NOTE – This is a pre-print version of the paper: de la Vara, J.L., Wnuk, K., Berntsson-Svensson, R., Sánchez, J., Regnell, B. (2011) An Empirical Study on the Importance of Quality Requirements in Industry. In: 23rd International Conference on Software Engineering and Knowledge Engineering (SEKE 2011) (accepted paper)

An Empirical Study on the Importance of Quality Requirements in Industry

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***Abstract*— Quality requirements can constrain many aspects of a software system and have a strong influence on its success. Therefore, they play a major role in the development of any software system. As software systems are designed to achieve various goals and perform different functions, the order of importance of quality requirements may vary depending on these goals and functions. Within this context, this paper aims to gain new insights into how industry deals with quality requirements. More specifically, its purpose is to analyze the importance of different types of quality requirements. An empirical study has been performed in order to determine practitioners' perspectives on this issue. The paper reports on a survey in which product managers, project leaders and programmers with different backgrounds have participated. Consequently, the paper provides further evidence about the perceived importance of types of quality requirements and how the importance may be different depending on the practitioners' roles, the types of project, the orders of magnitude of the requirements or the application domains.**

Keywords- requirements engineering, empirical study, survey, quality requirement, non-functional requirement, industry.

I. Introduction

The requirements of a software system can be considered the main indicators of its success [16] and of its quality [10]. As a result, the requirements engineering (RE) process has been widely recognized as the most important development stage. Not adequately addressing it can lead a software system to failure and increase its development time and cost [7].

Among the types of requirements for a software system [14], quality (aka non-functional) requirements (QRs) specify restrictions on a software system and how well it shall perform its functions. Some typical examples of types of QRs are usability, performance and security. The influence of these requirements on the success of a software system has been acknowledged both in academia [5] and in industry. Organizations can face many problems when dealing with QRs [4], and they can strongly constrain decisions related to important aspects of the development of a software system such as its architecture [23], planning [19] and evolution [8].

An important issue about QRs is that the importance of the types of QRs is not always the same. For example, it can vary among stakeholders' roles [11], types of project [2] and application domains [8]. If practitioners disregard this issue, then they may develop software systems whose quality is insufficient and/or does not meet the actual needs of its stakeholders. As a consequence, a project or a system may fail.

This paper aims to gain new insights into the importance of QRs in industry. For this purpose, an empirical study in the form of a questionnaire-based survey is presented. 31 practitioners from 25 organizations participated in the survey and determined the most important types of QRs for them and the rationale behind their decisions. The respondents also indicated their role, the types of project in which they participate, and the order of magnitude of the requirements [20] and the application domain of the projects.

The results of the study provide novel empirical evidence about the perceived importance of types of QRs in industry and how it may vary. Results are presented and analyzed for: a) product managers, project leaders and programmers; b) development of internal, contract-driven and market-driven software; c) small, medium and large-scale RE, and; d) public administration, telecommunications and software development application domains. The value of the results is twofold. First, they can help practitioners to determine the types of QRs that may be more important for a given software system and possible conflicting priorities on the QRs. Second, they can be very useful for academia to formulate hypotheses for new studies and to identify areas for further research.

The paper is organized as follows. Section II presents background and related work. Section III explains the research methodology that was followed. Section IV presents and discusses the results of the study. Finally, Section V summarizes our conclusions and future work.

II. Background and Related Work

Gaining insights into RE practice has been and is an important goal for the RE research community [17], and empirical studies are essential to achieve it. Important contributions have been made up to date, but more studies are necessary yet. The first significant empirical study on RE practice [6] was published in 1988. Since then, many issues of RE in industry have been analyzed, including QRs.

This work has been developed with the support of the Spanish Government under the project PROS-Req TIN2010-19130-C02-02 and the program FPU AP2006-02324, the Valencia Regional Government under the project ORCA PROMETEO/2009/015, and ERDF.

Several facets of QRs such as elicitation, dependencies, metrics, cost estimation and prioritization have been addressed in empirical studies. A systematic literature review on them is presented in [3]. Among the studies listed in the systematic review and others published after the search of the systematic literature review was performed, we have found publications that addressed priorization and/or focused on the importance of types of QRs in industry. These works are the following ones.

