they possessed this knowledge, they would most certainly formulate very specific requirements based on this additional information. In our smartphone example, picture a built-in virtual private network (VPN) that allows customers to connect to the internet around the world to avoid tracking by advertisers, access cheaper regional subscription plans for streaming services, etc. If more customers knew about tracking by advertiser and this option to avoid it (that is, not 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 must be aware that they cannot expect stakeholders to activate implicit knowledge and formulate requirements for something they lack knowledge of. It is the requirements manager's duty to support the stakeholders in a way that enables a manifestation of implicit and unknown requirements.

Therefore, before entering an interview in the context of requirements analysis, requirements managers must be aware of three categories of requirements. One of the most widely applied models in requirements analysis is the Kano model (Madzík, 2018). This model distinguishes between threshold attributes, performance attributes, and excitement attributes.

Figure 14: Classification of Attributes Based on the Kano Model



Source: Author (2023), based on Madzík et al. (2019).

Threshold attributes (must-be)

Threshold attributes are characteristics that refer to implicit knowledge of requirements on the part of the stakeholders. These must-be requirements "should be met automatically but meeting only these requirements does not lead to satisfaction of the customer" (Madzík et al., 2019, p. 390). Stakeholders might be too deeply involved in specifics, such that they are unable to access knowledge of requirements that are self-evident to them. If they are not met, however, contractors cannot refer to the documentation from 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.

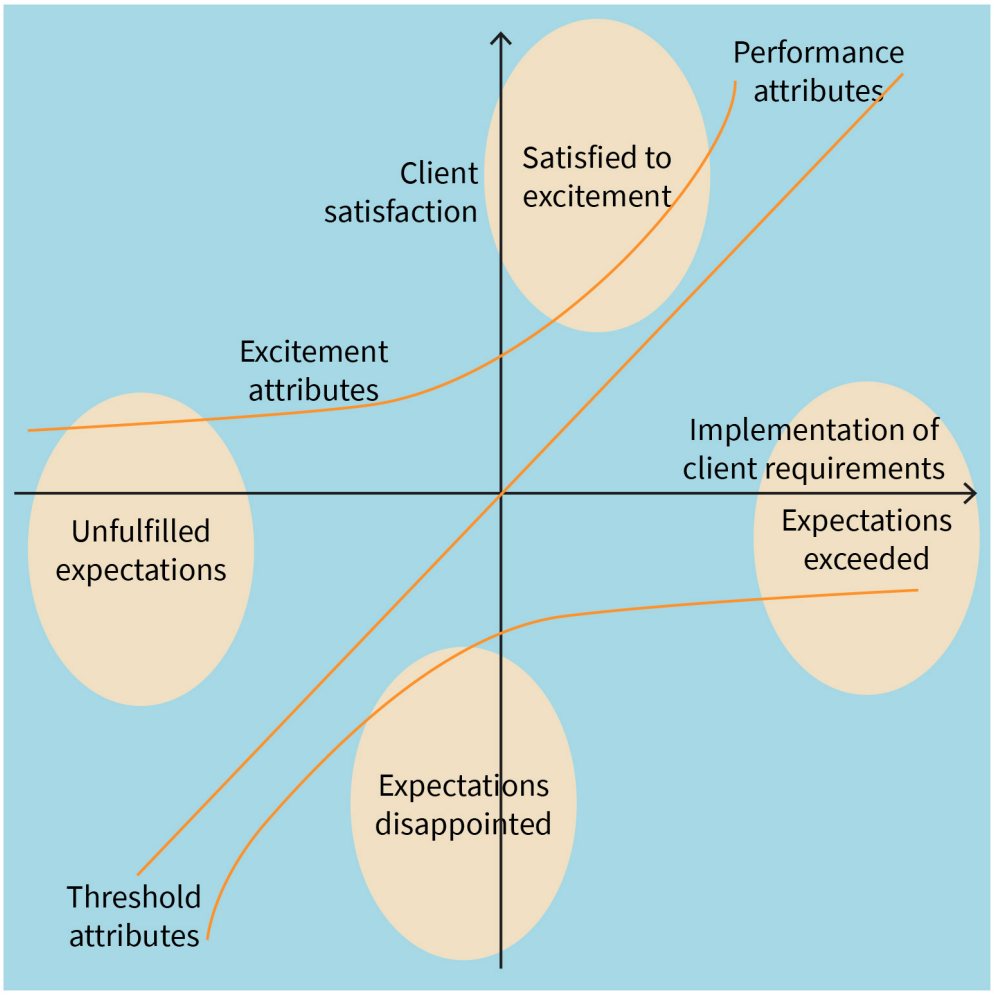
Excitement attributes (attractive)

Excitement attributes are 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 Madzík et al.'s (2019) representation, experience has shown that this type of requirement goes beyond extra features that generate enthusiasm and satisfaction. When contracting for a project, there is always an implicit expectation of hiring subject matter expertise. This includes coming up with solutions, which at least include 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; in contrast, failing to meet them will lead to increased dissatisfaction.

Figure 15: The Kano Model for Client Satisfaction



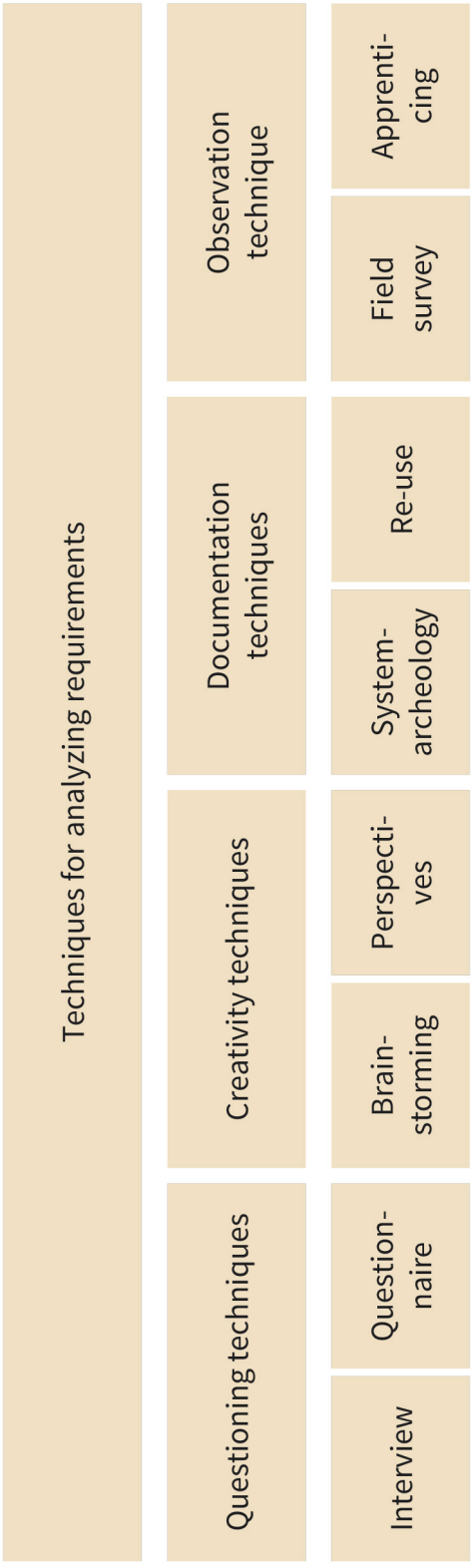
Source: Author (2023), based on Madzík et al. (2019).

The model shows how the different categories of requirements increases satisfaction, once implemented. To avoid disappointment, threshold attributes and performance attributes need primary attention. Excitement factors can contribute to raising the level of satisfaction. Experience has shown that clients tend to approach contractors with the expectation of contributing subject matter expertise – so be mindful not to disregard 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 for approaching requirements analysis.

Techniques for Analyzing Requirements

In the previous subsection, we have indicated that the stakeholder interview by the requirements manager is a primary method for requirements analysis. While this is not incorrect, the interview is only one of several techniques to analyze requirements.

Figure 16: Summary of Techniques Provided by the International Requirements Engineering Board



Source: Author (2023), based on Glinz et al. (2022).

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

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 of uncovering blind spots increases. As always in meetings, however, too many people actively contributing can harm the effectiveness of the analysis.

An advantage of interviews is that 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 of interviews are that, in case there are a greater number of stakeholders involved, interviewing any of them might be time consuming. Furthermore, success depends on the expertise and social skills of the individual interviewer.

Questionnaire

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

Questionnaires work if a large number of stakeholders must 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 having the time and chance to consider or discuss with colleagues. However, questionnaires only deliver explicit requirements and there is little chance that unknown or implicit knowledge can be activated. Furthermore, the designers of the questionnaire must be very precise in their questions. Typically, 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.

An advantage of brainstorming is that it 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. On the contrary, 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. Persona-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. However, experience has shown increasing resistance to isolated subject matter expertise. Some degree of openness is required in this analytical technique.

System archeology

We now move on to the documentation techniques. The object of the analytical process is 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 for the new system, as well. This can lead to a very complete set of requirements, which includes implicit requirements. Stakeholders might be used to a function that does not seem worth mentioning – system archeology will uncover these functions one by one. Furthermore, this technique helps the requirements manager understand the big picture, including the reasons why a new system is necessary. However, system archeology can be tough and exhausting for the requirements manager. To avoid a copy/paste approach, the documents must 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.

Reuse

Reusing 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, for example, different communities might not have vastly different requirements. Requirements are usually saved and archived by contractors to be reused in similar projects (Kluge & Schlör, 2016). If carefully applied, storing and reusing requirements can simplify the analytical process. This can accelerate the process and usually leads to more complete requirements. However, reuse bears the risk of implementing faulty or insufficient requirements. Each project is different to some degree; determining this 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 may take weeks or months and may require larger teams to visit and analyze the sites where the system will have some relevance. 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. On the contrary, humans regularly give

their best when they are under some sort of observation; however, this can distort the insights of the requirements manager. Furthermore, in case of a complete "revolutionary" approach of the new system, insights from the old system have limited usefulness.

Apprenticing

A slightly unconventional approach, but nevertheless one recommended by the IREB, is the apprenticeship (Glinz et al., 2022; Kluge & Schlör, 2016). Requirements managers actively participate in the role of different stakeholders to experience their biggest system-related challenges. This technique has the same benefits as field surveys. However, it delivers more insights into implicit and unknown requirements, as the technique allows requirements managers to develop their own ideas how to improve the system. On the contrary, this technique 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 in the daily operations of systems, this technique should be avoided.

Choosing 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; thus, 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 of factors requirements managers usually consider when choosing an analytical technique for requirements analysis.

