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People, Organizational and Technological Dimensions of Software Requirements Specification

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Abstract

A software specification can be defined as a short statement of the requirements that the software must assure. Through these requirements, software must provide facilities or capabilities to users, enabling them to achieve the specified organizational objectives. Nevertheless, the inappropriate specification of requirements is still considered one of the reasons for the failure of software development projects. One of the reasons that may explain this failure is that requirements specification tends to overvalue the technology side of requirements. Good requirements are only assured by the right combination of three dimensions: people, organization and technology. This paper reviews significant literature about software requirements management, particularly software requirements specification, identifying major issues and concerns. Through the lenses of each one of these three dimensions, several important facets of software requirements specification are analyzed, covering each of their main quality attributes. Implications for future research are discussed.

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Keywords: software requirements specification; requirements management; technological dimension; organizational dimension; people dimension

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1. Introduction

The branch of software engineering concerned with the functions and constraints of software systems that helps to accomplish the objectives of the real-world is called requirements engineering (RE) [1]. On the other hand, the main outcome of RE is the requirements specification (RS) which is a short statement of the requirements to be fulfilled by the software [2-3]. From an user perspective, a requirement can be defined as "a condition or capability needed by a user to solve a problem or achieve an objective". From the system side, it may be defined as "a condition or capability that must be met or possessed by a system or system component to satisfy a contract, standard, specification, or other formally imposed document" [4].

The complexity of requirements engineering is huge. Requirements engineering is becoming accepted as a set of processes that operates on different levels [5]. One of main difficulties of requirements engineering is the heterogeneity of the topics usually considered part of requirements. Among other topics, it may be considered the tasks that must be completed, the problems that must be solved, the solutions to problems, the ways of contributing to knowledge or types of system. This complicates the construction of a possible organization scheme [1]. Usual practical approaches of requirements specification mostly focus on objects, functions and states [6]. However, this is not sufficient. Complementary perspectives of requirements are needed, considering among other different angles of the problem, like the economy, the time, the performance or human facets. Several studies evidences the need of using alternative approaches to analyze the requirements [1, 6-8]. Another perspective about requirements specification is suggested at this article. It proposes the adoption of the lenses coming from the dimensions proposed by the Orlikowski's model to shed light the complexity of requirements specification.

The model developed by Orlikowski underlined the importance of analyzing three distinguished components: people, organization, and technology (POT). The Orlikowski's theory addresses the influences of these components and their reciprocal interactions [9]. The Orlikowski's Model of Technology (see Fig. 1) identifies four different influences: a) technology as a creation of human action, b) technology as an instrument of human action, c) organizational conditions of interaction with technology and d) institutional consequences of interaction with technology.

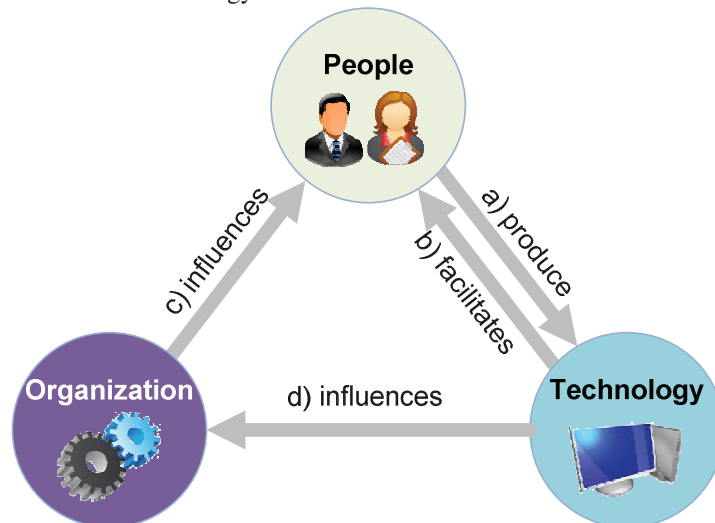


Fig. 1. People, organizational and technology dimensions and their main relations. Adapted from the Model of Technology [9].