Haigh [11] performed the existing survey with the largest sample. 318 students and alumni of a MBA ranked the importance of types of QRs on the most important software system in developing their work responsibilities. The factors analyzed were the stakeholders' role and the type of system. In a similar line, Berntsson Svensson et al. [2] examined how QRs of embedded systems were handled. They interviewed product managers and project leaders from five organizations, and analyzed the importance, interdependencies, quantification, dismissal, challenges and non-challenges of QRs.

Leung [15] conducted a user survey on QRs of intranet applications for which he obtained 30 valid responses. Another study on specific products was presented in [22]. A process framework for customization of software quality models was proposed and validated with two software products. The importance of types of QRs in the products was determined.

A survey with respect to cost and lead-time impact in development of software platforms is presented in [12]. This study analyzed 34 responses from two organizations and addressed the architect, system designer and marketing roles. Ameller and Franch [1] also analyzed QR-related practices of architects. 60 subjects participated in a web survey, and they indicated the importance of types of QRs in their projects.

Finally, Ernst and Mylopoulos [9] studied the importance of QRs along project lifecycle and the interest on them in different projects. They analyzed mailing list discussions, bug reports and commit logs of eight open-source products.

The contribution of this paper on understanding the perceived importance of QRs in relation to these works are that 1) it provides new insights about factors and treatments that have been studied previously (e.g., importance for project leaders), and 2) analyzes factors and treatments that have never been addressed (e.g., order of magnitude of requirements and software for public administration). With regard to the results of these works about common factors, they are used in Section IV for comparison with the results of this paper.

III. Research Methodology

The empirical study that is presented corresponds to a part of a survey on RE practices and perspectives in industry (hereafter referred to as wider survey). It was performed using a mixed research approach [21], i.e., there are parts of the study that correspond to quantitative (fixed) research whereas others correspond to qualitative (flexible) research.

On the one hand, some parts of the study and its analysis were pre-specified, e.g., overall rating of the importance of the types of QRs on the basis of the percentage of respondents that selected the types. These parts aimed to obtain quantitative data for comparison of variables and corresponded to the fixed side of the study. On the other hand, analysis of other parts evolved during the research process, e.g., analysis of some factors was not initially intended but was later decided. In addition, we aimed to investigate and understand phenomena within its real context and to seek new insights, ideas and possible hypotheses for future research. These conditions allowed us to regard the study as qualitative [18].

The following two subsections present the research process that was performed and discuss the validity of the survey.

A. *Research Process*

The study was performed through 6 stages [13].

Objectives definition: The first stage of the study involved brainstorming and meetings to identify the areas of interest. Of all the objectives of the wider survey, this paper addresses further understanding of the importance of QRs in industry. The research questions analyzed are: **RQ1:** What types of quality requirements are considered the most important ones by practitioners? **RQ2:** Is there any difference in the perspectives about their importance among roles, types of project, orders of magnitudes of the requirements or application domains?

Survey design: The survey was cross sectional [13] and explorative [25], and was administered by means of a web-based self-completion questionnaire. As explained above, a mixed approach was followed.

Development of a survey instrument: Relevant literature has been presented in Section II. The survey instrument was created with inspiration from [2]. We defined 21 types of QRs on the basis of Lauesen's comparison between ISO 9126 and McCall quality factors [14]. In addition to background information (about the possible factors and treatments to analyze), respondents were asked to indicate 1) the top five most important types of QRs, 2) the most important type, and 3) why they regarded that type as the most important one. Before listing the questions, a description of the survey was provided. It must also be indicated that more questions were asked for the wider survey.

Since the first and the fourth authors were initially responsible for data collection, it was expected that most of the respondents worked in Spain. Nonetheless, it was also planned to obtain responses from other countries. As a result, a Spanish version and an English version[1] of the (same) questionnaire were created. The expected time for completing the questionnaire (wider survey) was between 10 and 15 minutes.

Instrument evaluation: Four pilot studies were conducted for pre-testing, two for each version of the questionnaire. Time for completion was within our expectations, and some minor changes were made in question wording.

