Title: Guidelines for Requirements Engineering in Research Projects

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1 Introduction

1.1 Objective of iWIDGET

The aim of the iWIDGET project is to advance knowledge and understanding on smart metering technologies in order to develop novel, robust, practical and cost-effective methodologies and tools to manage urban water demand in households across Europe, by reducing wastage, improving utility understanding of end-user demand and reducing customer water and energy costs.

To base the system on current robust and proven techniques and technologies providing, as a minimum, the following functions:

- innovative demand management including adaptive pricing
- decision support systems (DSS)
- data management.

To exploit the following technologies:

- advanced metering including combined water and energy metering
- real-time communication of consumption patterns.

To have the following impacts:

- progress towards the Europe 2020 targets on climate and energy by reshaping the demand side of our energy-dependent society, reducing energy consumption, and subsequently CO2 emissions.
- reduced demand for water and hence the energy required for its treatment, delivery and safe return to the environment
- better management of supply and demand
- the creation of new partnerships between European water distributors, water management equipment suppliers and the ICT sector.

The main scientific challenges for iWIDGET are the management and extraction of useful information from vast amounts of high-resolution consumption data, the development of customised intervention and awareness campaigns to influence behavioural change, and the integration of iWIDGET concepts into a set of decision-support tools for water utilities and consumers, applicable in differing local conditions.
1.2 Objectives of this document

According to the DoW of iWIDGET, it is necessary to derive, sort and classify all requirements, using the state-of-the-art methodologies. It is vital to consider what households require from the iWIDGET system, e.g. what type of information they would find useful, and their reactions to the possibilities of such a system. Task 1.3 aims to provide a detailed specification of requirements and is therefore organized in two sections. Firstly, the particularities of collecting and deriving requirements in a research project have to be taken into account. Secondly, functional and non-functional requirements should be specified in detail, based on the evaluation of the use cases (Task 1.2), the two case studies (e.g., time step between readings, time series length, availability of water only or water and energy data), as well as the state-of-the-art section (Task 1.1). This document reports principally on the first objective of Task 1.3.

As requirements engineering (RE) is applied in various contexts, methods to conduct the process of collecting and deriving requirements would correspondingly vary. Type of project (research/non-research), scale (size), team composition (physical dispersion), and enclosure of disciplines (e.g. interdisciplinarity) are among the decisive factors. What is surprising, however, is that, to date, there is still no suitable approach introduced for research projects, even though the quality of the outcome depends strongly on the quality of requirements. Challenging factors such as large and multidisciplinary project scope, and geographical dispersion of teams, make large scale international research projects (LSIRPs) such as iWIDGET worthwhile and interesting to investigate, given its distinctive setting. The bottom line is that, those factors result in a unique setting, which combines various industries, organizational structures and perspectives, i.e. team members with different focus, interest and backgrounds that results in cognitive distance. This setting is further challenged by research uncertainty, which naturally affects RE, considering the effort to elucidate stakeholders, their needs, and requirements for a system that would fulfill them. In an area that is currently investigated, those concerns themselves are parts of the research task. Having no methodology designed and intended for research projects is a potential obstacle for research project accomplishments.

Thus, in this document, the essence of RE relevant challenges in iWIDGET is described. Brief guidelines based on analysis of the collected data from an empirical study concerning iWIDGET RE process. The suggested guidelines are suggested to be utilized in the future with a retouch in line with specifics of the particular EU-funded research project.

1.3 Background for the requirements

What does investigation of requirements mean? Or, what is a requirement in the first place? A requirement refers to the product or service, describing how it should perform (Aurum & Wohlin, 2003). The IEEE Systems and Software Engineering Vocabulary (“Systems and software engineering -- Vocabulary,” 2010) defines requirement as:
1) “a condition or capability needed by a user to solve a problem or achieve an objective,
2) a condition or capability that must be met or possessed by a system, system component, product, or service to satisfy an agreement, standard, specification, or other formally imposed documents,
3) a documented representation of a condition or capability as in (1) or (2)
4) a condition or capability that must be met or possessed by a system, product, service, result, or component to satisfy a contract, standard, specification, or other formally imposed document.

