An Approach to Evaluating Requirements Engineering Methods for Applicability to Time-to-Market Projects

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Abstract
This paper presents the RETTM selection methodology - an approach to evaluating the applicability of Requirements Engineering (RE) methods and tools for use in time-to-market (TTM) projects. In this context, a TTM project is one where the production of a software product in accordance with the proposed schedule is the most important factor, above both budget and scope/quality requirements. In this environment, software organizations must choose a combination of RE methods and tools which facilitate the construction of a set of requirements that is of acceptable quality, while not consuming a great amount of time and effort in the process.

The approach presented in this paper is based on the assumption that there are three fundamental ways of reducing schedule time required to perform a set of tasks. By examining RE methods and tools in respect to these three ways of reducing schedule time required, one is able to obtain a relative comparison of the applicability of each RE method or tool for use in a TTM project. The reasoning behind this conclusion is that the easier it is to achieve one or more of the three schedule-reduction objectives with a certain RE method or tool, the more applicable it will be to a TTM project.

This approach examines the reduction of schedule time not just within the RE stage of a project, but over the entire product life cycle. It is possible to do very little RE during the initial stages of a project, thus reducing the schedule time required for the RE process, but this does not necessarily translate to an equivalent reduction in the schedule time required to bring the product to market while still satisfying the requirements of the stakeholders. If too little work is done in understanding stakeholder requirements, there is a great risk that the product will not meet the stakeholder expectations, thus requiring effort to rework the product to bring it into compliance with stakeholder needs.

In this paper, two RE methods, Joint Application Development (JAD) and Quality Function Deployment (QFD), are analyzed to show a proof-of-concept for the proposed analysis approach. Along with the TTM analysis, additional information is provided on the RE methods to support the requirements engineer's selection of appropriate RE methods and tools for use on a TTM project. Although the approach contains analysis methods that are somewhat subjective, it should still help the requirements engineer in making an educated decision about the RE methods and tools that will assist in the development of an adequate set of system requirements while still facilitating the software production according to stringent schedule constraints.

Key Words
Requirements Engineering, Time-to-Market, Technique Selection Methodology

1 Introduction

Requirements Engineering (RE) is an important part of the software development process. Unlike other industries where the majority of capital is spent on tangible materials, the tangible materials in software product are a very small part of the overall cost of the project. By far, the costliest part of a software product is the development of the application. Reproduction costs are insignificant. As a result, requirements of software are typically quite volatile, as it is often difficult to map changes in requirements to a specific increase in project cost. When requirements change, effort is required to modify the product to meet the new requirements, thus increasing the cost and delaying the schedule of the project. If requirements remain volatile for too long, the likelihood of project success decreases dramatically, as modifying software to incorporate new/modified requirements is often complicated and error-prone [3]. It is important to have a firm grasp of the essential requirements of a project so that the architectural foundation of the product may be built around these requirements.

As the Internet becomes a popular medium for distributing and using software, the volatility of requirements becomes even more of a problem as the reproduction costs shrink to virtually nothing. In the relatively immature market place of the Internet, consumers are increasingly looking towards the Internet to meet their information and software needs. As a result, there is a strong push from Information Technology (IT) companies to meet the needs of the customers as quickly as possible in order that the profitability of their ventures be maximized. However, to meet the needs of their customers, IT organizations must be adept at learning what the customer needs, and developing products to meet those needs as quickly as possible. In addition to meeting the needs of today's users, IT organizations must be able to quickly adapt to the changing technology that is available to, and is used by, their customers.

Several RE methods and techniques have been developed to assist large projects in their RE process, but it is not clear if/how these frameworks will adequately scale-down to be useful in a small project where Time-to-Market (TTM) is critical. The purpose of this document is to identify the essential components of an RE process, and then provide a methodology to the Requirements Engineer to assist in determining an appropriate set of RE methods for use on a particular project.

Section 2 give background information on requirements engineering and describes the essential aspects of the RE process and how the RE process fits into a TTM project.

Section 3 discusses the special considerations that a TTM project must pay to the RE process and suggests a set of core activities that should be part of the RE activity performed for any TTM project.

Section 4 outlines the proposed RE technique selection methodology specifically for TTM projects, and the assumptions upon which the methodology is based.

Section 5 shows the methodology in action in a comparison of Joint Application Development (JAD) and Quality Function Deployment (QFD) for use on a TTM project.

Section 6 discusses the conclusions drawn from the research on the RE technique selection methodology and possible future research areas.