Table 16: Elements to Consider When Choosing Analytical Tools

Type of knowledge	Supporting question
Explicit/implicit	What kind of requirements do you want to analyze? Implicit requirements need different tools than explicit ones.
Functional/nonfunctional	Is the current part of the analysis targeted at functional or nonfunctional requirements?
Level of detail	Is the analysis in the early stages and are high-level insights sufficient? Or must you go deeper?
Personal experience	Is the requirements manager experienced in more subtle 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?

Source: Author (2023).

This list is a great starting point for consideration; however, it is by no means conclusive. When becoming involved in requirements management, try to avoid pushing 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, it is recommended that a structured application be followed.

4.3 Requirements Modeling and Review

During requirements analysis, requirements are gathered as ideas. 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 must be drafted in a way that they are easily comprehensible by everyone involved in the project. Writing a list with sentences that describe the requirements seems like an obvious idea – and this is always part of the process. Sentences, however, can quickly become ambiguous and hard to understand for the reader, particularly when it comes to more complex requirements and their relations to each other. This is why the discipline of requirements management has incorporated the concept of models (Glinz et al., 2022).

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) does not yet exist; only the requirements for the system are already in existence. Requirements models bring order into the chaos of singular requirements and display more with fewer words than written sentences could.

Requirements management usually applies graphical models that are designed to represent the sum of all requirements in a defined scope (Glinz et al., 2022). These graphical models are based on modeling languages (e.g., the unified modeling language). Modeling languages are graphic systems that 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 in which elements interact with each other (interfaces, operation, etc.) or how elements are grouped (system, team, etc.) are restricted by the defined modeling language (Kluge & Schlör, 2016).

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 customers and operators. Instead, both are illustrated as a person, who is then labeled as customer or operator within the text. Furthermore, it must be stated that requirements should always be documented with both natural language and models.

Modeling languages are easy to learn and, once learned, 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 subsection, we will introduce you to the modeling of the most typically modeled elements in requirements documents: goals and use cases.

Model-Based Documentation of Goals

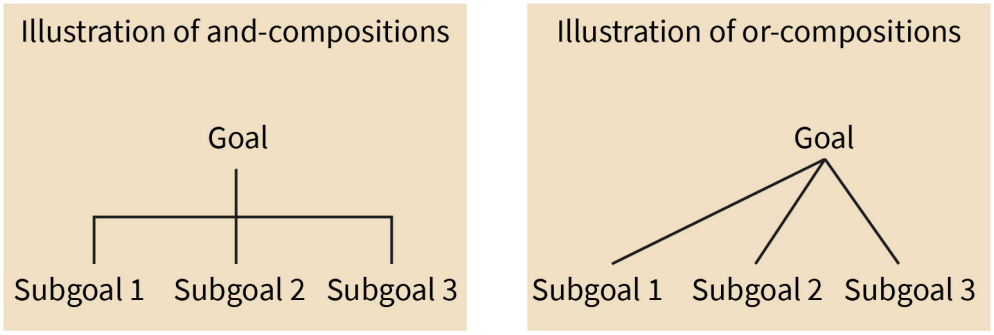
Goals are an essential aspect of requirements documentation. Even in low-complexity projects, individual requirements can be difficult to interpret without an understanding of a clear goal. It is, therefore, an essential element of any requirements analysis to collect and document all goals that relate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

Goals are usually composed of a set of sub-goals; and the breakdown of goals into sub-goals is a composition (Glinz et al., 2022). In requirements management, there are specific ways to graphically illustrate goals and sub-goals. The most common distinction is made between and-compositions and or-compositions, as follows:

- and-composition: goals that are reached by a complete combination of sub-goals
- or-composition: goals that are reached by at least one of the different sub-goals

As evidenced above, 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.

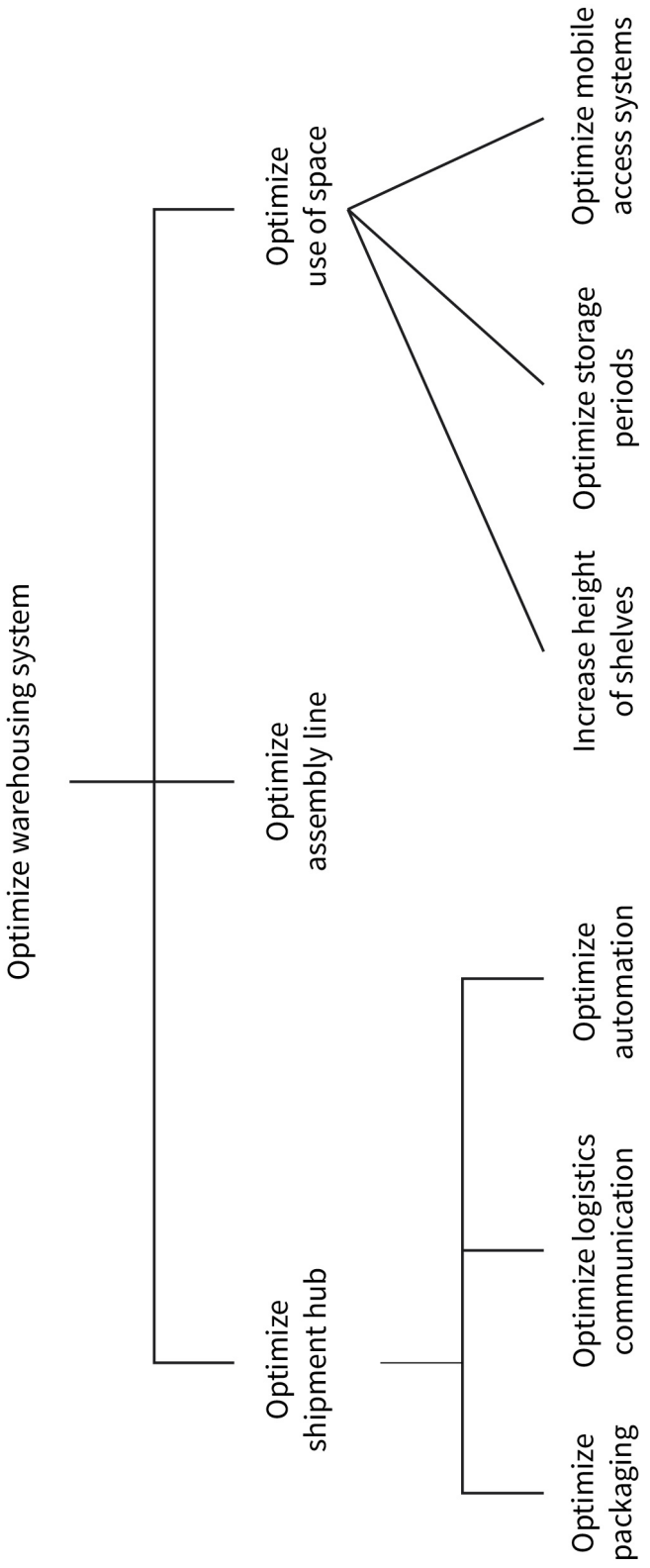
Figure 17: UML-Based Illustration of And-/Or-Compositions



Source: Author (2023), based on Kluge & Schlör (2016).

The decomposition of goals is usually more complex. In the context of this hierarchy, documentation of the goals in the context of requirements analysis creates an interface between requirements and higher levels in the hierarchy, for example, business needs or business goals. Let's illustrate this with a more practical example.

Figure 18: Example of the UML-Based Graphic Illustration of Goals



Source: Author (2023).

The example refers to a hypothetical project of a company that aims to optimize their warehouse operations (business goal). Of the 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 sub-goals – 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 the goal's sub-goals (indicated by skewed lines).

Model-Based Documentation of Use Cases

The second most typical situation for 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 illustrates the real-life purposes of a system.

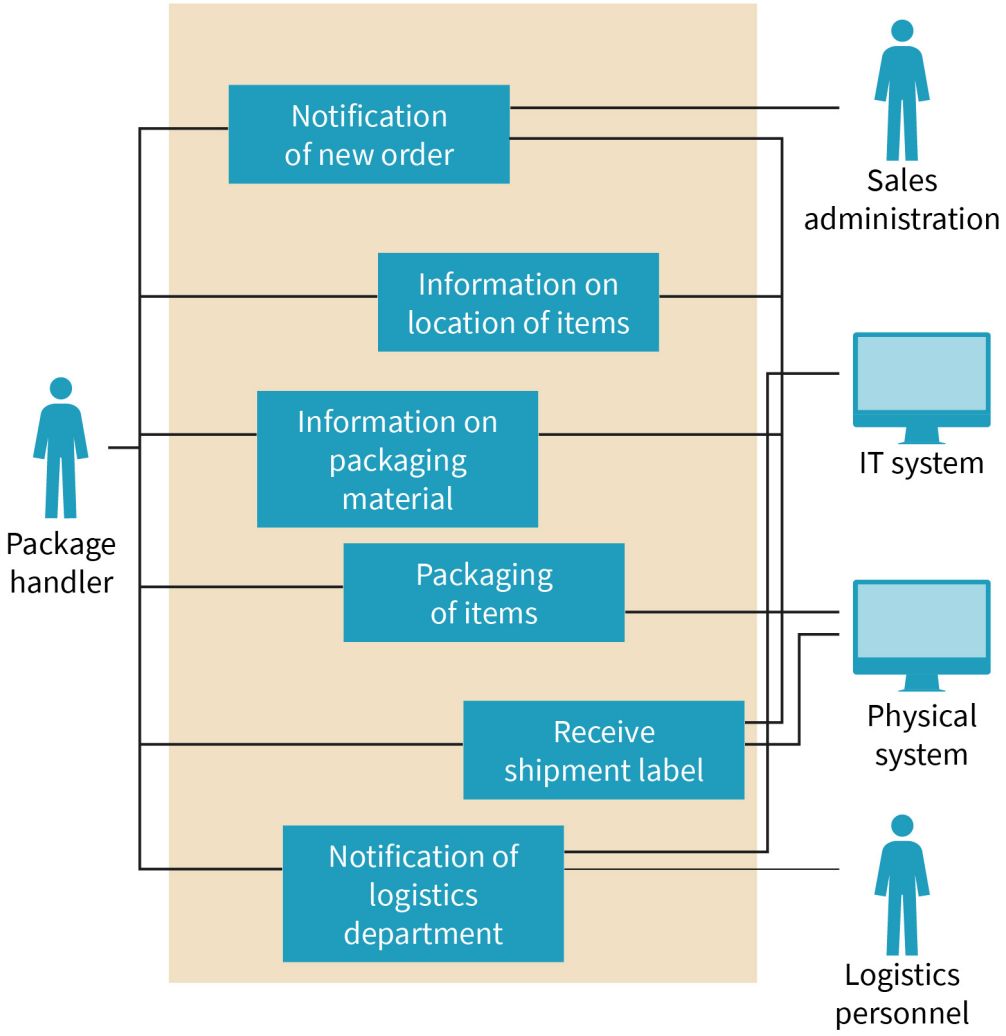
Keep in mind, that no client really wants a new warehousing system – what the client (of our previous example) really wants, for example, is a faster way to package goods (optimized packaging). This business need can be satisfied by a warehousing system that delivers more efficient ways of achieving 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 must connect requirements to specific use cases. In some cases, for example with quality requirements, this is hardly 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, p. 51). It unambiguously documents how the system is required to operate. Furthermore, use case diagrams make it easy to connect different use cases with one another. This can deliver insights into the interactions of different parts of the system.