Requirements include the quantified and documented needs, wants, and expectations of the sponsor, customer, and other stakeholders.” (p.301).

With respect to service (and product) development, a requirement describes an individual, specifically documented need that this service (or product) has to fulfil. It defines an action the product/service needs to take in order to be useful to its users. (Robertson & Robertson, 2006). The specification of requirements determines the necessary properties, capabilities, and characteristics of this service or product with respect to the value and utility that it has for the users or customers.

RE is argued to be a crucial activity in software-intensive system development. (Konrad & Gall, 2008). A system that has insufficient or unaligned requirements will not fit the intended purpose. Therefore, RE process in iWIDGET identifies system stakeholders, along with their needs and constraints. The documentation of requirements is analysed for system design and implementation in successive tasks.

For every project, requirements are the basis to perceive the needs of stakeholders and to understand what satisfies those needs. Also, use of natural language to express requirements is a measure to have requirements well understood by everybody (Hull, Jackson, & Dick, 2010). The project activity in iWIDGET is built upon requirements, once they are identified and documented.

**1.4 Structure of the document**

Following this introduction, the report includes the following sections:

- Section 2 specifies the iWIDGET RE methodology, its challenges and links to corresponding guidelines.
- Section 3 provides guidelines for RE in research projects.
- Section 4 summarizes the main conclusions of this document.
2 RE in iWIDGET

2.1 iWIDGET RE Methodology

The iWIDGET case study exemplifies the RE process applied in a LSIRP, with its accomplishments as well as inherent challenges. An overview of the RE process in iWIDGET is presented in Figure 1.

![Figure 1: iWIDGET RE Process Overview](image)

The RE process in iWIDGET was realized in three main phases: Planning, execution, and completion. First phase was largely part of overall project planning to guide through the process. Execution phase initially had two consecutive steps: Water domain experts would first author use cases in template form based on their research and collected data from research and workshops, and then they would derive requirements in collaboration with technical experts. Use case description was chosen as the elicitation technique from the beginning as it was believed to be the most appropriate technique for the purposes of iWIDGET. However, the cognitive distance, as a result of diverse organizations involved, was apparently wider than expected, thus the team needed to introduce an add-on step between use cases and requirements. By conducting mockup discussions, use cases were clarified; partners exchanged their expertise and concretized findings in a template to derive requirements. Finally technical partners took over the responsibility to derive requirements. Mockup discussions also elucidated the procedure to validate requirements. Due to different parties deriving use cases and requirements, considering physical dispersion as well as perspectives on the research task, a consolidation consisting of technical, content and methodology was applied. Outcome of those three phases was a draft of requirements for iWIDGET system, to be taken as input for system research and development.
2.2 RE-Relevant Challenges in iWIDGET

Analysis of expert interviews and field notes taken in the course of iWIDGET RE process revealed numerous RE-relevant challenges. In the following section, the observed significant challenges are cited from empirical data using first person narrative. Each challenge is linked to corresponding entries in the guidelines for RE in research projects, which are depicted in the next chapter.

**Table 1: RE-Relevant Challenges and Corresponding Guidelines**

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3 Guidelines for Requirements Engineering in Research Projects

Insights into iWIDGET as a representative research project reveal guiding principles to conduct RE processes in research projects. The following list specifies recommended general aspects to consider in RE planning, execution, consolidation and downstream feedback phases.

RE Planning

I. Incorporate Domain Research and RE Expertise

In interviews and field study conducted, a main concern was the vitality to involve all relevant organizations from the beginning of RE tasks. Especially in LSIRPs, it should be recognized that a wide coverage of expertise is required and for that objective the project team might need partners from various domains.

In the case study, it was reported that the expertise of the team met the desired level and the team believed that all the knowledge required to achieve the objective had been present. Once the needed span of expertise is in place, the concentration is rather on building and sustaining shared knowledge, particularly among partners involved in different domains.