2 RE Fundamentals

The RE process consists of four main activities: elicitation, analysis, specification, and validation [6]. Elicitation is the activity of gathering the requirements from stakeholders. After gathering the requirements, they are analyzed to determine areas requiring clarifications, logical groupings, etc. After being analyzed, the requirements are (formally) documented. And finally, the documented requirements are validated with the stakeholder to ensure that the product developed from the requirements will meet the needs of the stakeholder.

When determining the essential aspects of the RE process, the first place to look is the generic RE process itself. Is it necessary to perform all four steps? To answer this question, the purpose of each phase needs to be examined to determine if it is necessary for a successful TTM project.

Elicitation – The purpose of the elicitation phase is to gather the requirements. Davis suggests that this stage of the RE process is actually more of an exercise in discovery - learning about the problem, understanding who the user is and what the user really wants [4]. This phase is absolutely essential, because without it, it is not possible to build a product at all. Even for software development projects where no specific customer provides the requirements, the software developer implicitly provides the requirements from which the product is to be developed. However, for TTM projects, and especially for Internet applications, it is not necessary that the entire task of elicitation be performed before subsequent work commences. All that is necessary for TTM projects is that the core requirements be determined. For the first iteration of product development it is necessary that the architecture be built upon a relatively stable set of core requirements. Requirements discovered later can then be implemented in subsequent releases.

Analysis – The purpose of the analysis phase is to create a complete and consistent set of requirements [6]. This may include examining the set of requirements to determine if the requirements meet each of the commonly defined attributes of good requirements: unambiguous, complete, verifiable, consistent, modifiable, traceable, and usable [5]. It is quite likely that deficiencies will appear in the set of requirements, requiring that the requirements engineer go back to the customer to clarify ambiguities and possibly elicit further requirements or remove/modify inconsistent or conflicting requirements. Kotonya and Sommerville suggest that the Elicitation and Analysis phases of RE are interleaved in a spiral model, consisting of Elicitation (which produces a draft set of requirements), Analysis (which results in a set of problems with the set of requirements), and Negotiation to resolve the differences [6]. Intuitively, the smaller the set of requirements, the less time that the analysis phase should take. As was the case in the elicitation phase, if the set of requirements can be kept to the minimum set required to implement the core functionality, the analysis phase should take less time than it would otherwise have taken.

Specification – The purpose of the specification stage is to document the requirements such that they may be validated by the stakeholder and used by the implementers to develop a product that meets the requirements. Without a specification, there is no way to determine if the final product has met the initial needs of the customer, nor is there any concrete artifact for the implementers to use when constructing the product. The only situation where it would be possible for this phase to be skipped would be where the RE analysts and implementers are the same group, and either there is no customer, the customer is part of the development team, or the customer has no need to validate the set of requirements or the resulting product. That said, however, it is possible for the specification to consist of a prototype and users' help documentation [8].

Validation – The purpose of the validation phase is to ensure that the set of requirements is sufficient in that if a product is built which meets the specified requirements, it will meet the needs of the customer. The validation phase also allows an opportunity for stakeholders to review the requirements to determine if the document, as a whole, consists of a set of well-specified requirements [5, 6]. This phase may be skipped, but doing so greatly increases the risk that the set of requirements is insufficient for the purpose of creating a successful product. If the project is structured such that very little specification is documented, the validation phase will require minimal effort. The purpose of validation is simply to ensure that the specification accurately reflects the requirements of the customer.

It is possible to leave out any or all the RE phases except for Elicitation, however doing so greatly increases the risk that the product will not meet the expectations of the stakeholders. If the software development effort is anything but insignificant for a given project, it is in the project's best interests not to skip any of the RE phases.

3 RE Process in TTM Projects

The overall objective of this research is to help software developers structure an RE process which will support the performance of an adequate amount of RE while requiring a minimal amount of effort. The key to reducing the effort required to perform sufficient RE is to keep the set of requirements sufficient but minimal. By keeping the set of requirements minimal, the requirements analyst focuses on producing a specification that captures the essential set of requirements and thus the effort required in all phases of the RE process can be reduced. The Standish Group reported that only 20% of a product's features are commonly used, while 45% are virtually never used [9]. It stands to reason that an effective RE process for a TTM project would help the project team determine the 20% of the features most needed by the customer.