Figure 19: Generic Use-Case Diagram for the Example of Packaging in Warehouse Optimization



Source: Author (2023).

Keep in mind that use-case diagrams only deliver a picture of the static elements of a system. They are not well-suited for illustrating processes. Furthermore, requirements modeling has its limits when it comes to details.

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 how the requirement is specified is decisive.

In this section, we will elaborate on the different quality criteria for individual requirements, as shown in the figure below. 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.

Figure 20: Quality Criteria for the Specification of Individual Requirements

Source: Author (2023), based on Glinz et al. (2022); Kluge & Schlör (2016); & Rupp (2014).

Feasibility

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

Table 17: Feasibility of Requirements

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

Source: Author (2023).

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 in the specification.

Independence

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

Table 18: Independence of Requirements

Dependent specification	Independent specification
REQ1 The operational reporting of the system must include item 1 – n. REQ2 It must be made available in English and French languages.	REQ1 The operational reporting of the system must include item 1 – n. REQ2 The operational reporting must be made available in English and French languages.

Source: Author (2023), based on IBM (2008).

Even though this makes sense with both requirements combined, both requirements independent from each other are no longer comprehensible.

Consistency

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

Table 19: Consistency of Requirements

Inconsistent specification	Consistent specification
Requirement 1: The operator shall be allowed to remain at the workplace throughout the entire shift. Requirement 2: The operator must hand in the printed report at the production manager's office twice a day.	Requirement 1: The operator shall be allowed to remain at the workplace throughout the entire shift. Requirement 2: The operator transfers a digital copy of the report to the production manager's office twice a day.

Source: Author (2023), based on IBM (2008).

Technically, this is a change in the requirement, not the specification; these cases, however, must 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 stakeholders' requirements. Thus, requirements may be added to the list that are not really required by anyone, and the system would not change its functionality if they were removed from the list.

Table 20: Necessity of Requirements

Unnecessary specification	Necessary specification
REQ1 The screen in the operator's cabin shall have mirror flip functionality.	-

Source: Author (2023), based on IBM (2008).

Once confirmed that no one desires 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 must by specified in a way that does not allow for more than one interpretation.

Table 21: Unambiguity of Requirements

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.

Source: Author (2023), based on IBM (2008).

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 just refers to the trigger. Furthermore, the left-hand example remains unexplained if 65° refers to the Fahrenheit or Celsius scale.

Verifiability

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

Table 22: Verifiability of Requirements

Unverifiable specification	Verifiable specification
REQ1 The handrails on the maintenance walkway shall have a height that is safe for walking.	REQ1 The handrails on the maintenance walkway shall have a height of 1.2 meters.

Source: Author (2023), based on IBM (2008).

The righthand example specifies the height as safe. This could not be tested if implemented, however, as safe is a relative term. Safe has a different meaning when referring to high above the ground versus elevated by a few centimeters. Try to apply precise information that can be measured.

Simplicity

While novels – and even course books – can benefit from additional and seemingly random information, requirements do not. It is recommended that the essence of a requirement be written down using as few words as possible to get the meaning across.

Table 23: Simplicity of Requirements

Complicated specification	Simple specification
REQ1 Oftentimes, the code will be entered incorrectly 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 his or her identity.	REQ1 When the code is entered incorrectly three times; the security company shall call the landline phone and confirm the homeowner's presence in the building.

Source: Author (2023), based on IBM (2008).

Even though the righthand example is only slightly shorter than the lefthand example, the intention becomes clearer, and the specification is made with greater clarity.

Correctness

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

Table 24: Correctness of Requirements

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.

Source: Author (2023).

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

Understandability

To make all involved stakeholders understand all requirements, they must be specified in simple and correct language. The righthand example in table below uses less complicated terminology and allows for an understanding that is independent from one's educational and regional background.

Table 25: Understandability of Requirements

Hardly understandable specification	Understandable specification
REQ1 The machine's coating shall withstand thermal climaxing up to –60°C.	REQ1 The machine's coating must be certified for temperatures up to –60°C.

Source: Author (2023), based on IBM (2008).

Non-Redundancy

Two requirements frequently refer to the exact same functionality, even though they are formulated in very different ways. When confronted with a larger number of requirements (e.g., from questionnaire feedback) this is often overlooked. Redundancies in the specification must be eliminated to avoid assignment of the same tasks to different workstreams.

Table 26: Non-Redundancy of Requirements

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.

Source: Author (2023), based on IBM (2008).

Even though both requirements use different terms, they are referring to the same system interface. If unsure about the technicalities, requirements managers must evaluate the specifications with subject matter experts.

These criteria are to be considered while specifying requirements in natural language. While requirements control 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 extend to the complete overhaul of the specification sheet.

4.5 Identification of Requirements Smells

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; quality assurance of requirements especially has been taken to a new level. There are a multitude of reasons for this development (Femmer et al., 2016), some of which can be described as follows:

- Reading complicated requirements burdens everyone's resources.
- Practice has shown that complicated requirements are often ignored.
- 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. As described, individual requirements managers or controllers evaluate requirements one by one, implement their changes and either directly change requirements or return the document to the author. While this has proven effective, it is far from efficient. First, the manual review is lengthy and requires a high intensity of resources. Feedback loops take their time to manifest themselves in improved requirements. Furthermore, requirements managers who are not subject matter experts tend to focus their comments on formal aspects, yet 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.

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 that identify spelling errors, grammatical mistakes, interpunctuation, and even problematic sentences that 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), as shown in the following figure.

Figure 21: Problems that Allow for Automated Requirements Quality Assurance

Structural problems	Lexical problems	Grammatical problems	Semantic problems
These refer to the document (e.g., lack of compliance with prescribed structure).	These refer to problematic terms (e.g., imprecise terms, such as "improved" or better").	These refer to noncompliant grammar (e.g., passive sentences).	These refer to the content of requirements (e.g., incorrect requirments).

Source: Author (2023), based on Femmer et al. (2016).

None of these problems can be fully eradicated automatically. Semantic problems especially call for intense manual scrutiny. The concept of automated real-time support when specifying requirements would be served, nonetheless.

Requirements Smells

The idea of identifying 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 term is derived from a comparison with human olfactory organs. The “smell” of something is just an indicator of a smelling object – but it is not proof. According to Beer et al. (2017), “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” (p. 323). If a sentence contains an imprecise term, this could be an indicator of an imprecision. If a sentence is specified using passive grammar, this could be an indicator of the lack of an actor.

Again, much like autocorrect in Microsoft Word, requirement smells only indicate shortcomings in the requirement specifications. If a person’s 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 change the specification.

Automated Ways to Detect Requirement Smells

There are different technical ways to manifest the concept of automatically detecting requirement smells, as described hereafter.

Keywords

The simplest method is to create lists with keywords that should be avoided. This technique picks up on lexical problems in requirement specifications. It is theoretically possible to close holes in the net of insufficient terms to a certain degree. In practice, however, there is no guarantee that 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 the quality of requirements.

Requirements parsing

The automatic screening of formal shortcomings focuses on structural problems. For multiple reasons, requirements documents have a fixed structure that must be complied with. This is difficult to control, especially when using flexible software such as Microsoft Word. Requirements parsing tools can screen those documents based on compliance with a structure that must 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 requirement smells is NLP. The technology was mainly developed to analyze natural human language. With some tweaking, NLP can identify sentences, which may be correct in a linguistic sense, but that 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 2023, there is no tool available to unify all available technologies in one system. Even the individual systems themselves need some more development. The emergence of artificial intelligence technologies will certainly accelerate this development, and we are optimistic about seeing this concept established over the next years.

SUMMARY

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, scoping is decisive for requirements management, as the scope builds the foundation for the specification of the requirements. Here, the requirements manager must 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; and technical sources are field surveys, business proposals, concept of operation, procedure manuals, and proposals for new systems. The Kano model supports this process by differentiating between 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 specifications, whereas graphic models are applicable for high-level specifications. The most common graphic system is the Unified Modeling Language (UML).

Quality criteria can be met by manually evaluating the quality; however, this is time and resource consuming. There are new technological approaches to identify “requirement smells” that can help automatically identify shortcomings in the requirements.

UNIT 5

PROCESS AND INDUSTRY-SPECIFIC NEEDS OF REQUIREMENTS MANAGEMENT

STUDY GOALS

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

- understand the basic process of requirements management, shared by all fields and industries.
- describe specifics of project requirements of industries and fields.
- discuss how all fields and industries can benefit from insights into the specific conditions for requirements management.

5. PROCESS AND INDUSTRY-SPECIFIC NEEDS OF REQUIREMENTS MANAGEMENT

Introduction

Requirements management is relevant in all industries and sectors, from business to arts, from politics to the social sector. We will illustrate the necessity and specifics of different sectors in this unit. First, we will learn the very basic terms necessary for an understanding of the core message of this course book. Then we will demonstrate the differences based on four sectors and evaluate how all professionals can benefit from insights into the specifics of different sectors. In the following sections, we will introduce the commonalities and differences of some illustrative industries and sectors, as well as discuss the specific conditions regarding requirements.

5.1 Basic Process of Requirements Management

Regardless of the sector, most nontrivial projects share the need for a certain number of requirements-related tasks. Any system that is developed in a project is motivated by the various requirements of a client. For all sectors, the project manager or members of the project team need to ensure that the finished system fully complies with all implicit and explicit expectations. Implementing a conscious planning process for requirements management is the solution that is usually applied in successful projects across all industries.

