Issues Dealing with Non-Functional Requirements Across the Contractual Divide

Eltjo R. Poort  
Logica  
Amstelveen, The Netherlands  
eltjo.poort@logica.com

Andrew Key  
Logica  
London, United Kingdom  
andrew.key@logica.com

Peter H.N. de With  
Eindhoven University of Technology  
The Netherlands  
p.h.n.de.with@tue.nl

Hans van Vliet  
VU University  
Amsterdam, The Netherlands  
hans@cs.vu.nl

Abstract—Agreement on Non-Functional Requirements between customer and supplier is crucial to a successful IT solution delivery project. In an ideal world, stakeholders and architects cooperate to achieve their common goals in a win-win situation. In a commercial setting, however, one dominant feature often introduces powerful forces from outside the technical realm. That feature is the customer/supplier relationship, usually formalized in bidding rules or as a delivery contract. Formal customer/supplier relationships often place severe limitations on information exchange between stakeholders and architects. In this paper, we explore the effect of such limitations on the interaction of architectural design with the quantification of Non-Functional Requirements, and explore a number of avenues to deal with them.

I. INTRODUCTION

In the commercial setting of bespoke system development and integration projects, customers and suppliers embark on a quest to converge to a point where requirements can be agreed between them. Starting points on this quest are the customer’s needs and the supplier’s capabilities to meet those needs. Agreeing on functional requirements is usually the first step. The harder part is agreeing on non-functional requirements, which are more tightly tied to the architecture. One of the aspects that get in the way of a proper integrated approach to develop NFRs and architecture is the formal character of the client/supplier relationship. This formal character is expressed in bidding and tendering rules in the pre-contract stage, and in the contract itself after that. The formal representation of NFRs in these situations is often a number, especially when they refer to solution quality attributes: a quantified NFR. The process of getting to these numbers is called NFR quantification.

A. Requirements and architecture in client/supplier situations

Traditionally, designing a solution to fit stakeholders' needs is done in two phases:

RE Requirements Engineering expresses the needs of the stakeholders in a set of Requirements (FRs and NFRs).

AD Architectural Design finds the optimal solution to address the Requirements, and expresses the solution in a Solution Architecture

In the commercial setting of fixed price IT projects, Requirements Engineering is done by the customer, and Architectural Design by the supplier. After RE, the customer invites a number of potential suppliers to bid for the privilege of supplying a solution that fulfills the Requirements. This invitation is usually called Request for Proposal (RfP) or Invitation to Tender (IT); we will use the term RfP. After receiving the RfP, the candidate suppliers will perform enough of the Architectural Design to be able to calculate the cost and time needed to deliver the Solution within a reasonable margin of error.

NFRs are widely seen as the driving force for shaping IT systems' architectures [1]–[3]. In other words: of all the Requirements in an RfP, the NFRs have the biggest role in the Architectural Design. Several approaches exist for capturing NFRs [3], [4] and deriving a solution’s architecture from them [1], [3], [5]. However, as already noted by Boehm [6], the notion that an architecture can be derived from requirements in one go is an oversimplification. Architecture and requirements are so closely related, that many aspects of requirements engineering can only be addressed properly if the architecture is developed at the same time. This point is made particularly eloquently in [2], which pleads for a tightly integrated approach for Functional Requirements, Non-Functional Requirements and Architecture. In our experience such an integrated approach is indeed necessary, but it is particularly difficult to achieve in the type of fixed price tendering situation described above. This is due to the traditional strict separation of roles in the tendering process, a separation that is mandated by law [7], [8] for many government related organizations.

II. REAL-LIFE ISSUES DEALING WITH NFRs

NFRs, whether documented in the RfP or not, are a regular source of dilemmas for suppliers responding to RfPs. If an RfP contains hard-quantified quality attribute requirements for solutions that are newly to be designed, the

1We use the term Solution Architecture rather than System or Software Architecture to encompasses high-level solution shaping for most of the solutions built and operated by IT services companies: applications, service solutions, embedded systems, infrastructure, SOA implementation, systems integration etc.
supplier often faces a dilemma caused by the uncertainty in the cost of fulfilling them. In a tendering situation, there often is no time to reduce the uncertainty. On the other hand, if quality attributes are ignored in RfPs, the supplier still needs to take them into account in the architecture. Too much attention may inflate the price. Too little may lead to severe problems later on, because customers have expectations about quality attributes, even if they are not explicitly quantified in the RfP. There are well-documented court cases [9] that show that suppliers have a duty of care in this area that can go beyond the contractually explicit requirements.