Developing a minimal yet sufficient RE process is not an easy task. If too little RE is performed at the beginning of a project, the upfront effort saved may be dwarfed by the rework effort expended. If too much time is spent in the

RE phase of a project, the overall project schedule may be jeopardized. In fact, Truex et al suggest that there is no such thing as a stable set of requirements and that projects should plan for maximum flexibility and maintenance if a product is to be successful [10].

Based on the discussion in section 2, it is in a project's best interest to devote some amount of effort to each of the four main phases of RE (elicitation, analysis, specification, and validation). To assist the software developer in the RE phase of a project, the developer may choose to employ an RE technique. RE techniques include Joint Application Development (JAD), Quality Function Deployment (QFD), Cooperative Requirements Capture (CRC), User-Centered Design (UCD), etc [4]. However, focussing effort on implementing one RE technique is not enough to ensure adequate result for minimal effort. To compliment the main RE technique, a set of core RETTM activities is suggested to help develop a minimal yet sufficient set of requirements.

The core set of activities are identified in the following table:

Table 1: Core RE activities for TTM projects

Activity	**Description**
Requirements Prioritization	Prioritize the set of requirements either on an ordinal or absolute scale.
Requirements Checklists	Develop and use requirements checklists to ensure acceptable quality of each requirement, acceptable quality of the overall RE specification, and the conformance of the RE process to the project's defined RE process.
Requirements Reuse	Reuse previously developed artifacts (or portions thereof) in the RE activities of a new project.
Requirements Tracing	Trace requirements to source, rationale, and test procedures/cases as well as to architecture, design, implementation, and testing artifacts if deemed appropriate for the project.
Requirements Reviews	Conduct reviews of the artifacts constructed during the RE phase (with the user if applicable) to help validate and verify the RE specification.
Requirements Change Management	Implement a requirements change management process to avoid feature creep and help maintain the integrity of the RE specification.

By including the core RETTM activities in conjunction with the chosen RE technique(s), the project group improves the overall quality of the RE specification without requiring that these factors be explicitly covered in the main RE technique itself.

Structuring an RE process around the construction of a minimal set of high-priority requirements still does not completely define the RE process for a TTM project. Software project teams may choose to implement a RE technique to assist them in eliciting, analyzing, specifying, and validating the requirements. The RETTM selection methodology has been developed to serve that purpose.

4 RETTM Selection Methodology

The RETTM selection methodology is relatively straightforward. It consists of applying four selection criteria to each of the candidate RE techniques, evaluating the techniques against the criteria, and determining which technique is best-suited to the TTM project at hand. Four criteria were chosen for the analysis of RE techniques' applicability for TTM projects. The first three criteria are based on the allowance for the RE technique to reduce TTM of the project overall. The last criterion concerns the quality of the project and the likelihood of project success. The four selection criteria are:

- Allowance for performing tasks more quickly.
- Allowance for performing fewer tasks.
- Allowance for performing tasks concurrently.
- Allowance for user involvement.

1. Perform tasks more quickly

To perform a task more quickly is to do a given amount of work, but with less total effort (in terms of person-hours). In the context of RE, there are several factors that can affect the total effort of performing the RE phase. If the amount of time required to become proficient at a particular technique is less than the time required for a second

technique, using the first technique will reduce first-time effort, although the second technique might be more efficient once the project team becomes proficient. If there is tool support for one technique but not for another, the first technique will likely take less effort because the tool can be used to automate some of the tasks that would otherwise have been performed manually. If a particular technique requires training, the amount of availability of training resources might affect the total effort expended in performing the RE phase. Finally, if the technique can be scaled-down if necessary, this would assist the analyst in performing the RE phase more quickly.

2. Perform fewer tasks

Performing fewer tasks decreases effort for a particular phase, but this must be put into the context of the entire project. Many projects have failed because they performed fewer tasks in the RE phases, but needed to rework their product in the latter phases of the project because the up-front work had not been sufficiently performed [9]. Indeed, it is possible to virtually skip the entire RE processes, but this would be very risky from a project management perspective.

3. Perform tasks concurrently

Performing tasks concurrently does not decrease the overall effort. Indeed, performing tasks concurrently will likely increase overall effort because coordination effort is required to manage the interaction of tasks. It should, however, decrease schedule time, which is desirable for TTM projects. Analyzing RE techniques in terms of concurrency means determining if different tasks within the RE phase may be performed concurrently, or if RE tasks may be performed concurrently with tasks in Design, Implementation, or Testing phases.