The building blocks of this guiding step are found in the planning phase of the research project, and thus RE. Considering the technical aspect and development implications of RE, it is useful to include RE experts in preparation of the DoW of the project, as well as any relevant planning task during the course of the project. Organizations that are capable of leading research on particularities of the project domain are essential to alleviate the identification of requirements. Thus, the focus should be both domain and technical expertise; neither should be given less importance. Additional expertise should not be sacrificed for the sake of smaller team size, as long as it would be in line with the context of the project.

II. Comprehend Interfaces and Set Decision Points

RE process in a LSIRP requires multidimensional approach to RE. While the knowledge and exploration of the project domain is crucial for substantial requirements, technical team members have the strength to analyze system constraints and requirements, using techniques for structuring, standardizing and harmonizing requirements. Beyond the organizational viewpoint, it is therefore essential to investigate proactively from the start who can contribute in what way and who has capability and interest in particular aspects of the RE phases. That approach would also reveal the cognitive distance, which triggers brainstorming of measures to reach common understanding during RE execution phase. Wide expertise brings diverse capabilities and interests of work/research in the team. That also makes assignment of tasks an important activity. While it might not be possible to link
RE tasks on one-to-one basis with relevant WPs, consideration of their interrelations, interactions, milestones and decision points would facilitate the RE process.

Organizational cognitive distance is also reflected in individuals. The iWIDGET team consisted of a mixture of partners from water management and technical domains. From the technical partners’ perspective, it is reported that if they had known that partners involved in the water management domain area find it challenging to derive requirements, they could have gathered more domain knowledge to take over the part that they did not feel comfortable with. On the other hand, partners from the water domain stated that it could have been better to get some assistance in the beginning regarding how to derive requirements and what the most important considerations would be. While both parties were ready to help each other, by relying on the DoW, they believed that it would be possible to forge ahead without major challenges. Furthermore, partners from technical domain believed that use case partners should have taken part in deriving requirements. On the other hand, partners who authored use cases reported that it could have been better to include technical partners in the use case description procedure to improve it further and have it more aligned with needs of deriving requirements. Moreover, it is frequently stated that developers of the system should be considered active partners in RE process.

Although having dynamic teams and many organizations involved may challenge that, it is strongly recommended to analyze and survey partners regarding their interests and capabilities beforehand as a measure to achieve awareness of capabilities. These findings should be kept up-to-date, reflecting changes in team composition during the project. It is important to not only have the coverage of expertise as needed, but also to recognize capabilities of partners before assigning tasks to them. Having partners involved in all RE relevant processes in the project, developers can positively affect the system by proposing ways to conduct the processes that lead to the development activities. Likewise, from the pool of human resources available, the team should strive to achieve the best match possible for the task. Those interfaces should lead the project manager to consider which tasks and individuals need to synchronize with what frequency to keep the track in the RE process. For knowledge exchange, involving interaction of technical aspects and research domain, as well as for making decisions regarding alternative approaches, decision points, i.e. milestones should be planned early on.

III. Consider Research Implications for Schedule Flexibility

According to a partner interviewed, the biggest distinction of a research project from other projects is wider temporal scale, which increases the opportunity to research creative approaches to come up with a solution to the given problem.

There are referrals to flexibility in many aspects of research projects. In architecture phase, its dependency on requirements creates need for more time. Moreover, it is reported that the proactiveness and agile approach in research projects call for more time-wise flexibility to perform the research tasks appropriately. By having longer time scale, research projects
can have better practices of RE, given that they have the time to refine the requirements with respect to the changing and refined inputs for requirements, as well as feedback from downstream.

Tolerating more flexibility is central to requirements in research projects, where it is not possible to predict the time needed in exact terms. However, it does not mean that unlimited time is assigned to a task. It is still emphasized that from project management perspective it has more effect to set deadlines for activities as needed.

IV. Clarify Research Uncertainties via Alternative Communication Channels

In LSIRPs, partners need to communicate due to coexistence of different domains, as well as a research agenda to investigate over time. Such discussions help the team clarify research uncertainties, which directly affect the final outcome and therefore reflect requirements as well. The medium of exchange could be team conferences, face to face meetings, e-mails, online platforms such as Wiki pages, or separate one-to-one meetings.