In practice, NFR-related tendering dilemmas regularly lead to severely troubled projects. A public example is a Dutch highway tunnel suffering from software quality problems that led to a two year delay [10]. We have also seen tenders canceled after all responding bids were unexpectedly high due to overspecified NFRs. One sometimes gets the impression that the tendering rules force customers to contract the supplier that has the lowest level of understanding of the NFRs. A supplier that is insufficiently aware of the impact of NFRs will generally submit a lower priced offer, because other suppliers will calculate the proper cost of addressing the NFRs in the architecture. Tendering rules do not allow customers to adjust weighting criteria to properly reflect the importance of NFRs if they notice this after submission. As happened in the highway tunnel case, the NFR-unaware supplier that wins the bid subsequently performs poorly in terms of quality attributes, and overrun delivery time and budget.

III. NFR QUANTIFICATION AS AN ECONOMIC PROBLEM

NFRs in RfPs can be expressed to various degrees of (un)certainty. They can be documented as vague goals that still need to be clarified and disambiguated, like the softgoals of the NFR Framework [1]. They can also be expressed in quantified values. A lot of literature is available on the benefits of quantifying NFRs [3], [4].

From an economic perspective, NFR quantification can be seen as an exercise in optimizing the value cost ratio. Quantified NFRs have to be related to two economic entities: the business value of the realized NFRs (quality attribute) to the customer, and the cost to the supplier to realize the NFR (which in turn translates to price to the customer). These relationships have been extensively explored in literature [11]-[13].

1) Cost: Quality requirements tend to be very cost sensitive. The relationship is called the “cost function”, and it is determined by the architectural decisions influencing the NFR. At the time of writing the Request for Proposal, the cost function is unknown by the customer because the architectural choices have not been explored in depth (this is the job of the supplier). At bidding time, even the supplier usually does not have the time to sufficiently explore the cost and time needed to fulfill NFRs. For newly designed solutions, figuring out the true cost function of NFRs often requires extensive model calculations or architectural prototyping, for which the deadline of tender submission is usually far too short.

2) Value: The business value of quality is often a highly intractable entity [14]. The relationship between quality attribute and value is called the “value function”. At bid time, this relationship is unknown to the supplier; even if the response time requirement is quantified in the RfP, it is a single number or a statistical spread of numbers, but rarely explicitly related to the business value.

3) Optimization: Once we know the cost and value function, we can find the optimal quantification from an economic point of view for a single NFR. In reality, quality attributes are not orthogonal, so a full cost/benefit analysis would require a more complex, multidimensional calculation involving cost and value functions of all relevant quality attributes.

Whatever method we use to trade off cost and value for NFR quantification (e.g. [1], [11]), three things are essential for any realistic approach to quantifying NFRs in a way that makes economic sense:

- supplier knowledge of the NFR’s cost function
- customer knowledge of the NFR’s value function
- communication of said knowledge between customer and supplier

IV. NFR QUANTIFICATION AS A NEGOTIATION PROBLEM

All three of the essentials mentioned in the previous section are usually low at tendering time, and signficantly increase only after the contract has been signed:

- Cost function knowledge increases by the research and experience of the supplier’s delivery team.
- Value function knowledge increases as end-users and business managers of the customer organization get more involved in the execution of the project and see more and more of the solution at work.
- Communication between customer and supplier is severely restricted at tendering time, and gradually opens up after contract signing, as mutual trust grows.

So the reasonable thing to do is to postpone the quantification of NFRs until after the contract signing, when there is a relationship between customer and supplier that allows free exchange of information, and sufficient time to elaborate architectural alternatives and establish their costs. However, uncertainty in NFRs implies significant risk, leading to the dilemmas described above.

The risk and cost of NFRs often become objects of contract negotiations. This does not help the three essentials mentioned above, as customer and supplier now have to deal with negotiation tactics such as risk avoidance, divide and
conquer, good guy/bad guy, salami nibbling and slicing, on top of the technical difficulties of the engineering process. Especially communication of cost and value aspects between customer and supplier falls victim to the commercial necessity of playing ones cards close to the chest.

We thus come to the core of the issue: from an engineering and economic perspective, NFRs should not be quantified until cost and value knowledge and customer/supplier communication have been sufficiently established, which usually occurs well after contract signing; on the other hand, commercial reality often demands quantified NFRs committed to in the contract. In the next section, we will explore some possible solutions to this issue.