Data collection: Respondents were selected through a combination of maximum variation, convenience and snowball sampling [18] within our industrial collaboration network. We mainly aimed to obtain responses from product managers, project leaders and programmers of different organizations,

[1] http://hci.dsic.upv.es/jdelavara/REsurvey_instrument_en.pdf

TABLE I. SUMMARY OF RESPONSES AND RESULTS

Factor	Treatment	n	Top 5 types			#1 type	
			SEL	N_SEL	J_SEL	SEL	J_SEL
Role	Product manager	6	PERF (1), USAB (2), STAB (2)	MAIN	-	-	-
	Project leader	14	USAB (1), MAIN (2), SUIT (3) FLEX (3), SECU (5)	-	-	SUIT (1), USAB (2)	SUIT
	Programmer	11	MAIN (1), PERF (2), USAB (2)	-	-	-	-
Type of project	Internal software	6	MAIN (1), USAB (2), RELI (2), SUIT (2)	STAB	-	-	-
	Contract-driven	9	MAIN (1), USAB (2), PERF (3), CORR (4)	-	-	-	-
	Market-driven	10	PERF (1), USAB (1), RECO (3), RELI (3)	-	RECO	USAB (1)	-
Order of magnitude	Small	11	MAIN (1), USAB (2), PERF (3), FLEX (4)	-	-	USAB(1)	-
	Medium	8	USAB (1), MAIN (2), RELI (2)	-	ANAZ	MAIN (1)	MAIN
	Large	7	USAB (1), MAIN (1), PERF (3), SECU (4)	-	-	-	-
Application domain	Public admin.	9	USAB (1), MAIN (2), RELI (3)	-	CORR	-	-
	Telecom.	4	PERF (1), FAUL (2)	-	-	-	-
	Sw. development	4	USAB (1)	-	-	-	-

Types of QRs: analyzability (ANAZ), correctness (CORR), fault tolerance (FAUL), flexibility (FLEX), maintainability (MAIN), performance (PERF), recoverability (RECO), reliability (RELI), security (SECU), stability (STAB), suitability (SUIT), usability (USAB).
Perspectives: selected in the treatment (SEL), not selected just in that treatment of the factor (N_SEL), just selected in that treatment of the factor (J_SEL).

thus we focused on potential respondents' role for sampling. The role was the only treatment for the people contacted that we knew for all of them before analysis. They worked for regional, national and multinational organizations.

Analysis: This stage was performed by the first and the fourth author. 35 responses were obtained, but four were rejected because of inconsistent or lack of information. One was modified because the respondent indicated software testing as application domain ("other" option), which was considered to be part of software development. Therefore, we finally analyzed 31 valid responses (data points), 22 from the Spanish version of the questionnaire and 9 from the English one. The respondents worked for 25 different organizations[2]. Three responses from two organizations, two from two organizations and one from the rest of organizations were obtained. One respondent worked for several organizations, but it was regarded as a single organization for analysis.

After overall rating of the types of QRs, partition of responses involved determination of the factors (e.g., respondents' role), treatments of the factors (e.g., project leader) and perspectives in a treatment (e.g., usability is a top five type) that should be reported and thus analyzed according to the scope of the paper. Some criteria for determination of results to report and analyze were defined (Table II).

Criteria for respondent's perspectives aimed to determine selections and no selections of perspectives to analyze. P1 is related to the importance of a perspective in a treatment in general. P2 is related to the non-importance of a perspective in comparison to other treatments of a factor, and P3 in comparison to other perspectives of a treatment. P4 is related to the importance of a perspective just for a treatment. T1 and T2 aimed to determine the treatments to analyze, and F1 to determine the factors. These criteria apply to the whole questionnaire. Some extra ones for analysis and report of specific questions are described in Section IV.

Table I shows a summary of the data points (n) of the treatments (twelve) of each factor (four) that was considered for analysis. Most of the factors had less than 31 data points due to answer exclusions, i.e., the rest of data points until 31 correspond to answers that were not part of any of the treatments defined. Finally, it must be indicated that statistical tests [25] were not used for analysis. We did not use probabilistic sampling methods, thus statistical inferences could be made in the survey [13].

TABLE II. CRITERIA FOR DETERMINATION OF RESULTS TO ANALYZE

Criterion	Description
T1	A treatments is not analyzed if it has less than four data points (less than 10% of the sample)
P1	A perspective in a treatment that fulfils T1 is analyzed if at least three participants of the treatment (75% of the smallest sample for a treatment) selected the perspective
P2	A perspective in a treatment that fulfils T1 is analyzed if no participant selected the perspective but P1 is fulfilled in the perspective for all the other treatments of the same factor
P3	A perspective in a treatment that fulfils T1is analyzed if no participant selected the perspective but P1 is fulfilled in all the other perspectives of the same treatment
P4	A perspective in a treatment that fulfils T1 is analyzed if it fulfills P1 and P1 is not fulfilled in the perspective for all the other treatments of the same factor
T2	A treatment that fulfils T1 is not analyzed if it does not have any perspective that fulfils P1, P2, P3 or P4
F1	A factor is not analyzed if it all its treatments fulfill T1 or T2

B. Validity

This section discusses how threats to validity were addressed. We consider the four perspectives proposed in [25].