In all the recommended measures mentioned above, communicative skills have crucial importance on the overall understanding of the concept and therefore to develop requirements in research project. Including the cultural difference within LSIRPs, communication channels should be diverse and effective. Recognizing that face to face meeting is not possible to take place very often in internationally dispersed teams, alternative communication channels are emphasized by the project team interviewed. In LSIRPs, there is often to exchange knowledge, ask questions and discuss controversial viewpoints to agree on the creative exploration of the topic. It could be well the case that such issues are solvable via short one-to-one telephone conversations or instant messaging/video conferences. Knowing partners in person, as well as having personal acquaintance with them enables the informal communication channel to discuss and solve issues before they would become task-wide major problems.

Face-to-face meeting is an appropriate starting point to establish interpersonal communication. Having such meetings from time to time would enable partners to acquaintance each other to realize who the person to consult is, in case they have a specific issue to address. Therefore onsite team workshops and meetings are not totally replaceable by other channels and should be arranged as frequently as possible within project constraints. Also, introducing a Wiki platform would be useful to address a specific community to informally brainstorm open issues. Having established such communication networks, the team could identify and alleviate RE process difficulties as a result of decision point/milestone interactions agreed upon. The partners may choose the communication channel they would see fit to arrange their idea exchange and synchronization sessions. By achieving that, there would be fewer issues discussed left to discuss during team meetings that involve the entire WP team.
RE Execution

V. Acknowledge That Requirements are Incomplete

In a research project, team of experts work on requirements, which are based on their implicit knowledge and understanding of the system-to-be. The dynamically changing vision of the system to be designed also affects the path towards requirements. It should be therefore taken as a fact that requirements are incomplete from the beginning, as an implication of inherent research uncertainty within the project.

Having incomplete requirements is not an obstacle to strive for the best possible outcome. On the contrary, acknowledging that could prevent dissatisfaction with the current state and further drive action to encapsulate undiscovered requirements that apply to the system. While RE experts cannot identify all requirements at once, iterations in the RE process as a result of iterated input data for requirements and project objectives would refine the requirements and enhance its coverage of the entire system.

Requirements are to be rethought. In harmony with the dynamic change in the project objective, gaps, explorations in the domain and technology, the requirements would change respectively. State-of-the-art research and identification of potential gaps increase preparedness to uncharted requirements. Not acknowledging the incompleteness of requirements would cause requirements to be not representative of the aimed system. Furthermore, such unawareness within a team could cause unnecessary dissatisfaction due to incompleteness of requirements.

VI. Embrace an Iterative Process Design

RE activities in research projects are characterized by continuous idea development for an aimed final outcome. To achieve that, implicit knowledge needs to be developed, combined, validated and iterated. That indicates the consequence that RE activities cannot be deemed linear, that is, one-off activities that are following each other exactly in sequential order.

Analysis of data revealed that partners believe RE involves amendments. With a circular approach, firstly the methodology is discussed, agreed, and the process is iterated as needed. This does not mean that there are no temporal dependencies of tasks relevant to RE, but still, identifying it as linear process is to be avoided. Iterations are needed because in the context of research, not all requirements are known from the very beginning of the RE tasks. Therefore, iterations make sure more comprehensive coverage of the objective, representing all relevant aspects.

With an agile approach to RE, revised requirements may modify the system specification and architecture, which might re-affect the requirements. Nevertheless, in a research project, developing the concept should not involve fear or resistance to change later on. Test and approval of requirements and approach towards RE is provided by sample developments and demonstrations that also promote creativity in RE. Calling each session...
of iteration a sprint, requirements comprise a draft that is updated and refined at the end of each sprint.

VII. Improve Research Goals and Requirements with Stakeholder Perspective

Research projects might have abstract and conceptual views of a vision. However, connecting research to design is a commonality in research projects, which involves RE process. To define the objectives of research, as well as to bridge the gap between research and the outcome, stakeholders, especially the objectives of the end users are vital. In RE phase, requirements should cover specific user needs, with respect to varying characteristics, needs and priorities depending on aspects such as demographics and physical distribution.

The challenge of research project is that; alongside with the objective, the project team needs to define the product, market, and its stakeholders. Therefore, for iWIDGET there had been need to consider all aspects regarding the aim. Moreover, in such a research project the progress depends on brainstorming on the final objective and ideas, rather than clearly defined timeline of foreknown events.