The project manager, client, or any other responsible stakeholder will have specified the project's requirements; therefore, a planned process for the identification, assessment, tracking, documentation, implementation, and control of each requirement is usually applied. The relevance of a planned process can be ascribed to the need to ensure that each demand connected to the project and the project development process is tracked, captured, addressed, and analyzed. Furthermore, a planned process will prevent project team members from losing track of a requirement that has been established by the client, the contractor, and the stakeholders involved in the project. A planned process also resolves all the common reasons that can result in the failure of a project such as requirements risks, uncontrolled expansion of the project scope, loss of control over the budget, and delayed milestone delivery. The following will examine how to develop a basic planning process that is shared by all sectors and industries before we delve into the specifics of particular domains.

Basic Structure of Commonly Shared Requirements Planning Processes

The following steps are an abstraction from practical application. The steps are compiled to emphasize the need for special planning tasks in the requirements process, regardless of whether they are technical, digital, or social projects:

1. Specifying the project's purpose and scope
2. Involving and listening to all stakeholders of the client's organization
3. Establishing an accountability structure
4. Resolving requirements-related conflicts between stakeholders
5. Defining priorities of requirements
6. Setting up traceability standards
7. Monitoring, integrating, and administering requirements changes
8. Outlining and disseminating requirements to all relevant stakeholders
9. Choosing the right methods for requirements analysis and administration

We will go through these processes in more detail and elaborate on how they are generally necessary, independent of the project domain.

Specifying the project's purpose and scope

By definition, a project is a unique endeavor to perform a task in a limited period. In any domain, this endeavor needs to be defined in a project scope. The scope specifies all the project's deliverables, expenses, objectives, activities, and due dates, as well as everything the client hopes to accomplish through the project and all of its components (Haley et al., 2006).

Once defined, the scope is integrated into a project charter or project plan and is often the final piece before the approval process. Without the scope, the biggest threat is that project managers design and implement a system that goes beyond the limitations of the project. Project management, furthermore, will lack the knowledge needed to recognize all the changes that become project requirements.

Involving and listening to all stakeholders of the client's organization

The second domain-independent step is to identify and involve all relevant stakeholders in the requirements process. This way, project organizations ensure they do not leave out important functions and elements from the system and that they build connections for easy and rapid contact during the project process (Project Management Institute, 2016). Different domains have different styles of communication and organizational cultures. While the process of involving and purposefully activating stakeholders may vary, systematic involvement is key in any domain.

Establishing an accountability structure

The third domain-independent shared task of the basic planning process is to define responsibilities. Any project is a consolidated effort of multiple people to execute tasks that, when purposefully connected, resulting in the creation of the desired system. By

nature, a project is a shared effort with the aim of exploiting the division of labor. The creation of an accountability structure is an essential aspect, regardless of industry or sector. This structure attributes the requirements to phases and parties (individual managers, teams) and allows for holding them accountable for the work done (Larson & Larson, 2013). Additionally, project organizations of any domain need to ensure that the requirements process is accessible and transparent to anyone involved, as it outlines each person's responsibility in the project process.

Resolving requirements-related conflicts between stakeholders

Any project, no matter how professional, will experience some conflicting requirements that not all stakeholders will readily accept. Depending on the project context, the number of distinct managers, stakeholders, and people involved varies; and even though conflicts will increase in number, the more stakeholders are involved, the more difficult it will be for any project to avoid any kind of conflict. A strategist, for instance, might request a tool that can carry out a significant number of separate activities simultaneously, but the operating team might view most of these capabilities as unnecessary and unworkable (Kossmann, 2016). To get all stakeholders to agree on the system's features and resolve this requirements conflict, projects in any domain must include a solution in the requirements process plan. Consequently, getting all stakeholders on the same page is a crucial part of project management in any industry or sector.

Defining priorities of requirements

Be aware that the more intricate the initiatives in a particular sector are the more requirements the stakeholders related to these initiatives will create. When confronted with a large number of requirements, projects are forced to correctly prioritize them, so that the project development team will know when and how to implement each requirement (Larson & Larson, 2013). Thus, it is part of any project to identify all requirements that are essential to the progress of the project. These need to be allocated to the members of the implementation team who will work on them during the upcoming project phase. To make a clear and educated decision when prioritizing requirements, the influence of stakeholders, the technical requirements, and the approval by key stakeholders should always be taken into account.

Setting up traceability standards

Defining standards and procedures for traceability is the sixth phase of the requirements planning process. As discussed previously, requirements traceability refers to the method used to monitor project requirements over the course of the entire project in question. An efficient traceability system is used to support the implementation as desired by the client.

Traceability standards are used in most projects across domains and are usually defined in documents that map and trace all requirements in accordance with their unique use cases. In order for the development team to know what was committed and what needs to

be delivered to the client, any contractor needs to ensure that they have a requirements baseline in place, while the responsible parties are handling the requirements traceability (Rupp, 2014).

Monitoring, integrating, and administering requirements changes

Projects in all industries must realize that adjustments to the specifications and the project's overall development process are unavoidable. No matter how thorough a project strategy is, changes will nonetheless occur. All project managers need to set up a procedure to handle the changing needs as they occur over the course of the whole project development life cycle. In most cases, requirement strategies include a change control process to accommodate this condition of changing project environments. If structurally integrated into the basic requirements process, project development strategies will remain flexible throughout the life cycle and allow for a variety of changes that may arise. Based on experience, a number of main points need to be addressed in the planning process to set up a solid requirements change structure, as follows:

- justifications for the change request
- a brief statement that relates the "before and after" to each other
- stakeholders that need to formally approve and implement the changes
- the effects that the changes might have on the project as a whole

Outlining and disseminating requirements to all relevant stakeholders

The next step of the process to bear in mind is that the requirements planning process should explicitly lay out the channels of communication and collaboration between the project's stakeholders and the project team (Haley et al., 2006).

Therefore, an important element of any requirements process is to define who will communicate the requirements (especially in the case of changes) to all stakeholders and participants. Furthermore, when they will be informed, who should be made aware of the adjustments, and how stakeholders will be made aware of the changes must be defined.

Choosing the right methods for requirements analysis and administration

Project teams of any domain can manage, document, prioritize, and specify requirements for system development and implementation with the aid of various requirements management applications. Additionally, these programs link development teams with relevant stakeholders and, thereby, open channels for discussion regarding the system's specifications and adjustments.

Tools for requirements management can provide contractors with a thorough, top-down understanding of every aspect of determining the scope of a new product or service. Using this program, contractors can ensure that new systems meet their client's standards, their budgetary restrictions, and the needs of their stakeholders (Alebrahim, 2017). Software for managing requirements enables a more systematic approach to developing and imple-

menting systems. In addition, they usually integrate well with other tools for managing the project life cycle. According to Alebrahim (2017), in the most general sense, the application of requirements management current standards should meet the following criteria:

- document requirements and connect them to the respective steps of the project process
- support the analysis of the requirements regarding the goals and restrictions of a system
- accommodate the need for flexibility by supporting a structured change process
- encourage an ongoing dialogue between development teams, stakeholders, and relevant parties involved and affected by the system and the project

Keep in mind that further individual needs for requirements-related IT tools are necessary for different domains.

5.2 Specification for Projects in Mechanical and Plant Engineering

Mechanical and plant engineering projects are predominantly characterized by volume and technical complexity. The related systems, the industrial plants for producing chemicals (e.g., polyethylene), processing metals (e.g., steel), or developing natural resources (e.g., mining) regularly tie up more resources than most other industries. The systems are usually complex technical systems that are designed and developed for individual customers. Since they tie up large amounts of resources, development projects have long been on a high professional level with intense utilization of requirements management concepts.

Increased Need for Resilient Supply Chains

The volatility of the social and economic environment (e.g., the COVID-19 crisis, developments in the financial markets, radical political developments, and economic sanctions) has left its mark on the corporate policies of the plant manufacturing industry. Companies have heavily invested in setting up supply chains that are resilient to crises since unforeseen environmental developments have a detrimental effect on value-adding supply and demand. It is apparent that the previous mantra of reducing costs before any other consideration has transformed international supply networks into an unstable structure. To stabilize this vast network of suppliers, companies have put more emphasis on crisis plans and scenarios, and the spectrum of viable courses of action should be established (Mukherjee, 2021).

Clients are well aware of their contractors' lack of control over the production of their own components. While clients are often heavily dependent on this supply chain, they rarely specify their concerns about supply chain reliability as requirements. While this condition is unique in the context of the four industries discussed in this course book, considering supply chains in requirement specifications may be valuable to all projects. The European

Union has implemented laws that force companies to thoroughly analyze their supply chains in case they might be held responsible for human rights violations somewhere up the supply chain. Implementing supply chain requirements in the specification is, therefore, a necessary step for all industries.

Combination of Reliable Planning and Flexibility

Artificial intelligence is a crucial element of the industrial and plant manufacturing industry's efforts to benefit from the promises of digital transformation. Yet, the industry still faces some barriers to fully exploiting the new opportunities. Even though some tangible implementations of the new technologies have now arrived in practice, other efforts, such as General Electric's open-source plant operating system PREDIX, have lowered the expectations for the digital transformation of industrial plants (deutschlandfunkkultur.de, 2020). Consequently, companies have been hesitant to implement their digital strategies. Current attempts to move on rely on making digital transformation efforts measurable in terms of specific objectives; only then are they transformed into tangible actions.

The complexity and the volume of most mechanical and plant engineering projects, in combination with shorter development cycles, challenge projects to combine two imperatives that appear contradictory: planning the development with maximum efficiency and a minimum of redundancy; and allowing more flexibility to accommodate new developments in the system during the process (Zontar, 2022). This challenge is not entirely uncommon in other industries. Even smaller projects are often under a lot of pressure to combine planning efficiency with a flexible approach. Agile project management has found its place to counter the inflexible approach of traditional project management. Contemporary approaches have successfully combined the advantages and disadvantages of both traditional and Agile project management and accommodate the need for requirements specification (Steinle et al., 2021). This may be interesting to industries, which still struggle with the inflexibility of requirements management.

Increased Focus on Services

Clients' needs for complementing industrial products with industrial services has risen. Plants have gotten more complicated, new companies have entered the competitive landscape, and technological substitutes have been developed. In terms of service, however, plant manufacturers still struggle to maximize their clients' sales and profitability potential. They are often a long way from turning a significant amount of the operating costs of their clients into service revenue. Manufacturers have identified this untapped potential and are investing in this transformation (Friedli et al., 2021).

Clients have become aware that no one knows the complex system of a large industrial plant better than the manufacturer itself. Once there is an agreement on not only developing and implementing but also operating and maintaining a plant, this agreement must be reflected in the requirements specification. As the contractor takes on some roles that have traditionally been in the hands of the client, we might observe an unprecedented shift in the way requirements management is carried out.