This multi-faced vision has already been explored by other interesting researches, like the role of people, organization, and technology dimensions on the enabling of knowledge sharing [10] or on the role of information technology (IT) as a competitive advantage [11], among others [12-13]. We also propose the use of this three key proposed dimensions (people, organization, and technology) and the use of Orlikowski theory to support the observation of the requirements specification process. First, requirements specification is mainly a social interaction between people. Second, the organization is the environment in which specification process happens. Third, information technology is an important facilitator for requirements specification and it is the final beneficiary of the specification process.

According to some prestigious consultants of business and information technology (IT), the goal of Enterprise 2.0, defined as the ability to leverage business and IT strategy together to increase the effectiveness and efficiency of technological initiatives, is only possible if people, technologies and processes help the organization to fulfill its mission [14]. Yet, Enterprise 2.0 came mounted in major technological changes and so, usually suffers from excessive focus on tools and technology, neglecting processes, people and strategies needed to get sustainable success.

The people dimension includes everything that is directly related to people, either employees or customers. The importance of human issues is recognized by most executives. A Fortune survey, where 1000 executives were asked to identify their most important strategic asset, evidenced that the most named asset were employees and almost three quarters named either employees or customers [13]. Employees are connected to each other by certain organizational structure, explicitly advertised or just implicitly assumed, which affects their behavior and involvement in the project. Each involved person has a particular knowledge about the business and its processes. Of course that usually no one knows all details about how an organization runs the business. Most people know in depth some specific processes while a minority have a global vision of the business, but usually not known about the detailed aspects of their processes. Anyway, right users and stakeholders should be accordingly listen and involved at technology requirements specification process in order to technicians produce systems that satisfy their needs [8, 15]. Moreover, among others aspects, people dimension should concerns with aspects like understanding specific motivations, not only from the customer side but also from IT side [16-17], negotiation among stakeholders [18-21], suitable education of requirements contributors or readers [22] and adoption expectation of specified systems [23-24].

According to Orlikowski view, organizational dimension have the following characteristics: “structural arrangements, business strategies, ideology, culture, control mechanisms, standard operating procedures, division of labor, expertise, communication patterns, as well as environmental pressures such as government regulation, competitive forces, vendor strategies, professional norms, state of knowledge about technology, and socio-economic conditions” [9]. A central aspect of organizational dimension is the process management. First, employee’s workday are ruled by documented methods. Second, people should be trained in those documented processes. Third, processes should be followed, observed, and improved by employees and their managers. At last, successful processes should be correctly designed by management and well adopted by employees [13].

Technology dimension includes material artifacts such as the software and hardware employed by people in organizations in order to perform their job [10]. The variety of technological topics is enormous, including concerns like the technology used in various aspects of business or projects activities [8, 20], impact of the proposed new technology [4, 25-26], existing or future interfaces [4], system migration issues [21], compatibilities issues, different suppliers or technological consultants subjects, system development lifecycle [21, 27-28], maintenance issues, security issues, prioritization methods or requirements representation [4, 8, 21]. Yet, although the potential of today's technology, with high processing speed, large storage capacity, elevated bandwidth and rapidly diminishing cost, "a vanishingly small percentage of that potential has

actually been realized" [13]. Definitively, technology must be purchased or developed taking into account people and organization.

Among the people, organization and technology, it is common the idea that technology often appears as the first concern of the three. Although most managers convey the idea that they have more concerns with people than with technical issues, they rarely act this way. And the main reason for managers to have a greater focus on technique than on the human side of work is not because it is more vital, but because it is easier to achieve [29]. Therefore, people should appear as the first concern.

The document that describes all the externally visible behaviors and expected characteristics of a software system is usually called the software requirements specification (SRS) [25]. This document is one of the early outputs in the process of software development. Among the most important qualities that an SRS must have, we highlight the following [4, 25, 30-31]: clearness or unambiguously, completeness, correctness, understandability, verifiability or validity, consistency and feasibility.

The lenses of Orlikowski multi-dimensional view will help to highlight the specificities of each of the three different perspectives of requirements specification, evidencing advantages over previous proposed approaches. This paper analyzes software requirements specification, covering each of the main attributes, through the lenses of people, organizational and technological dimensions.