Consulting with stakeholders is a technique to transform the approach from top-down to bottom-up, namely taking into consideration what they expect and need from the system. Stakeholder knowledge should equally encapsulate all segments identified that are relevant for the end product/service. While it is crucial to listen to perspectives of stakeholders, their applicability and feasibility should be checked by the RE and development teams. When it exceeds the existing capabilities, within time limits studying the issue and/or forming extended partnerships for that topic is recommended.

VIII. Introduce Easy-to-Use Standards and Templates

Aspects of LSIRP, most importantly the physical distribution and therefore the intercultural issues, as well as variation of skillset in people, an approach which might fit theoretically might not turn out effective in practice. A particular approach would not appeal to partners if he/she does not have the understanding of the methodology.

Considering resistance to static formats, in iWIDGET the team had been rather flexible in approaches. For instance, the use case approach for deriving requirements had been accepted in consensus. Nevertheless, while discussing the template and methodology for requirements, partners expressed that they would feel more comfortable if no template were strictly imposed and partners were given the option to work in the format in which they would feel comfortable. Even though it would cause more time consuming consolidation phase, the team would give the priority to enhancing creativity. In iWIDGET, the team agreed on a simple template in which all partners could easily work, and therefore it has been a productive approach.

Having candidate standards and templates is beneficial from project management perspective. Being structured and having static templates and processes are, however, not necessarily identical. In LSIRPs, it is recommended to be ready to discuss and adapt.
standards and templates in a way that all partners can understand and comfortably use, while allowing the progress to be traceable, with a concise structure.

IX. Test-Run the Entire RE Process

Having planned and identified the RE process and standards/templates to use, the harmony as well as applicability of the process should be tested. Test-runs that involve only subtasks would not suffice. A test-run should encompass the RE process phases as a whole to observe the entire conduct. In order to ensure the common understanding of parties involved, as well as to identify any unclear issues, or impracticalities, a test-run should cover the execution of the entire process.

In LSIRPs, a challenge could be having the data readily available to pilot, i.e. test-run, the RE process. In such cases, it is recommended to use input from another sample, i.e. another LSIRP, to test the RE methodology including all templates, standards, as well as organizational and individual interfaces planned. Even though the RE process might not be identical with the test-run with another case, the team could still become accustomed to particularities of the methodology and could perceive how the undertaken approach runs in practice. This procedure would eliminate potential problems regarding the application of chosen techniques that could occur during the execution phase. By making sure the methodology fit with the team, duplicate efforts and time losses to optimize the RE process would be alleviated.

X. Take Reactive Measures as Needed

In LSIRPS it is challenging to capture the entire picture and sustain the state of common understanding. While the defined processes are helpful for task awareness and clearness of assignments taken on, bridging the cognitive gap between partners might require consideration of alternative approaches to reinforce the effectiveness of interpersonal communication channels.

In iWIDGET, mockup discussions were the main constructive approach to enhance the common understanding in the team for deriving requirements. It was reported as a useful add-on to the use case descriptions and main flows. Using special slide templates, screenshots and by involvement in discussion, bypassing the knowledge gap between domain and technical experts has been possible. Having prepared use cases with appropriate level of elaboration, mockup discussions aimed to capture the entire picture and stood for feedback channel between experts. Technical experts stated that mockups had been very useful to understand the use cases better. While domain experts found it practical to transfer their knowledge on use cases, they denote that without having substantial use case documentation mockups could not have been that successful.

It is therefore important to discuss the uses of the system in an interdisciplinary consortium of participants to reach common understanding, even when tasks are modular and clearly separated. Despite the additional time needed to invest, especially for teams in which partners that have domain expertise and technical background to derive
requirements are separate, it is useful to consider add-on channels to bridge their knowledge gap and enable knowledge transfer. This would also positively affect elucidation of uncharted requirements.

**RE Completion & Downstream Feedback**

XI. **Utilize Mockup/Prototype Development**

A major implication of RE is that it guides the development by transforming stakeholder requirements to the requirements for the system-to-be. Therefore, to calibrate the focus of development and to test requirements, prototyping is a constructive approach towards better understanding of requirements.