5.3 Specification for Projects in Civil Engineering

Civil engineering refers to the design and development of building technical infrastructural systems and is traditionally contrasted with military engineering. Civil engineering comprises the construction of streets and highways, buildings, housing, airports, and harbors. Projects are of varying size and complexity; while the development of a playground in a residential neighborhood may be specified and implemented in a straightforward fashion, the construction of an airport is likely a tremendous effort, as the example of Berlin International Airport has suggested (von Gerkan, 2013).

The wide variety of projects summarized under the umbrella term civil engineering leaves little room for generalized trends that shape all segments of the industry. To provide an idea for current challenges, we will familiarize you with a selection of current developments in individual segments of civil engineering.

Transformation of Urban Areas

Urban social planning in Western European cities emphasizes the strategic development of residential areas to fit the world's changing standards. Open spaces, communal areas, and other facilities such as gyms, pools, and cafés are increasingly demanded by residents to improve the quality of life in their neighborhoods (Duvernoy, 2016). Elements of civil society are getting stronger and need to be integrated into the requirements elicitation process by companies involved in respective projects.

Digitalization of Heavy Labor

The utilization of technology and the automation of labor are among the current developments that change the way companies approach construction projects. Companies have heavily invested in operating with modern heavy equipment and automated technologies that minimize error margins and substitute hazardous human labor. With the appropriate technology, updated machinery, and robotic equipment, the danger of accidents is drastically decreased, opening the way for safer and more intelligent working conditions.

Health and safety have long been a concern of companies in industries that have traditionally been vulnerable to accidents. Process requirements in these industries often explicitly state health and safety standards, which are usually complied with in most Western projects. In recent years, health and safety have become a trend in industries whose conditions have no risk of fatal injuries (e.g., IT). These industries can learn from civil engineering to integrate these concerns into their requirements practices.

Remote Progress Monitoring

GPS tracking systems, monitoring, 3D inspection, and the deployment of drones reduce the need for project personnel to be always present on the project site. The use of GPS has steadily increased, and it is being employed innovatively to monitor progress and daily updates. The correct gathering of data frees engineers from site-bound responsibilities, enabling them to grow their workload and customer base.

Civil engineering clients are often public authorities without the market pressure to adapt to new technologies. Instead, these client organizations tend to place a greater emphasis on process requirements and regulations that were designed for predigital conditions. This may create conflicts regarding process requirements. It may also require some time to thoroughly evaluate the requirements and regulations; related industries may greatly benefit from the experience of working with civil engineering contractors.

Productivity-Enhancing Equipment

Productivity-enhancing equipment, such as smart excavators, are devices that work in collaboration with human operators. In civil engineering, they are applied by contributing to the restoration of human performance by enhancing mobility and physical strength. While their impact remains to be evaluated, the implication is that construction sites will appear drastically different.

As a matter of reliability and accountability, clients may insist on a certain level of human intelligence involved in the heavy work of civil engineering. This will be reflected, to an increasing degree, in the requirements specification. Civil engineering contractors will set a precedent for this question that, thus far, has rarely been part of requirements-related negotiations. Other industries are well advised to keep a close eye on this development.

Sustainable Use of Construction Materials

Environmental considerations have moved to the center of political and administrative decision-making. Using recycled material in the construction of buildings has become a major trend in recent years. Reusing material to lower communal carbon footprints is beneficial for the environment and has been increasingly called for by local governments (Halliday, 2018). Recent innovations include self-healing concrete, the application of 3D printing technologies, structures that consume pollution, and even kinetic pavement (although not fully developed).

While many local governments already require contractors to apply sustainable materials, the environmental trend could lead to a new requirements category altogether. Sustainability requirements could soon be part of most requirements specification sheets. Consequently, their development might be beneficial for most industries.

5.4 Specifications for Projects in the Social Sector

Social sector projects refer to the development of systems for the purpose of benefiting society. These systems are usually made of human interaction-examples include the establishment of structures for childcare, educational institutions, or the empowerment of marginalized groups. It is usually more difficult to measure the success of the development of a social system than it is to measure the success of a construction project. The condition that most resources spent on social projects are public resources or private donations makes social project management, even more demanding (Poulin et al., 2021). Specifying requirements plays a crucial role in solving this contradiction.

Experimental Project Methodology

The progressive and less key performance indicator (KPI)-oriented environment of the social sector has prevented individuals and organizations from developing a methodology-related tunnel vision. While project and requirements management methodologies have found their way into the social sector, organizations are free from routines and open to combined and experimental approaches. Possibly, for this reason, the notion of hybrid project management has received attention in social projects (Poulin et al., 2021).

Hybrid project management, in its simplest form, refers to methodologies that combine approaches from the conventional Project Management Institute (PMI) methods with agile approaches. This may suit the interpersonal and cultural work environment of the social sector. When intertwining the conventional approach with agile project methodology, project members with differing perspectives and working styles may collaborate in their own way, which has the potential for increased stability, engagement, and efficiency in the project (Steinle et al., 2021).

DIGRESSION

While the concepts of requirements management and agility may seem contradictory, the term “requirements” can actually be translated into “user stories” (Steinle et al., 2021). This calls for a careful setup of requirement specification documents and a mindful, process-oriented structuring of the project. Project organizations need to determine which techniques work best for a certain project using both their insights into the social domain and their project management expertise. For the best of both worlds, social projects are challenged to attract project managers who match this profile. Arguably, this may impose a challenge in this domain, which can only be solved by project-specific professional training and the specification of training as a requirement in the specification sheet.

The Impact of Human Emotions

The fundamental motivation in the social sector is different from the other domains discussed in this unit. Hard numbers are always a critical element in social projects as the spending of public resources exposes them to a higher degree of public scrutiny. The motivation of individuals to enter the social sector is arguably linked more closely to the social purpose of the domain. Thus, empathy is a greater emotional driver for entering a career path in the social domain than a high income and self-interest in general (King, 2011). While subordinating self-interest may impose a challenge to motivation from the perspective of classical economic theory, empathy also provides social project managers with advantages. Empathy increases the capacity to comprehend and identify emotions related to project success. The impact of project management extends beyond establishing the scope, meeting deadlines, and determining the budget. Additionally, project managers must manage people, which adds complexity. If they fail to read, understand, and address their team's emotions, it might result in increased tensions and negative emotional activity, the outcomes of which are not always ideal.

DIGRESSION

These conditions can be manifested in requirements management. The entire setup of the requirements elicitation and administration process can emphasize collaboration. The challenge is to find the optimal balance between centralized and cooperative decision-making. This, of course, refers to requirements administration to a higher degree than is relevant for each specification.

Introducing KPIs to Social Projects

To keep up with the professionalization of project management in the social domain, large amounts of information are required for realizing the potential for optimized efficiency in projects. Increasingly, social project managers are using data insights based on KPIs to make educated choices to better use their limited resources for the benefit of their clients (Taylor, 2016).

In different activities, such as project planning, quality control, or risk assessment, the application of big data analysis has changed the way projects are managed in most project domains and has now started to receive some attention from the social domain. The gathered data is valuable for learning the optimal way to staff project teams, the number of positions for each workstream, and the necessary skill sets for managing projects more effectively.

DIGRESSION

Social clubs or project companies in the social sector are well-advised to take a look at other domains where the use of KPIs is long-established. Clients are, by nature, interested in the efficient use of their resources and may very well insist on specifying them in the requirements specification sheet. Arguably, KPIs are difficult to measure in the development of systems with a high level of human integration. This is, however, even more of an imperative for social project managers, to proactively come forward with their own ideas on how to measure project success and how to implement these measures into the requirements specification sheet.

Remote Project Management

Public policy measures to battle the COVID-19 pandemic have forced companies to adjust to trends in the setup of the physical office structure that several other industries had long gotten used to. The home office trend could be established in social project management as well, and there is no indication this tendency will not persist.

Even in traditionally consensus-and communication-intense domains, such as social work, remote project management provides several advantages. The first is greater scheduling freedom, and the second is not having to travel to the workplace every day. Additionally, it is crucial to consider investing in solutions that might assist safeguard project organizations in a remote work environment.

The term social project management is sometimes referred to as a new collaborative project management methodology (Dalcher, 2017). While applying the term in its original sense, the collaborative nature of the methodology may be beneficial to the domain that shares the same name (confusion expected).

DIGRESSION

The social domain deals with systems that have a greater degree of human interaction than, for example, an automated power plant. This central condition of the sector needs to be accommodated in the requirements specification, as well. Contractors and clients can, for example, specify the required scheduling of daily meetings and phone calls to assess project progress and hold team members responsible by requesting regular status reports or utilizing team collaboration software that facilitates human interaction, instead of eliminating it.

5.5 Specifications for Projects in the Software Sector

When talking about IT projects, we focus on projects, where a client commissions a contractor with the design, development, and/or implementation of an IT system. Obviously, the entire spectrum of the software sector is much broader; but from the perspective of requirements management, this focus provides the best contextualization (Alebrahim, 2017).

IT development projects can range from small volumes and (relative) simplicity to extreme complexities that necessitate the involvement of multiple partners, such as project management office (PMO) service providers, requirements engineering companies, software developers, and business consultants.

Even for experienced professionals, it is difficult to keep track of the current trends and their consequences for requirements specification-as many current developments are of a strictly technical nature. We will, however, provide you with some examples to familiarize you with the pressing importance of intense requirements management efforts in most IT projects.

Automated Code Auditing

The increased velocity of life necessitates that IT companies implement new software systems more rapidly into their client's IT structure. For this reason, many developers have turned to automated code review, in which tools examine the functionality and reliability of code automatically based on predetermined standards. Considering the number of lines of code necessary to fulfill a single requirement, the usage of these tools is highly appreciated by IT project managers (Coenders & Rolvink, 2014).

DIGRESSION

As tools for the automated review of code are still in the early stages of successful application, informed clients may codify their own standards on automated reviews in the requirements specification sheet. Once industry standards have been established for this method, clients may even specify the review with these standards in the requirements documentation.

Concentration on Software Quality Standards

A growing number of clients expect their software developers to provide certification from internationally recognized agencies. This is occurring because of the integration of software applications into critical domains, including critical infrastructure, public security, military, and health. The popularity of the International Organization for Standardization

(ISO) certification is likely to continue since it assists businesses in enhancing their reputation and attracting more customers by indicating they adhere to high-quality standards (Nazeer & Marnewick, 2018).