Construct validity: This validity is concerned with the relationship between a theory and its observation. Mono-operation bias was avoided by collecting data from respondents with different backgrounds, and evaluation apprehension by guaranteeing anonymity and confidentiality when publishing the results. A remaining validity threat was the provision of lists for determination of background information and selection of types of QRs. It may have been easier for respondents to use the list items provided than to propose others.

Conclusion validity: This validity is concerned with the relationship between a treatment and the conclusions drawn from it. For reliability of measures, pilot studies were

[2] Although identification of respondents' organization is not necessary for analysis in this paper, it is for some parts of the wider survey.

conducted and all the types of QRs and concepts that may have been unknown to the respondents (e.g., small-scale RE) were briefly described in the questionnaire. Reliability of treatment implementation was achieved by providing the same questionnaire to all respondents. We also consider that the criteria defined for analysis increased the possibility to draw correct conclusions. A remaining validity threat is the fact that the treatments determined for each factor have different data points. The influence of this fact on overall rating of the types of QRs is further discussed in Section IV.

Internal validity: This validity is concerned with the causal relationship between a treatment and its results. Maturation was addressed by designing an instrument whose completion should take between 10 and 15 minutes. Pilot studies and development of the questionnaire with close reference to literature and influence of an administered and validated existing instrument reduced instrumentation threats.

External validity: This validity is concerned with the generalization of the conclusions. Given the exploratory and qualitative nature of the study, it does not aim to generalize conclusions beyond its actual setting, but to explain and understand the phenomena under analysis. Nonetheless, understanding the phenomena may help in understanding other cases. Interaction of selection and treatment was avoided by just contacting product managers, product leaders and programmers for data collection. In addition, many results and conclusions coincide with the studies outlined in Section II.

IV. Results and Interpretation

This section describes and discusses the results of the study. They have been divided into selection of the set of top five types of QRs and selection of the most important type.

A. *Top Five Types of QRs*

This section presents the results that were obtained when respondents selected the top five types of QRs for them. When reporting the results (in Table I and in the text), the ranking of the types is put in brackets. The ranking was determined by ordering the types of QRs on the basis of the percentage of respondents that selected them. It must be noted that the respondents did not rank the types when selecting the top five ones, but just selected the five types of QRs that according to them were the most important ones.

Figure 1 shows the overall rating of the types of QRs as top five types in the survey. Usability (1), maintainability (2), performance (3), reliability (4) and flexibility (4) are the five types with the highest overall frequencies. Therefore, they are the overall top five types of QRs in the survey.

The number of times that these types were selected as top five in the twelve treatments is: eleven times for usability, nine for maintainability, seven for performance, four for reliability, and two for flexibility. This order is equal to the overall rating except for flexibility. Just security (sixth type) and suitability (eighth type) were selected the same number of times (two treatments in total) than some of the overall top five types. Therefore, we consider that the threat related to not having balanced data points did not strongly affect the overall rating.

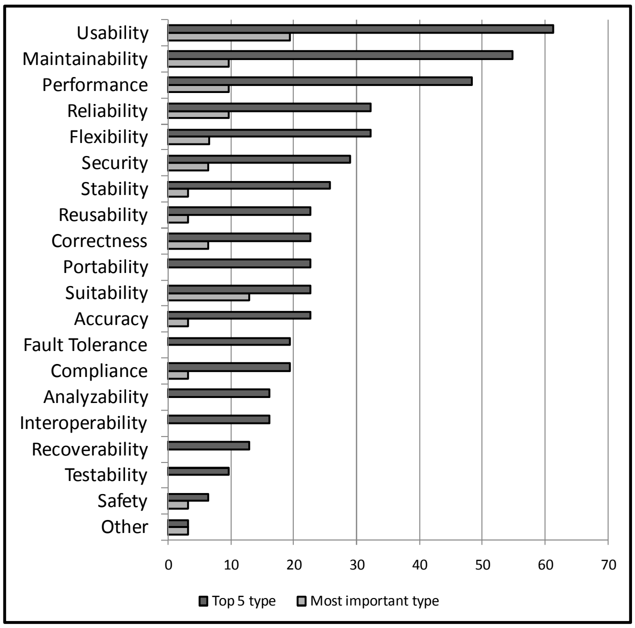

Figure 1. Overall selection frequencies of the types of QRs.