Teams involved in mockup development/prototyping could base their thoughts on the drafted requirements, as well as combine requirements with their own conceptual views and design alternatives. Testing requirements by low-fidelity development demonstrates a creative technique in line with the essence of research, and it brings further substantiality to requirements, by providing feedback from practical design attempts.

A pilot development strategy is also a useful and time-efficient approach, once there is a first draft for requirements involving higher priority and preferably modular parts of the system. It is reported that in a pilot development, problems perceived are helpful for the rest of the project, not to reinvent the wheel each time RE task is performed. Moreover, pilot development does not necessarily imply singularity. In a research project, it is beneficial to have multiple parallel ideas developed and demonstrated. Nevertheless, alternatives should not contradict the core of the system-to-be, also the parallel development must not challenge the available human/time resources in the project. The parallel-developed design examples should regularly lead to decision points to discuss and analyze the existing alternatives and to decide on which of those approaches should be pursued and which should be rather discontinued.

XII. **Consolidate Requirements: Consider Feedback from System Design & Development**

Having a good system framework is dependent on the quality of requirements. In the iterative process of elicitation and specification of requirements, it is crucial to define a strategy to merge and validate all requirements before finalizing them. Consolidated, precise and accurate requirements listing is central to all projects, and especially significant for research projects, due to their dynamism, where it keeps the order and traceability of requirements.

Implicit ideas and considerations are milestones to derive requirements. But how to consolidate the requirements derived by different partners who are experienced in different domains and dealing with separate aspects of the system? Reaching common understanding in refining requirements is also a priority need. In iWIDGET, partners who had domain knowledge called for technical experts to specify the strategy to consolidate
requirements, while technical experts were inclined to think that domain experts knew more about the context of the requirements from content perspective. Harmonization of requirements should be agreed through discussions in which partners from all relevant domains share their ideas to achieve the objective at the end. The documents such as DoW as well as direct sources for deriving requirements, e.g. use case report for iWIDGET, should be discussed to understand the criteria in requirements consolidation. The three-step consolidation in iWIDGET, consisting of technical, content and methodology phases is a recommended approach to pursue.

Downstream tasks bring another dimension to consolidation. Despite the fact that development and system architecture are dependent on the requirements to specify the system, the technical experts interviewed believe that they do not have to wait necessarily for requirements, as experts can already understand the basics of the system-to-be from the descriptions available. In addition, such an approach helps the team consolidate requirements in place by testing them in practice. Still, interview partners from technical domain had mixed feelings about timing of system development. Even though it is stated that in the optimal case system architecture would start based on the completed requirements, in a research project it would be challenging from two perspectives: Firstly, the requirements would need to be iterated, as the team could not identify all facts and considerations at once, and contribution of teams in system development & architecture would be needed. Secondly, it would take considerably more time to finish the tasks if brainstorming the system architecture waited for requirements to be fully delivered.

Besides the three-step consolidation as applied in iWIDGET, the two-way relationship between requirements and architecture is to be noted. Existing requirements could be used for pilot system architecture, and results from design and practical application also give feedback to requirements. There is an inherent risk in specifying architecture before having a fairly complete view of requirements; however a solution to this is to design a framework on the essential underlying aspects of the system from the perspective of technical experts. The details of the system-to-be would be provided from RE process and the architecture could be enriched accordingly.
4 Conclusion

In research projects, particularities of RE had been yet to be addressed. As the quality of the outcome depends highly on the quality of requirements, knowing how to approach RE in LSIRPs is central to the entire project. The guidelines mentioned provide what considerations are useful while planning and applying RE process in a research project.

Overcoming challenges previously mentioned is a major concern for designing RE processes. As research projects such as iWIDGET have physically and culturally diverse environment, with different types of partners, capturing requirements is not a straightforward practice. This is indeed a result of challenges mentioned. Therefore, to design an appropriate RE process for an LSIRP, a responsible project team could take the suggested guidelines as a basis for their project, combined with their own touch in line with specifics of the particular research project.
References