DIGRESSION

It has been an established practice in larger and more professional projects to place strict requirements on certifications. While clients can decide on only proceeding with certified companies, they have often been unsure about the qualifications of the project personnel. These can be mitigated by providing special training to employees that can be proven with certifications in IT development, project management, or requirements management. The need for a selection of these certifications can be part of the requirements specification sheet.

System Migration

Many businesses continue to use older IT products as part of their IT structure. Typically, they are built on obsolete technology that is incompatible with the most recent innovations, which can result in a variety of practical problems. One reason why companies are hesitant to migrate to a new system is the effort of migrating data to the new system and integrating it into the overall IT structure of the company.

DIGRESSION

Another requirements category that may become an integral part of requirements management is migration requirements. While this aspect is often specified in larger projects, it has not fully arrived in the project management mainstream. Other industries are well served, using this as an example for their own integration of new systems into existing structures.

Cloud Technologies

Evidently, software development organizations will use cloud-native technologies when clients commission them with app development, team administration software, and communication tools. They are, by nature, infrastructure agnostic and can operate on different servers, so any business may employ them without difficulty. Cloud-native systems enable flexibility and scalability and boost the productivity of software development teams by using containers and microservices.

DIGRESSION

The requirements-related issues that come with the need for cloud-hosting of IT systems are highly specific to the IT sector. Besides the main concern is security, clients need to decide if they prefer hosting on a public, private, or hybrid server.

Artificial Intelligence and its Limitations

The hype of artificial intelligence is regularly limited by disappointment in its practical usefulness. Developers distinguish between three types of AI, which can be applied to manage expectations in the requirements specification process. According to Page et al. (2018), IT project managers need to familiarize clients with three very different concepts, to avoid confusion.

Narrow AI

Intelligent systems that concentrate on a single objective and accomplish a single task. While naturally limited in their applicability, these systems are the most reliable. Common examples of narrow AI include language tools in word-processing applications such as Microsoft Word.

General AI

Intelligent systems that reproduce the human brain's full cognitive processes. They have the capacity to acquire new information and apply it to address new challenges. Clients need to be made aware that companies are still far from creating intelligent robots with this degree of intellect.

Artificial superintelligence

At this moment (and for the foreseeable future) artificial intelligence will not be able to imitate human behavior and cognitive processes or achieve self-awareness and exceed our capacities. While this topic is often discussed, there must be no confusion by the client that, at present, this is anything other than a theoretical concept.

DIGRESSION

It is crucial to manage the expectations of clients in terms of AI applications. Experience has shown that technologies cannot replace human cognition and intuition. Unrealistic media coverage may lead to unrealistic expectations when a client reads terms like machine learning in a requirements specification sheet.

While software developers may use these terms regularly in an appropriate context, clients may have unrealistic ideas of what these terms imply. Caution with the usage of these terms in requirements management is therefore necessary.

Low-Code/No-Code Programming

Low- or no-code development is a novel approach to producing software solutions, which aims to simplify software engineering. Through graphical user interfaces and setup, low-code systems allow for software development without using conventional code (Apurvanand et al., 2020) These programming environments may be desired by clients since they enable their IT staff with minimal or no particular software development expertise to add new functionality or interfaces at a later stage.

DIGRESSION

While tech-savvy clients will be aware of this trend and will specify their respective needs in the specification sheet, this trend highlights an aspect that is relevant for all industries: clients must consider their requirements in terms of independently extending their systems. In most cases, a strong dependency on the contractor is to be avoided and even translated into specified requirements.

SUMMARY

In this unit, we discussed the basic process and all the steps of requirements management that are generally necessary for complex projects, regardless of their domain. These steps include the specification of the project's purpose and scope, the systematic involvement of all stakeholders in and around the client’s organization, the establishment of an accountability structure, identifying and resolving requirements-related conflicts between stakeholders, the prioritization of requirements, the definition of traceability standards, the development of a requirements change process, communication of all requirements-related activities to all relevant stakeholders, and the selection of the right methods for requirements analysis and administration.

We then elaborated on the current developments in mechanical and plant engineering, civil engineering, the social sector, and software development. We also discussed on current developments in each domain and derived implications for requirements management in gen-

eral and requirements elicitation. Where applicable, we commented on insights relevant to other domains and what they can learn from these domain-specific challenges.

UNIT 6

CRITICAL REFLECTION

STUDY GOALS

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

- describe which costs are related to requirements management efforts.
- understand the requirements-related aspects of current trends to combine traditional and agile project management methodologies.
- analyze the limitations of requirements management.

6. CRITICAL REFLECTION

Introduction

This unit will reflect upon different aspects of requirements management that are not addressed by the classic requirements. This includes a critical reflection on measuring the costs and benefits of requirements management, a brief assessment of the concept of requirements in the context of agile concepts, as well as a more elaborate discussion of the limitations of requirements management.

6.1 Costs/Benefits of Requirements Management

The overall costs of the development and implementation of a complex technical-system project are impacted by the quality of requirements management. To optimize schedules, budgets, and the overall success of the projects, both contractors and clients rely on approaches that enable the gradual, systematic improvement of requirements management.

Since the discipline was established in the 1970s, all companies that develop technical systems in projects have encountered costly requirements issues (Sawyer et al., 1999). The logic of traditional requirements management implies that, instead of eradicating these issues, companies must uncover them at a stage when the monetary damage to the project is still acceptable. Even if uncovered in an early stage, these requirements-related issues cause delays in project delivery, cost more than expected, and are of lower quality, while falling short on important client demands. Consequently, it is safe to assume that requirements management efforts generally contribute to project success and that poor requirements management generally results in higher costs.

It is possible to improve requirements management based on tasks, tools, and practical considerations. There are, obviously, costs attached to these efforts. These costs manifest themselves in expenditures on human resources and possibly specific training efforts. The benefits are related to the very same aspects, as a precise requirements analysis, for example, not only costs financial resources but also prevents costly misunderstandings between the client and contractor.

There are several issues attached to the idea of measuring the monetary impact of increased requirements management efforts. All costs and benefits of requirements management are inseparably connected to hypothetical errors on a level that is specific to any industrial and economic environment, and to any company and project. Thus, while attempts to calculate investments in this area may lead to a false sense of security, some aspects can clear up the confusion for students and practitioners alike.

Costs of Requirements Management

Costs of requirements management are generally broken down into tasks of the project staff. Project controlling can measure precisely the time that each person has spent on certain tasks, and contractors can even agree upon these metrics with their clients (Project Management Institute, 2021). These include time spent on

- defining the scope of the project from a requirements perspective,
- analyzing requirements,
- modeling requirements,
- quality management efforts,
- management and control activities,
- requirement administration processes,
- implementation support and risk mitigation, and
- managing requirements changes.

These tasks are usually executed by internal staff. The efforts of these employees are usually measured in workhours. In total, there are four cost factors to consider:

1. Personnel hours: This refers to costs for internal staff.
2. Consulting: Contractors are often forced to hire external consultants in case qualified personnel is not available for the project.
3. Training: Many contractors invest in training their personnel in requirements management techniques, often based on International Requirements Engineering Board (IREB) certifications, to reduce the number of requirements-related errors in a project.
4. IT Applications: IT tools are designed to reduce manhours spent on a variety of requirements-related project tasks.

Investments in these elements can generally be measured and combined with internal manhours, they provide a sense of what it takes to put a solid requirements management structure in place.

Benefits of Requirements Management

Benefits are more difficult to measure. It is natural in any project that manhours will generate costs, regardless of whether the tasks are performed by an internal employee or a consultant. In contrast to most other project management tasks, requirements management tasks are preventive, not constructive. The costs/benefits of the training of maintenance personnel, for example, can be measured by dividing the cost of the training hours by the cost of personnel hours of the contractor's training staff. The activities of the training staff are constructive because they directly lead to monetary benefits: Both can be measured and compared. In contrast, the requirements management efforts do not directly lead to financial gain; rather, they prevent financial loss. The potential loss is always tied to unforeseeable events, such as errors or misunderstandings. These efforts are not constructive but preventive. Measurable benefits can be identified based on

- reduced number of errors and rework,
- shorter project life cycles,

- rehiring of contractor for later project stages (in iterative projects), and
- reduced operating costs, especially personnel hours.

These benefits, however, can only be measured in absolute terms and are not relative to a hypothetical scenario, where the benefit-related costs were saved. Be mindful that the benefits and costs of requirements management are not only dependent on the budget. They can also be attributed to factors unrelated to the requirements. Some of these factors can be described as follows:

- requirements awareness in the client organization
- centralized/decentralized subject-matter expertise in the client organization
- organizational structure of the client organization
- volatility of the project environment
- level of organizational complexity of the project
- size of the project

At some point, it must be conceded that it is up to the experience and discretion of the management personnel of a project organization to determine the necessary level of investment in requirements management. With the uniqueness of any project comes the necessity for a constant redetermination of the question of how to balance the costs and benefits of requirements management.

6.2 Requirements Management and Agility – A Contradiction?

At first glance, the concept of agile project management concepts conflicts with the basic ideas of classic requirements management. Requirements management is built upon the idea that the implementation of initially specified requirements can be planned in advance, while agile project management specifically recommends planning as late as possible. Yet, agile approaches to project management can very well supplement traditional project management and the related requirements-based approach. Backed by their focus on the client, agile thinking has the potential to create a sufficiently abstract and solution-neutral view of requirements. If done with care and consideration, agile concepts in requirements management can support capturing, documenting, and implementing requirements in a way that supports a highly effective integration of project stakeholders and their needs. Practical experience shows that companies find their own ways to work around the theoretic contradiction of agile and traditional project management. The success of these hybrid projects suggests promising new ways, especially regarding the management of stakeholders and requirements. In this section, we will illustrate how traditional and agile methods are not mutually exclusive in the practical reality of project management and familiarize you with ideas that practically bridge this conceptual gap.

Because of the volatile, uncertain, complex, and ambiguous (VUCA) world we live in, systems in client organizations – whether they are technological, digital, or organizational – must be updated more often in comparison to the decades previous. This often leads to

the necessity of updating existing systems or including new solutions in the technological or organizational structure. Deciding on the right system and implementing it in a project poses a challenge in most situations. Since all clients have unique organizational environments and characteristics, typical projects only have one element in common. They are all different and necessitate decisions under ambiguous circumstances. Consequently, system development projects are frequently labor-intensive endeavors with significant risk.

There is an ever-growing necessity for new process models, which assist businesses in the process of selecting solutions that are manifested in effective new systems. The complexity of the decision on which systems are beneficial to solving the business needs of the client can be managed by breaking them down into organizational, functional, and process-related elements (Steinle et al., 2021). Nonetheless, the traditional idea of applying analytical methods to specify the system-related requirements has its weaknesses in comprehension and applicability.