No respondent selected installabilty or replaceability, and one selected the "other" option. He specified *"hard core performance (speed and uptime, 99.999)"*, what we consider a specialization and combination of performance and reliability. This indicates that the types of QRs used in the survey can be combined when specifying requirements, and suggests that a clear cut between the types may not always exist in industry.

The overall rating is in line with related work. The most different results were the high ranking of accuracy and the low rankings of performance and flexibility in [11], and the low ranking of usability in [12]. The focus on software systems that respondents used and software platforms, respectively, may be the reasons. The results of [15] have not been considered for comparison because it just studied users' perspectives.

Table I shows a summary of the results for the treatments of each factor. The "SEL" column corresponds to perspectives that fulfill the criterion P1 (see Section III), the "N_SEL" column to perspectives that fulfill P2, and the "J_SEL" column to perspectives that fulfill P4. Less than five types of QRs are reported if P1 is not fulfilled (e.g., just one respondent selected the fifth type) or if more than five types should be reported (e.g., the fourth and seventh types have the same frequency).

When analyzing respondents' role, we can see that usability is a top five type for the three roles, and performance and maintainability for two. The difference in the selection of other types of QRs indicates that perspectives may vary among stakeholders. In relation to related work, performance, usability and stability were top five types of QRs for product managers in [2], and usability, maintainability and flexibility were for project leaders. In [11], maintainability and usability were top five types for developers, and maintainability and stability were for managers of development. The most different result is that no project leader selected suitability in [2].

For types of project, again just usability is ranked as a top five type for all the types of project, whereas maintainability, performance and reliability are for two. Four types of QRs are top five types in several types of project, thus it seems that there is less variation in this factor than in others. Nonetheless, this factor is the only one in which the criteria P2 and P4 are fulfilled. The high importance of usability, performance and reliability for market-driven development was reported in [2][9][12]. However, recoverability was lowly ranked in [2].

With regard to the order of magnitude, maintainability and usability are top five types in all the scales, and performance is in two. The impact of the order of magnitude of requirements on the importance of QRs has not been previously analyzed. Therefore, no comparison is possible. Nonetheless, we think that the results suggest that it is a factor that can have influence, although the coincidences in perspectives may indicate that the influence of the factor is lower than of others.

Concerning specific application domains, we can see that just usability is a top five type for more than one domain. This is the factor with the lowest number of coincidences between treatments. Although the low number of data points of the treatments and of perspectives reported affects them, the results suggest that this factor has a higher influence on the variation of the importance than others. The importance of performance and fault tolerance in telecommunications was acknowledged in [8], and usability was reported as a top five type of QRs for development tools in [11].

In summary, the results provide new evidence about the fact that some types of QRs are more important than others in industry and that their importance can vary depending on stakeholders' roles, types of project, orders of magnitude of requirements and application domains. It also seems that some factors may have more influence on variation than others, and that the types of QRs used in the survey can be combined for specification. Finally, many hypotheses can be formulated from these results and could be tested in new studies. For example, that the importance of recoverability is higher in market-driven development than in other types of project.

B. *Most Important Type of QRs*

This section presents the results that were obtained when respondents were asked to select the type of QRs that was the most important one for them and to justify the selection. The first question allowed us to further analyze the results about the top five types, whereas the second one allowed us to gain new insights into the perceived importance of QRs.

Figure 1 shows the overall selection frequency of the types of QRs as the most important one. Usability (1), suitability (2), maintainability (3), performance (3) and reliability (3) are the types most frequently selected. This result is very similar to the overall rating of the types of QRs as top five types. The main difference is the presence of suitability. Further analysis of this fact shows that more than half the respondents that selected suitability as a top five type also selected it as the most important one. No other type has reached such a high frequency as most important type in relation to its selection as a top five type (if the "other" option is not considered). This suggests that when practitioners care about suitability, it is usually really important for them.

Table I shows a summary of the results. They further indicate the importance of suitability for project leaders and of usability in general. Usability is the only type that is ranked as the most important type of QRs and whose selection is reported for several treatments. With regard to the result about maintainability, we consider that it may need further study.