4. User involvement

During our research, a survey conducted amongst 25 software development professionals, 23 reported that an important project success factor is customer satisfaction. The Standish Group CHAOS survey found that user involvement is the top project success factor according to software professionals [9]. It is possible to greatly reduce TTM using a particular RE technique, but if the project is not successful in terms of customer satisfaction, the benefit of reduced TTM may be lost.

The RETTM methodology is summarized as follows:

1. Choose a set of candidate RE techniques for use as the primary RE technique in the RE process.
2. Apply the four criteria in the RETTM selection methodology which are:
   a. Allowance for performing tasks more quickly.
   b. Allowance for performing fewer tasks.
   c. Allowance for performing tasks concurrently.
   d. Allowance for user involvement.
3. Determine the most appropriate RE technique for use as the primary technique based on the evaluation of the selection criteria.
4. Regardless of the primary RE technique chosen, implement the set of core RETTM activities in the RE process:
   - Requirements prioritization
   - Requirements checklists
   - Requirements reuse
   - Requirements tracing
   - Requirements reviews
   - Requirements change management

5 Example: Joint Application Development versus Quality Function Deployment

To illustrate the RETTM selection methodology, suppose that a project team was trying to decide whether to use Joint Application Development (JAD) or Quality Function Deployment (QFD) as the primary method of requirements capture. There is no particular reason why both methods could not be used in the same project, but since TTM is a factor for this project, the overhead of implementing both techniques might not be feasible.

5.1 Description of QFD

QFD was developed by the Japanese to determine quality requirements for the automobile industry. The primary focus of QFD is the House of Quality (HOQ) which shows the relationship between customer requirements and product features. The 'roof' of the HOQ shows the interactions between the various product features. In addition to relating features to requirements, QFD also supports market analysis of competitors' products [2].

The main advantage of QFD is that the analysis of requirements is explicitly built into the technique. The technique, however, requires that a set of requirements and product features be available for analysis. QFD does not explicitly help the analyst determine the initial requirements.

Another advantage of QFD is that it takes into account competing products in a structured manner. By utilizing QFD, the requirements engineer can quantitatively determine how his product compares to competing products on the market.

If QFD is used throughout the development of a product (i.e. HOQ diagrams are developed for each stage of product development), it provides traceability from customer requirements to software product artifacts. The downside to this is that a large number of requirements may quickly become unmanageable. However, if the analyst is careful to limit the list of requirements to the essential requirements, the unmanageability of a large HOQ becomes less of a risk.

5.2 Description of JAD

JAD is a method whereby system stakeholders work together in facilitated group sessions to specify and perform preliminary development (requirements engineering and analysis) of a system. JAD sessions include representatives in the following roles: session leader (facilitators), user representative, specialist, analyst, information systems representative, executive sponsor [1].

JAD, along with other group techniques, has the advantage of explicitly requiring that the coordination and communication between stakeholders be present. As Macaulay illustrates in a case study, a project might be technically sound and have a well-prepared software development process, but if effective human communication does not exist between the stakeholders, the project can easily get out of control [7].

JAD has another advantage in that, with the help of a facilitator, the project development focuses on constructing project deliverables very quickly. Each team member is expected to prepare for each JAD session, and is given responsibilities that must be achieved by the following JAD session.

A disadvantage of JAD is that there are a limited number of individuals who can be a part of the JAD group. As such, it is very important that each member of the JAD group ensures that the concerns of his stakeholder group are fully represented.

Another disadvantage of JAD is that, although it facilitates fast development of specifications and designs, there is a risk that continuity will be lost between the stakeholders. Although JAD sessions promote the building of relationships during the sessions themselves, care must be taken to ensure that the relationships are maintained throughout the project.

5.3 Comparison of JAD versus QFD for a TTM Project

For the following comparison, JAD and QFD are rated on a scale of 1 to 3 where:
1 = Technique does not make allowances for the criterion.
2 = Technique may be tailored to allow for the criterion.
3 = Technique explicitly allows for the criterion.

5.3.1 Allowance for performing tasks more quickly:

QFD

During RE Phase:

QFD sessions may be performed more quickly by limiting the number of requirements and product features being analyzed.

During Product Development:

QFD allows for performing tasks more quickly if the HOQ diagrams are used throughout product development. If this is the case, system implementers can easily determine the implications that changing requirements will have on the implementation and modification of product features. Without a HOQ diagram to refer to, it might be more difficult to track this information down.