Traditional requirements management methods are ideal for outlining the functionality and the organizational integration of a system. Their thoroughness, in particular, provides an excellent foundation for creating agreements between suppliers and users (Steinle et al., 2021). Nevertheless, practical experience has shown that these methods have difficulties in understanding the system from both the user and the process perspectives. They furthermore require a substantial amount of subject matter expertise in both the technical and business aspects of the system, which contractors – especially project management office (PMO) service companies – can often deliver only on a very fundamental basis. In the following subsections, we will elaborate on current trends and methods that combine agile methods with traditional concepts of requirement management.

Requirements-Related Issues in Traditional Project Management

The early stages of any system development project are characterized by choosing the system that best meets the client's needs in terms of budget, time, technological and operational structure, and business needs. When the project's goals, budget, and system characteristics are decided but its duration is flexible, traditional project management is the obvious choice in methodology. Agile methods twist this approach and recommend an initial decision on time and budget while leaving the system characteristics open to a more flexible future decision.

The practical realities of the management of complex technology projects have shown that even in more traditionally managed projects, the most common (and pressing) challenge is not the implementation of all required functions, but a lack of time and resources. Based on this observation, it is evident that companies are increasingly moving to an application of methods that allow for prioritizing time and budget. Contractors in larger projects are forced to deal with many requirements-related issues, both in (a) the very early stages of the planning and system design phases, and (b) throughout the implementation processes.

The involvement and activation of the affected organizational stakeholders present one of the most important, sensitive, and demanding challenges. Usually, clients make their best effort to involve the most relevant internal stakeholders in their considerations early on,

but there are also peripheral stakeholders, such as support functions (human resources, finance-accounting-information-technology support) and additional operational units that are indirectly affected by the new system. All these stakeholders are, by definition, presented with new working procedures and procedural steps through its replacement and a new introduction, which causes uncertainty and leads to resistance (Steinle et al., 2021). Not only do all stakeholders need to be involved from a change management perspective, but they also tend to ask questions that potentially guide requirements managers to new technical and organizational insights.

Figure 22: Typical Stakeholder Questions During the Analysis

Operational questions	Organizational questions	Business-related questions
• How is this function affecting the overall process? • How is this function affecting the workflow that I'm part of? • Is there room for a specific function that would benefit my work? • How will the system interface with other technical systems?	• Our legacy system is working well. Is this change even necessary? • How is the system dealing with our individual organizational demands (may refer to specific demand)? • How will the system support organizational integration both structurally and procedurally?	• How is this function supporting our business goals? • How do our competitors handle this challenge? • Taking the entire change process into account. Do the benefits outweigh the costs?

Source: Author (2023).

Complex technological projects are, therefore, organizational projects rather than purely technological projects. The organizational, and consequently human element is a critical dimension that is not accommodated by traditional requirements management to the degree that it merits. Technological system development and implementation projects usually involve a sizable number of the organization's members who will be affected by the system, necessitating a significant amount of change management activities. In this thinking, the foundation for a successful project can be found in the proactive handling of the opposition and anxieties as well as the innovative ideas of the direct users (stakeholders).

In addition to change management considerations, the actual technical system (in terms of a solution to the business challenge and the consequent technical problem) as well as time constraints present another difficulty. There is some leeway available if a legacy sys-

tem is replaced or complemented with a new system. A new technical and/or operational solution does not necessarily have to replace a legacy system to promote harmonization (Steinle et al., 2021). When the current system performs essential functions whose greenfield design would increase costs to a prohibitive degree, one option may be to replace the legacy system only partially. At this stage, the client and the contractor need to decide whether to use the standard system developed for and implemented in projects for similar clients (including associated standard processes) or to modify the technical structure to the specific technical system and processes used by the current client. No doubt, this results in additional design and implementation efforts, but the increasing organizational/technological/operational individualization of businesses has forced contractors to develop respective capabilities. At the same time, it has emboldened clients to enter negotiations with this option in mind.

Complex technological systems are often developed and implemented as **brownfield** projects. While **greenfield** projects have their advantages from a design and implementation point of view, the reality is that companies and their technical setup are both constantly evolving and have increasingly become historically divergent or heterogeneous because of restructuring and even mergers and acquisitions. Therefore, the most complex projects have mandates for harmonization, which necessitates a multi-layered approach that includes organizational (that is, change management) considerations.

Greenfield/brownfield
Projects whose goal is to build a system from scratch without building upon or being constrained by any legacy system are called greenfield projects. Greenfields are the opposite of brownfields, where systems need to be integrated into a technical and operational infrastructure.

As a result of these considerations, the initial phase of the development of a system that constitutes a solution to both the business problem and the technological challenges necessitates the definition of a clear project vision. On a high level, a project vision constrains the scope of the system to keep the project manageable. These visions tend to remain the same even in highly volatile organizational environments. Amidst these environmental complexities, ambiguities, and volatilities, a project vision provides the project team with an orientation when dealing with stakeholders, procedures, target systems, and constraints. These practical realities of managing complex technical system development and implementation projects demonstrate the challenges in eliciting requirements and managing stakeholder relationships.

Project Management Concepts: Traditional Versus Agile

The project phase and the conditions of the current framework play a significant role in the decision of whether to work with traditional waterfall project methods or opt for agile methodologies. While traditional project management handles requirements as described in this unit, agile methods take the approach of user stories. Both concepts recognize the need for the definition of minimum requirements, at least before a respective project phase is initiated. The concepts vary, however, when it comes to structure, level of detail, and the changeability of requirements and requirements management.

If requirements managers over-specify by developing a lengthy requirement specification document, stakeholders may have difficulties understanding and supporting the process. The standardized language and template-based documentation make it difficult to re-use elements of one phase in a later stage of the project. Furthermore, requirement specification documents are difficult for users to understand because they are formulated separately from the actual system design and implementation process. Stakeholders may

experience challenges in understanding a specification without prior training in the technical subject matter and requirements-related terminology. This lack of stakeholder orientation has the potential to interrupt any change management effort and frequently results in unreasonable challenges for stakeholders involved with the system (e.g., operation and maintenance).

Based on a concept developed by Steinle et al. (2021), the different approaches to user stories and requirement specification documents can be applied together to deal with the listed drawbacks and realize their respective benefits. User stories can unfold a high level of user orientation and can be applied throughout the spectrum of domains. By integrating user stories in system development and implementation projects, the involvement and activation of all stakeholders are facilitated, and the change process will be supported by reflecting on the desired requirement and crafting it as a story. Thereby, user stories function as a supplement to the requirements specification documents and as an accessory to the tender in the later stages of the project.

Given that the free formulation of the story is frequently unfamiliar territory for stakeholders, training in the methodology is crucial for a positive manifestation in the involvement and activation of stakeholders. Stakeholders can be supported by introductory training. When working with requirements specification documents and user stories at the same time, requirements managers need to ensure the level of detail is the same in both documents.

To manage the project with an expedient methodological setup, it often makes sense to combine both traditional and agile project approaches and requirements management in a hybrid form to combine the various benefits. Practical realities have limited the initial enthusiasm of the project management community and have often led to the recognition that the drawbacks of both methods cannot be fully eliminated and to the call for mindful handling throughout the project.

Experiences From Combined Requirements Documentation

Steinle et al. (2021) refer to several projects within which a combined approach to requirements management based on traditional and agile project management methodologies was tested. Despite the increased workload in documentation, their experience shows an improvement in requirements elicitation and documentation under the involvement of user stories as an addition to the traditional requirements specification.

The central problem faced by these projects that used a combined methodology is identified in one of the key criticisms made by proponents of agile project management of classical requirements management, that the requirements are solution focused and (by nature) disregard the development and implementation process. Just translating traditional requirements specification into user stories leads to the same problem. A simple translation places the weight of contextualization of user stories without any attribution to steps in the design, development, and implementation process on the stakeholders. Steinle et al. (2021) point out that user stories require a precise assignment to both the project phases and the operational environment after completion. This cross-referential effort establishes not only a visible and tangible connection between user stories and their

respective context but also guides stakeholders to a detailed understanding that enables their active involvement in a successful design, development, and implementation process.

Conclusion and Further Sources

Steinle et al. (2021) are high-ranking members of the *Forschungsinstitut für Rationalisierung* (in English, Research Institute for Rationalization, FIR). The FIR is part of the *Rheinisch-Westfälischen Technischen Hochschule Aachen*, one of Europe's most productive academic powerhouses for technological development, where countless successful high-tech start-ups have been founded.

The ideas that we have elaborated on in this section are based on the Aachen Implementation Model (ImplAiX; Reschke & Treutlein, 2019). While this **reference model** is focused on the implementation of software projects, it provides an ideal foundation for the idea of integrating user stories into requirements management. The ImplAiX Implementation Methodology is based on the identification and formulation of user stories at the beginning of a project without disregarding the need for requirements specification. Its main advantage is the integration of three crucial elements of the management of complex technological projects:

Reference model
This is the theoretical attempt to integrate all relevant elements of a business challenge (e.g., implementation of software projects). It aims to display all relevant elements and show how they relate to each other. Oftentimes, reference models serve as helpful tools for orientation in practical corporate management.

1. Requirements management: engineering, elicitation, specification, and administration of requirements (both in user stories and in requirements specification documents)
2. Change management: necessary structural and processual changes as a consequence of technological change
3. Project management: integration of Steps 1 and 2 into any step of the overall management process of the project

In traditional project management and related requirements management techniques, an integration of these crucial elements is only possible with a confusing number of documents and cross-references. We recommend looking into the concept to build upon the content of this course book, as the cited models serve as a great foundation for comprehensive knowledge management that makes requirements accessible throughout all project phases.

6.3 Limits of Requirements Management

There are several practical challenges to requirements management, which may imply limitations to it. One example is the lack of connection between requirements specification and project implementation processes. This problem, as well as all other issues, however, are methodology related; these can always be mitigated by adjusting structures and processes, possibly even strategies of requirements management.