2. Analysis through people, organizational and technology lenses

This session shortly presents the meaning typically associated to each quality attribute of software requirements specification. Moreover, it raises several questions, some supported by relevant references, placed at each one of the three dimensions, evidencing a larger scope of analysis for each attribute. This paper presents an excerpt of pertinent questions, obviously not intending to provide an exhaustive list of all possible issues. The questions reference some literature that addresses each issue and also shows that some subjects may be less well covered. The adoption of a question format instead of statements was a deliberate approach option. Presenting a list of things to do or to take attention could be done, but a "system of questions is more consistent with the spirit of curiosity, wonder, and intellectual adventure essential to critical thinking" [32].

If a requirement can only be interpreted in only one way, it may be classified as unambiguous [4]. A SRS can be defined as clear or unambiguous if each of its requirements is unambiguous [25]. Yet, this definition doesn't totally take into account the complexity of the real-world, because the interpretation is a subjective process and because there is a very different range of people involved in the requirement specification process.

Also, when everything that the software is assumed to carry out is considered it may be said that we are facing a complete SRS [25]. The Institute of Electrical and Electronics Engineers (IEEE) standard 1233 states that a completed SRS should include all customer requirements, as well as those needed for the definition of the system. Moreover, it should have all pages, tables and figures numbered, all terms defined, all units provided and all referenced material present. Finally, it should not have any to be determined (TBD) sections [4]. Table 1 presents several questions at each of the three analyzed dimensions which should be raised about SRS clearness/unambiguously, completeness and correctness.

Correctness is typically one of the most referenced attributes of a good SRS. A SRS is normally classified as correct when every requirement contributes to the satisfaction of some need [25]. Despite knowing that perfection is a goal that is usually not fully attainable, it does not mean that it should not be attempted. Whenever things are detected as incorrect, the specification should be kept updated [27]. Although IEEE standard 1233 do not explicitly talk about a correctness attribute, it underlines the importance of repeating the process of correcting the initial requirements errors or to add new requirements to enhance the systems features [4].

Table 1. Clearness/unambiguously and completeness questions at POT dimensions

	People dimension	Organizational dimension	Technological dimension
clearness/unambiguously	<ul style="list-style-type: none"> • Do partners have the right domain knowledge to interpret the requirements specification [8, 20, 33]? • Is the type of RS discourse proper [8]? 	<ul style="list-style-type: none"> • Is the transformation process of the information obvious? • Are language and modeling techniques suitable to understand the system objectives [20]? 	<ul style="list-style-type: none"> • Do IT team understood the technological impact of the requirements [26]? • Do requirements have clear needs assessment done [8, 20, 33]? • Are requirements properly elicited [21]?
completeness	<ul style="list-style-type: none"> • Were all partners listen on SRS completeness [20]? • Are the requirement tests made by the correct persons [4]? • Was prioritization a result of an adequate negotiation among stakeholders [18-19]? • Were specific motivations taken into account (at customer and IT side [16-17]? • Is there an incentive policy oriented to build a complete system [16-17]? 	<ul style="list-style-type: none"> • Does the process of information transformation contain all relevant parts of the real process? • Did prioritization take into account the business requirements [18-19]? • Did requirements specification considered customer requirements [4]? • If there is a request for proposal (RFP), was the requested requirements considered [4]? 	<ul style="list-style-type: none"> • Are requirements fully specified [21]? • Is still there any TBD task [3, 20]? • Were requirements and its tests planned and approved by users/customer [4]? • Is it worthy to build and run a prototype [33]? • Was there reuse of RS of existing systems [20-21]? • Is the RS compatible with external system interfaces [4, 20]?
correctness	<ul style="list-style-type: none"> • Where requirements approved by the right customer [33]? • Are the requirement tests made by the correct persons [20]? • Was the negotiation process well conducted [20-21]? • Were the software requirements in accordance with users and stakeholders requirements [15]? 	<ul style="list-style-type: none"> • Is the process of transforming the information correct [3]? • Is the delivery of each process correct [3]? • Is the detail modeling coherent with higher models [4]? • Were the software requirements in accordance with business requirements [15]? 	<ul style="list-style-type: none"> • Were requirement tests approved by customer or users [4]? • Was the prototype in accordance with the needs [3, 20, 33]? • Was it used a negotiation tool [20]? • Are requirements well specified [21]?