V. TOWARDS SOLUTIONS

In this section, we will present two approaches that can help alleviate the issues around NFR quantification in a commercial setting: Requirements Convergence Planning and Competitive Dialogue.

A. Requirements convergence planning

When responding to an RfP containing hard-quantified NFRs, suppliers with insufficient assurance that the requirements can be met basically have two options:

A. Respond “compliant” and deal with the resulting risk.
B. Respond “non-compliant”, and offer an alternative for addressing the underlying stakeholder needs.

Scenario B requires room for discussion in which the hard requirement can be moved to a “target value”. Instead of committing to the NFR value quantified by the customer, the supplier will commit to a process to find a proper balance of affordability, i.e. a number that is acceptable to the customer and achievable at reasonable cost. This process is sometimes called “calibration” or “clarification”. We call the process referred to in Scenario B a Requirements Convergence Plan (RCP). An RCP is a plan to quantify specific quality attributes that cannot be committed to at contract signing time. This plan sets out a process of discovery and ultimately convergence on quantification of performance or other NFRs with open collaboration from a customer. The plan seeks to identify the most favorable balance of value and cost for quality attributes, whilst implicitly reducing risk.

The RCP concept is visualized in an example in Fig. 1. At contract signing time, customer and supplier agree to the execution of the RCP, which in this case contains two activities: a series of stakeholder workshops (e.g. Quality Attribute Workshops [3]) to increase knowledge about the business value of the quality attributes, and an architectural prototype to research what quality attribute level can be achieved at what cost. Both customer and supplier are involved in both activities, stimulating the flow of information needed to make the trade-offs. At the end of the RCP period, the results of the stakeholder workshops and prototype evaluation are put together, and result in a firm quantified NFR. The supplier then commits to delivering the solution fulfilling the NFR.

Requirements convergence planning can be called a two-stage commitment approach for NFR quantification: at contract signing, the supplier does not commit to a quantified NFR, but to the execution of the RCP. At the end of the RCP, once a mutually agreed balanced NFR is achieved, it is signed off and committed to. The details of what happens in the RCP can be worked out on a case-by-case basis, as long as the three essentials mentioned in Section IV above are sufficiently addressed: cost function knowledge, value function knowledge and communication between customer and supplier about them.

Apart from getting close to economically optimized NFR quantification, a benefit of this approach is that it allows the supplier to more keenly price its offer, as the plan is openly effort-boxed and no explicit commitment is made to meeting specific NFRs at time of tender. The additional advantage to the customer is that he is not paying for the possibly large contingency that a supplier would otherwise have to load his offer with.

This approach can not always be applied, since it requires an RfP that allows it to be proposed. Also, the customer must be willing to give up the certainty of a committed and quantified NFR, in exchange for the probability of better value for money spent on achieving NFRs. The success of the RCP approach also depends on the ability for customer and supplier to trust each other. There is an inherent information asymmetry between them, which the supplier could make use of by misleading the consumer to agree on a less optimal choice but more profitable to supplier. The supplier needs to be transparent and open towards customer with information emerging during RCP execution, in order to balance the information position and create a basis for trust.

We have had some success with customers that welcome the openness, feel that they are more likely to get what they need and feel that they will not necessarily pay overly for it. Suppliers feel better in control of the risks, and feel as
though they are in a better position to satisfy the customer’s needs and make a profit.

B. Competitive dialogue

In 2004, the European Council added a new tendering procedure for the public sector, called “Competitive dialogue”: a procedure in which any economic operator may request to participate and whereby the contracting authority conducts a dialogue with the candidates admitted to that procedure, with the aim of developing one or more suitable alternatives capable of meeting its requirements, and on the basis of which the candidates chosen are invited to tender. [8] The Competitive Dialogue is meant for “particularly complex contracts”. The aim of the dialogue is to “identify and define the means best suited to satisfying their needs. They may discuss all aspects of the contract with the chosen candidates during this dialogue.” The Competitive Dialogue tendering procedure contains significantly less restrictions in the communication between customer and supplier at tendering stage. US regulations [7] contain a form of tendering called “Contracting by Negotiation”, which was introduced in the regulations in 1997; like Competitive Dialogue, it has less communication restrictions than its counterpart, Sealed Bidding.