Rating: 2

JAD

During RE Phase:

JAD allows tasks to be performed more quickly because it focuses the system designers and developers on constructing system artifacts quickly. The degree to which this is effective depends, to a large degree, on the ability of the facilitator to ensure that responsibilities are delegated and that assigned tasks are carried out.

During Product Development:

JAD sessions may be used throughout the product development lifecycle. By using separate JAD sessions at each phase of product development, task time may be reduced throughout the life cycle of the product.

Rating: 3

5.3.2 Allowance for performing fewer tasks:

QFD

During RE Phase:

QFD does not allow for performing fewer tasks during the RE phase.

During Product Development:

QFD does not allow for performing fewer tasks during product development.

Rating: 1

JAD

During RE Phase:

JAD sessions may decrease the number of tasks performed by decreasing the number of meetings required between the stakeholders and the system developers. By having the stakeholders included in the JAD sessions, issues can be resolved immediately rather than requiring the overhead of meetings and further communication to resolve issues discovered by the system designers during requirements analysis.

During Product Development:

If JAD sessions are used throughout product development, they may decrease the number of tasks performed the same as was the case during the RE phase.

Rating: 2

5.3.3 Allowance for performing tasks concurrently:

QFD

During RE Phase:

The creation of a HOQ is essentially the creation of a traceability matrix. This means that by using QFD, a project group is embedding traceability into the set of requirements that would normally have to be performed as a separate task.

During Product Development:

If HOQ diagrams are kept up-to-date during product development, the tracing of requirements to product features is implicitly kept up-to-date. Keeping this traceability current would normally need to be performed as a separate task.

Rating: 2

JAD

During RE Phase:

JAD allows tasks to be performed concurrently in RE because, by having stakeholders working together in an organized fashion, elicitation, analysis, specification, and validation may be performed concurrently.

During Product Development:

JAD sessions during the RE phase might include the development of preliminary design artifacts. If this activity is done during JAD sessions, RE is essentially being performed concurrently with preliminary design.

Rating: 2

5.3.4 Allowance for user involvement:

QFD

During RE Phase:

QFD does not explicitly require user involvement. However, the project team could easily choose to involve users in the construction of the initial HOQ (feature comparison).

During Product Development:

QFD does not make allowances for user involvement during product development.

Rating: 2

JAD

During RE Phase:

JAD explicitly requires user involvement during the RE phase.

During Product Development:

JAD may allow for user requirement during product development if JAD sessions are held throughout product development in which users are included as a stakeholder group.

Rating: 3

Table 2: Summary Comparison of JAD vs. QFD

	QFD	JAD
Advantages	- compares product features to requirements. - requirement tracing built into HOQ diagrams.	- promotes healthy stakeholder communication. - focuses stakeholders on achieving acceptable solution.
Disadvantages	- HOQ diagrams may become unmanageable. - initial requirements must be determined before QFD may be used.	- participation in JAD sessions is limited to a few individuals. - risk of continuity loss between JAD participants after session has ended.
Perform Tasks more Quickly	2	3
Perform Tasks Concurrently	1	2
Perform Fewer Tasks	2	2
Allow for User Involvement	2	3
Total	**7**	**10**

The comparison illustrated in Table 2 suggests that, all other things being equal, JAD is more appropriate for a TTM project than is QFD. There are, of course, instances where QFD might be more applicable if the purpose of the RE exercise is to determine a feature comparison with competing products. However, for a TTM project, the RETTM analysis shows that it is more likely that a greater schedule reduction will be achieved by using JAD rather than QFD.

6 Conclusions and Future Research

The RETTM selection methodology provides practitioners with a guided approach to determining the most appropriate RE technique for use as the primary RE technique in a TTM project. The use of this methodology still requires that the project team evaluate the advantages and disadvantages of several RE techniques in order to come up with the set of candidate RE techniques, but the RETTM selection methodology can assist in determining the most appropriate technique from the set of candidate techniques.

Care must be taken to ensure that the RE process and artifacts produced are of sufficient quality, even though schedule constraints may be tight on a TTM project. For this reason, the RETTM methodology includes an explicit consideration of user involvement as well as a set of RETTM activities that will help to ensure that a RE process of sufficient quality is followed to improve the chance of project success.

Future research in this area includes expanding the RETTM selection methodology to include an objective analysis of the common RE techniques in use in the IT industry. An objective analysis of RE techniques as well as a

summary of the advantages and disadvantages of each technique would help to solidify the usefulness of the RETTM selection methodology for use by software development professionals.

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