Bounded Rationality in Requirements Management

The fundamental assumptions about the human condition, which traditional project management and requirements management are built upon, are in part conceptually stuck with the traditional idea of John Stewart Mill's (1836) *Homo Economicus*. While the human element in requirements elicitation is frequently addressed, for example, regarding conflicts, traditional concepts naively assume that these conflicting requirements, if they exist, will be brought forward, one way or another. In order to understand the limitations the human element imposes on requirements management, we can turn to the Nobel Prize-winning ideas of Herbert Simon. The concept of bounded rationality was developed as a reaction to contemporary rational-choice thinking (Simon, 1990). Even if replaced decades before its development, we can still find rational choice thinking embedded in the assumptions and tools of requirements management; for example, in the belief that stakeholders would deliver the best requirements as it is in their best interest to do so. The concept of bounded rationality questions this assumption and argues that stakeholders' judgment on the requirements of a new system is limited by their own cognitive constraints. Bounded rationality is based on three primary restrictions that limit the stakeholders' rationality in the requirements elicitation process (Simon, 1990). These are as follows:

1. Cognitive limitations
2. Imperfect information
3. Time constraints

We will elaborate on each of these, connect the concepts to requirements management, especially requirements elicitation, and illustrate how these conditions of the human condition impose limitations on the fundamental ideas of requirements management.

Cognitive limitations

Cognitive limitations refer to the incapacity of humans to optimally digest all information that might be relevant at a given moment. In other words, stakeholders cannot evaluate all accessible variables when asked for their opinion about a certain function of a system (Simon, 1990). When a maintenance professional is asked for their role preference in a maintenance process of a system, they may opt for the solution that sounds best at the moment. Based on rational choice thinking, it is assumed that the individual has complete information on all variables that may be important in this decision. How well does the role in the new maintenance process match the role in the maintenance of other systems? How manageable are the new geographic distances? Does the new process allow for the same flexibility that the maintenance professional has become accustomed to in the old process?

As the example demonstrates, there are several questions that must be addressed to make an accurate conclusion. Yet, most questions relevant to an assessment of the respective requirement will not even be examined, while some will just become too difficult to comprehensively answer on the spot.

Requirements management tends to oversimplify the elicitation process, to an extent that may do more harm than good. Even though complexity in the presence of an insurmountable number of available options necessitates a higher degree of processing, requirements management creates the illusion of simplicity. Admittedly, this is one of the essential functions of requirements management, but one point remains: Requirements are rarely the product of a fully rational cognitive process.

Imperfect information

The stakeholders' lack of complete information only contributes to the problem of cognitive limitations. For example, a machine operator is unlikely to distinguish between two kinds of processors that run the operating system of a machine, and not many operators are going to devote hours to understanding what it is and how it impacts their machine's performance.

Additionally, there is important information that stakeholders do not necessarily know. We addressed this issue earlier when stressing the importance of requirements managers explaining details. The same condition, however, applies to them, as well. They may be aware of the price, performance, and reliability of both processors, but they may not know that a crucial application is not supported by technology.

Time constraints

The requirements elicitation process is often constrained by the time set by the project-management office. Additionally, management choices must be made with limited information and time. For instance, an online shop may have the choice between two locations for a new logistics facility in the hope of reducing their delivery times. At the same time, the shop may lose more customers the longer it takes to decide.

Time constraints limit stakeholders' capacities to evaluate and assess a situation and make the best possible choice. Even for requirements that are unaffected by their cognitive limitations, time constraints impede their capacity to digest new information that is necessary for an informed assessment of a given requirement. In summary, when stakeholders are pressured by deadlines, they tend to make suboptimal judgments.

What this means for requirements management

It is evident that these limitations of human cognition are impossible to eradicate. It may be argued that they are limitations not only in eliciting optimal requirements, but in the very purpose of the entire requirements-management discipline. Without these limitations, requirements elicitation would merely be a minor step in the project-management process. So why is bounded rationality still important when elaborating on the limitations of requirements management?

The problem can be identified in the way requirements are treated, once elicited and approved. Traditional requirements management regards requirements as decisions made by the client. Based on the concept of bounded rationality, we can very well question this assumption. Requirements are often not the result of well thought-out, rational

considerations based on complete information under the consideration of all related consequences. Instead, they may very well be the product of obscure cognitive processes. In the following, we will integrate this thought into consideration of another limit of requirements management that focuses on the role of the contractor.

The Principal–Agent Problem in Requirements Management

We have now identified the first major limitation to the fundamental idea of requirements management. The requirements provided by the client are not necessarily reliable while the contractor treats them as if they were. This condition is much less of a problem when we follow the assumption of traditional requirements management in which both client and contractor unequivocally work toward the best possible solution for the client.

As the principal–agent concept (and more than enough practical experience) suggests, this may not always be the case. As opposed to requirements management's implication, the principal–agent concept presumes that the interests of the contractor and client are not perfectly aligned toward reaching the optimal solution, and instead views both parties as wanting to maximize their benefits in the course of the project (Kleine, 2013).

Roles

The concept analyzes the relationship between a principal and an agent in any given business transaction. To apply this to the limits of requirements management, we need to clarify the roles in this line of argument.

The principal

The principal is a client who requests the design, development, and implementation of a system for monetary compensation (Kleine, 2013). Inspired by the fundamental assumptions of requirements management, the principal does so with the expectation that the services will be performed in their best interest and accepts the dependence on the agent to complete the project. Due to the information asymmetry between the principal and agent, the principal is unable to influence or even witness the agent's commitment or attributes and, hence, has an information disadvantage (Kleine, 2013).

The agent

The agent is the contractor commissioned with designing, developing, and/or implementing the requested system by the principal and receives compensation in exchange for their services. Compared to the principal, the agent is usually more skilled and has a greater competency base upon which to build all further project activities. The basic argument of the principal–agent concept is that the contractor's need to maximize their own benefit creates strong incentives to exploit this information advantage to the disadvantage of the client, whenever given a chance to do so (Kleine, 2013).

Principal–agent problem

Let's turn to the problem and elaborate on the basic assumptions that may lay out some limits to the concept of requirements management. It is natural in any business transaction that the contractor's objective differs from that of the client. The client desires a system and the contractor desires remuneration. Traditional requirements management works with the assumption that the transaction element of a project naturally aligns both interests. Conflicts may arise, however, when opportunistic behaviors result in a divergence of interests. Opportunism refers to the maximization of one party's utility and accepting that this occurs at the cost of others (Kleine, 2013). There are several scenarios that have been formalized in the framework of the principal–agent concept.

Asymmetric information

The principal–agent concept examines the uneven distribution of information as a core issue (Kleine, 2013). More precisely, the concept of information asymmetry depicts a situation in which a contractor has more information available than the client. When, for example, a stakeholder issues a requirement that works well for the moment but may cause significant issues in a couple of years, requirements management assumes the contractor will point this out. Doing so may be beneficial to the contractor, as this behavior generally increases client satisfaction. If, however, the contractor realizes some sort of benefit by not addressing this issue, they may take the opportunity and not address it. There are multiple scenarios in which this is possible. If the requirement is a core function of the contractor's system and any alternative requirement that is more beneficial to the client would necessitate subcontracting a further contractor, the original contractor will be tempted to exploit this imbalance and not mention the alternative.

Moral hazard

Moral hazard is an asymmetry of knowledge that occurs after the approval of a requirements document and refers to concealed activities or information that are carried out or exploited after the fact by the contractor (Kleine, 2013). There are several scenarios to connect this issue to requirements management and illustrate the discipline's limitations. Moral hazard contrasts the traditional notion of aligning the interests of the client and the contractor with the reality that any client is dependent on the contractor. If a contractor discovers one or multiple requirements that are beneficial to them and disadvantageous to the client, the contractor may be tempted not to raise the issue. Once again, presenting oneself as a reliable contractor by openly renouncing benefits and standing up for the client against one's own interests is not a disadvantage. If the benefits of moral hazard outweigh the costs, the decision to take this route will be more likely. Requirements management, as it is applied, does not consider this very real condition.

Adverse selection

The asymmetry of knowledge prior to the approval of the requirements specification document is referred to as adverse selection (Kleine, 2013). In this scenario, contractors know their inability to fulfill requirements before they are approved. If, for example, the client insists on an unfeasible requirement during requirements elicitation, the contractor

will be tempted to agree to this initial requirement to be allowed to move on to the next project phase. Once the implementation has started, the contractor may suggest a workaround that technically fulfills the requirement but fails to fully satisfy the client.

Hidden intentions

In addition, one of the parties may conceal some objectives and reasons prior to the approval of the requirements specification sheet. These hidden intentions might result in a breach of commitment after the requirements document has been agreed upon. While moral hazard and adverse selection may very well never be discovered by the client (and are, therefore, very tempting to the contractor), hidden intentions will necessarily become evident (Kleine, 2013). The risk of customer dissatisfaction is often outweighed by the benefits, which is not uncommon in many business relationships. Examples include agreeing on a price that will be increased later, agreeing on impossible requirements, or promising nonexistent manpower or subject matter. Even if the client may not appreciate this turn of events, the costs of changing contractors may be higher than accepting an undesirable workaround suggested by the current contractor. Looking back, the client would have opted for another contractor or would have followed the contractor's indication that their way is the only way to deal with the problem.

An Appreciation of Traditional Requirements Management

While these issues illustrate the limits of the very idea of traditional requirements management, they do not delegitimize the entire discipline. Many of the arguments made are common conditions of any business transaction, even beyond requirements. Requirements management should be seen as an attempt to mitigate these conditions – an attempt that reaches its goals, but not to the fullest degree. At the same time, requirements-management efforts specifically target problems such as moral hazard or imperfect information. Without these efforts, the problems that are outlined by principal–agent concepts and bounded-rationality theories would be more problematic.

SUMMARY

In this unit, we reflected on the requirements management discipline beyond tools and methodology as applied in consulting and manufacturing firms. While elaborating on the costs and benefits of requirements management, we learned how requirements-related project efforts are primarily preventive. Preventive measures are aimed at preventing costly events from happening; their primary success is rooted in ensuring that negative events do not happen. It is, therefore, difficult to measure and quantify the return on investment of requirements managements efforts.

We then elaborated on the relationship between traditional requirements management and agile project management. While agile project management seems to contradict the idea of early requirements specifi-

cation, agile ideas can still eliminate some of the defects of classic requirements management. By translating requirements into user stories, project managers allow for a deeper involvement of stakeholders and the integration of requirements into the implementation process.

We then turned to the limits of requirements management and introduced the concepts of bounded rationality and principal–agent relations. Bounded rationality helps elaborate a more realistic view of the cognitive process of eliciting requirements from stakeholders. It is key to understand that traditional requirements management takes stakeholders' views at face value, while their rationality is limited by several factors. The principal–agent concept can uncover traditional requirement management's limitations regarding the risks of moral hazard. The concept delivers valuable insights into the relationship between contractors and clients and how information imbalances impair classical requirement management's assumptions on fair play.

We have pointed out, however, that requirements management is not only limited by these conditions of practical realities but is explicitly designed to counter them – if not to the fullest degree, then certainly to a satisfactory level.