The fact that Competitive Dialogue allows a freer exchange of information between customer and suppliers makes it more suitable than the previously existing procedures for an integrated RE/AD approach in the IT solution domain. In practice, we see more and more use of the competitive dialogue tendering procedure, but it is still only applied in a minority of tenders: in 2011, only about 5% of the IT tenders Logica is interested in follows the competitive dialogue procedure.

In Competitive Dialogue cases, suppliers are often asked to conduct stakeholder workshops and/or to provide a proof of concept, analogous to the Requirements Convergence Plan. The four central ideas that make up RCP are all used in practice in Competitive Dialogue tendering situations: two-stage commitment, stakeholder workshops, architectural prototyping and customer/supplier dialogue.

VI. DISCUSSION AND CONCLUSIONS

We have presented some key issues related to NFR quantification and architectural design in customer/supplier relationships. Critical NFRs should be quantified, but we should beware of premature quantification: prematurely quantified NFRs can cripple projects, leading to ill-fitting architectures and diverging points of view in customer/supplier relationships that are very hard to resolve.

We have concluded that, in most cases, it is impossible to find the optimal (best value/cost ratio) quantification for important NFRs at tender time. Optimal quantification requires sharing of information between customer and supplier, and it requires time to establish enough of the architectural design to perform a reasonable estimate for the cost and value relationships. One possible way to create better NFR quantification circumstances for customers and suppliers is by means of a Requirements Convergence Plan. The European Union has a new tendering procedure that can be used for requirements convergence, Competitive Dialogue.

There is no unambiguous recipe for balancing cost and value of quality attributes. Performing the balancing act while negotiating a contract is fraught with uncertainty and danger, and can lead to failure of IT projects. The industry could benefit from a change in attitude that reflects this state of affairs. Transparency and awareness between customers and suppliers about NFRs is one part of that attitude; willingness to share the risk of unquantified NFRs is another. Both transparency and risk sharing require a basis of trust to exist between customers and suppliers in the IT industry. Without this trust, formal requirements documents or contracts with precisely quantified NFRs will not help to guarantee success.

A. Related work

1) Negotiating and uncertainty in requirements: Viewing NFRs as a negotiation problem was first introduced in the iterative WinWin Spiral model of Barry Boehm et al [5], [15], [16] introduces the use of Implementation Proposals to facilitate the negotiation and understanding between stakeholders and architects. The need for iterating between stakeholders to resolve requirements conflicts and reach agreement is one of the key drivers for iterative software lifecycles like the Unified Process [17]. Issues with requirements elaboration in tendering have been recognized by others, and [18] proposes a solution involving Progressive Acquisition. Another discussion of the difficulties of requirements specification in RfPs can be found in Paech et al. [19], which reports on the experiences of a supplier in a tender process, identifies challenges and presents some possible solutions for the supplier.

The gradual increase of certainty during IT projects (Section IV) is often visualized as a “cone of uncertainty” [20]. For dealing with uncertainty in requirements, two approaches appear in literature: modeling the uncertainty [21], [22], and tuning the development process to better deal with change, which is one of the basic premises of the Agile movement [23]. Alan Davis [24] gives lots of practical advice on how to prevent overspecification of requirements. [25] presents another economic perspective on NFR quantification, focusing on the risk-based need to quantify versus the cost of the quantification activities.

2) Need for integrated RE and AD: Fricker and Glinz [26] present a case study analyzing and monitoring the hand-over and negotiation process between stakeholder and architect. Even though that study was not specifically targeted at NFRs, the results strongly confirm our position that proper NFR determination requires knowledge of the
solution architecture. Tom Gilb [4] appears to be a strong opponent to this position, advocating ‘How Good’ and ‘How Much’ before ‘How’ as a matter of principle. However, in the same list of principles Gilb also states: “You cannot have correct knowledge of all the interesting requirements’ levels for a large and complex system in advance,” indicating at least partial agreement with our position. The Design Engineering process presented in [4] requires the same “three essentials” of cost knowledge, value knowledge and communication to work, indicating that it too would suffer from the communication limitations often encountered in formal client/supplier relationships.

Summarizing, we have found no existing method in industry and literature that allows proper quantification of NFRs in a situation with severe communication constraints between customer and supplier. The only way to address the issues highlighted in Section II is to use contract negotiation models with less constraints, taking into account the need for an integrated process for NFR quantification and architectural design.

REFERENCES