Maintainability was highly ranked in all the orders of magnitude of requirements when asking the top five types, but its selection as the most important type just in medium-scale RE suggests that the type is more important in that scale. This may have happened because of different reasons. For example, it may be thought that organizations that deal with large-scale RE need (and thus have) more mature software development processes, which impose execution of practices targeted at facilitating maintainability. Once these practices have been introduced, maintainability may be easier and consequently its perceived importance may decrease. Although important, the type would not be the most important one.

When reviewing the reasons behind selection of the most important type of QR, we realized that answers could be divided into three categories: product, project and customer-oriented. An example of product-oriented answer is *"flexibility is necessary for adaptation of a product to new use cases"*, of project-oriented answer is *"highly confidential data are managed in the projects"*, and of customer-oriented answer is *"security is the main point that clients demand"*. This division allowed us to perform two analyses that had not been planned and have not been addressed in any previous publication.

First, we analyzed the frequencies of the categories. Customer-oriented answers are the most frequent ones (at least half the answers had this orientation) for project leaders, market-driven development and small-scale RE, whereas product-oriented answers are for medium-scale RE. No product manager gave a project-oriented answer, and the perspective fulfilled the criteria P2 and P3. Finally, no product-oriented answer was obtained from small-scale RE and the perspective fulfilled P3. This analysis indicates that focus on products, projects or customers when dealing with QRs may vary depending on some factors.

Second, we realized that another analysis was possible. On the basis of existing works [24], we classified the types of QRs selected as the most important one into more important for users (customer-related) and more important for developers (development-related). Maintainability, flexibility, stability and reusability were considered development-related types of QRs, and the rest of types selected as the most important one were considered customer-related types.

Figure 2 shows the theoretical and actual frequencies of customer-related and development-related answers. The theoretical one was calculated on the basis of the previous classification and the selection frequency of the types of QRs as the most important one, whereas the actual one was calculated on the basis of the frequency of the categories of justification answers. The actual frequency of development-related answers was considered to be the sum of the frequencies of product-oriented and project-oriented answers, i.e., we considered that product-oriented and project-oriented answers were development-related.

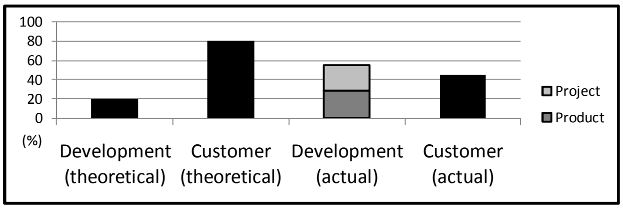

Figure 2. Frequencies of customer-related and development-related answers to justify the selection of a type of QRs as the most important one

Although the actual frequency of customer-related answers is the highest one in the survey, it is lower than in theory. This result suggests that there is a gap between theory and practice on the importance of types of QRs for customers or for development. Difference in the perception of types between academia and industry was discussed in [2], although not in relation to their importance for development and customers.

In summary, the results are in line with those from top five types of QRs. An exception is suitability, whose importance seems to be especially high for the practitioners that focus on it, and maintainability seems to be more important for medium-scale RE. The results also suggest that product, project and customer orientation when considering a type as the most important one may vary, and that there is a difference on this issue between theory and practice. Again, hypotheses can be formulated, such as that market-driven development mainly focuses on customers when prioritizing QRs.

V. Conclusions

This paper has presented an empirical study on QRs in industry. By means of a questionnaire-based explorative survey, practitioners' perspectives on the importance of types of QRs were obtained.

The results of the survey provide more and new evidence about how the importance of QRs may vary in industry. In general, usability, maintainability and performance are the three most important types for product managers, project leaders and programmers. Nonetheless, the importance of all the types may vary depending on different factors. Among them, evidence of variation has been provided for practitioners' roles, types of project, orders of magnitude of the requirements and application domains. In addition, although practitioners usually think of customer issues when selecting a type of QRs as the most important one, they may also think of development issues even when dealing with customer-related types.

The most immediate future work is to analyze the answers to the rest of questions of the wider survey. New empirical studies would also allow us to gain more insights into the importance of QRs in industry. These studies should aim to test hypotheses formulated from the results of this paper or to further analyze some phenomena by means of different empirical studies. For example, case studies would allow us to analyze the importance of QRs in project development settings.

Acknowledgment

The authors would like to thank all the people that participated and collaborated in the study, and Jose Ignacio Panach and Jose Luis Hervás for their comments on analysis.

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