The understandability of a SRS occurs if all types of SRS readers can easily comprehend the meaning of all requirements with a minimum of explanation [25]. Since SRS readers may be so diverse as customers, users, project managers, programmers, testers or business managers, must be taken a particular attention to the writing of the requirements. The natural language assumes a special importance because the majority of requirements specification are written in that way. The assurance of the readability of requirements includes the usage of simple words/phrases/concepts, the uniform arrangement and relationship, the definition of unique words/symbols/notations and the use of grammatically correct language and symbology [4]. Table 2 presents some relevant issues about understandability and verifiability/validity at the three analyzed dimensions.

Table 2. Correctness and understandability questions at POT dimensions

	People dimension	Organizational dimension	Technological dimension
understandability	<ul style="list-style-type: none"> • Were clients amply involved to dismiss eventual miss of understanding [8]? • Are SRS readers sufficiently educated on business process modeling [22]? • If not, is there an alternative representation in natural language [8]? • What initiatives were planned to deal with different adopted languages? 	<ul style="list-style-type: none"> • Are goals, business rules and high levels of requirements understandable [8]? • Is the enterprise model clear [34]? • Is the data model clear [34]? • Is the behavioral model clear [34]? • Are business processes modeled in an understandable way [22, 34]? • Are the concepts clearly presented [4]? 	<ul style="list-style-type: none"> • Could it help the use of a tool to analyze requirements sentences potentially ambiguous [8]? • Were common ambiguities of writing requirements in natural language avoided (e.g. misplacement of words like "only") [8]? • Are the words and phrases simple [4]?
verifiability and validity	<ul style="list-style-type: none"> • Are V&V done by the right people? • Are requirements tests acceptable in terms of human lives costs [25]? • Are there enough human resources to make the planned V&V? 	<ul style="list-style-type: none"> • Are requirements aligned with mission and organizational objectives? • Is the expected time to test requirements acceptable? • Is the expected cost to test requirements acceptable [25]? 	<ul style="list-style-type: none"> • Does any requirement corresponds to an undecidable problem [25]? • Is there a validation & verification (V&V) plan [27]? • Is there any framework or tool to support acceptance tests [28]?

A verifiable SRS must have available techniques, at an acceptable cost, used to verify that every specified requirement are satisfied by the system when built [25]. IEEE 1233 standard uses the attribute "validatable" to characterize requirements that have the means to prove that the system satisfies it [4]. Usually these two concepts are closely linked. Verifiability wants to ensure that system "do the thing right" while validity wants to ensure that system "do the right thing". Verification and validation (V&V) of requirements may become difficult if requirements are ambiguous, because different interpretations may occur [27]. Also, undecidable requirements, like "the system shall never halt" based on the halting problem, are not verifiable. Finally, some requirements should not be specified because they aren't worth the cost of their tests [25].

Moreover, the content of a SRS should be consistent and non-contradictory. This attribute should be valid in the level of detail, style of requirement statements, and in the presentation of material [4]. Some authors use the concepts of internal and external consistency. On one hand, there is an internal consistency of a SRS if and only if no subset of individual requirements stated therein conflict. On the other hand, an external consistency exists if and only if there are no requirement conflicts with any other baseline project documentation [25].

At last, feasibility is usually considered an extremely important requirement attribute as well. A SRS is consider feasible if all its requirements can be implemented with the available technology, human resources and budget. On the other hand, when including a requirement in the system project, it means the requirement is worthy to be included because it contributes positively to the return of that investment [20]. Feasibility evaluation depends on the present state of technology (e.g., commercially available components or new development), the customers environment (e.g., readiness or acceptance to change), and the risk or cost associated with each requirement [4].

Table 3 presents some issues concerning consistency and feasibility attributes on people, organizational and technological dimensions of a SRS.

Table 3. V&V, consistency and feasibility questions at POT dimensions

	People dimension	Organizational dimension	Technological dimension
consistency	<ul style="list-style-type: none"> • Are requirements consistent with defined human resources policies? • Are requirements consistent with established culture [20]? • Are software requirements conflicting with other baseline project documentation (for example; user requirements) [25]? 	<ul style="list-style-type: none"> • Are hierarchically dependent requirements consistent with each other [20]? • Are requirements consistent with government and industries policies or standards [4]? • Are RS conflicting with other baseline project documentation (e.g.; business requirements) [25]? 	<ul style="list-style-type: none"> • Is management of the SRS file well done? • Do RS process use any tool which may allow the detection of inconsistencies [21]? • Are models consistent (e.g. ER diagrams) [21]? • Is data-dictionary consistent [21]? • Are RS consistent with technological policies or standards (e.g. safety or maintenance standards) [4]?
feasibility	<ul style="list-style-type: none"> • Are the appropriate human resources necessary to develop requirements available? • How can stakeholders find feasible alternatives [20]? • What kind of training is necessary? • Is change management planned [20]? • What is the expected system’s level of adoption [23-24]? 	<ul style="list-style-type: none"> • Are the requirements too costly to develop [20]? • Are the requirements too time consuming to develop [20]? • Does the system functionalities allow the desirable organizational changes [20]? 	<ul style="list-style-type: none"> • Are the requirements too difficult to develop? • Should requirements be developed internally or externally? • To what extent the proposed system is compatible with existing systems [20]? • Is there a change management tool [20]?

There is no enough space to discuss other quality attributes usually also considered important in a SRS. Among others, we have traceability [3-4, 25], conciseness [25], electronically stored [25], uniquely [4, 25], modifiability [3-4, 25], granularity [4], reusability [25], degree of stability [3, 25] or degree of necessity [3, 25].

3. Conclusions and future work

The complexity of requirements specifications process is huge. Diverse preceding researches evidenced different issues, perspectives and concerns about requirements specification. However, until now, requirements specifications process has not yet been seen through the lenses of people, organizational and technological dimensions. This article highlights some issues at each one of these three dimensions, using questions organized by some of most important quality attributes of requirements. The employed quality attributes were clearness/unambiguously, completeness, correctness, understandability, verifiability/validity, consistency and feasibility.

The multi-dimensional perspective proposed at this article evidences several advantages at the requirements specification process. First, it values the human side of the requirements specification more than other previous perspectives. Above all, human aspects are usually underestimated, either at the IT team side,

or at the user and client side. These human issues should involve the Chief Human Resources Officer (CHRO) and the managers directly involved at the negotiation process, including the Chief Information Officer (CIO).

Second, typically, there are different managers for each of human, organizational and technological dimensions, each one with a different and biased perspective. Although there is normally a project manager, which is responsible for coordination of the all project, the experience of the project manager gives him a limited perspective of the software requirements specification process valuing more some dimensions than others. This biased perspective may overemphasize some needs, prejudicing some others. The organizational needs must be balanced with the development efforts, its complexity, its costs, time and specially taking into account not only the technological environment, but specially the human aspects which are normally neglected.

Third, the dimension separation of people, organization and technology, facilitates the requirements specification process and the negotiation between the involved parts. This happens because it evidences the issues at each dimension, eventually its costs, risks and consequences. The main relations between people, organization and technology, evidenced by the Orlikowski's Model of Technology [9] may also be underlined to help to specify the software requirements. Summarizing, users, stakeholders and developers, adequately influenced by the organization should work together to produce and use good technological products. These products will facilitate the people work-life. Consequently, people may work better and more efficiently, improving the organization.

Finally, the analysis of requirements specification through quality attributes allows a richer evaluation of the quality of the SRS. The guidance on the quality attributes will strengthen the role of the three-dimensional analysis on the process of software requirements specification. Also, a better understanding about SRS quality will let to detect SRS errors and avoid them to happen, reducing their costs to detect and repair [24].

There are other quality attributes that can be associated to requirements which were not analyzed at this article. Future work may use those extra attributes to complement the present research. Additionally, this article presents just an excerpt of questions at each dimension for each requirement attribute. Other different questions and a practical application can also be envisaged in future work.

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