Evaluating the Applicability of Requirements Engineering Tools for Distributed Software Development

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Contents

1 Introduction

Requirements engineering (RE) is the first part of the software engineering process (Partsch 1991; Sommerville 2004). It consists of distinct phases in which certain stakeholders deal with the problem of creating and maintaining a systems requirements document. This artifact should clarify what the customer expects from the system and how the developer should design it. RE is often mentioned as the most critical phase in the software development process (Maciaszek 2001). Mistakes made during the requirements phase can cost up to a hundred times more than coding errors Kotonya and Sommerville (1998). Moreover, The Standish Group International (2003) found out, that on average only 54%, of the originally defined features of a project are delivered and 45% of those features that are delivered are never used. Misidentified requirements are the most significant source of customer dissatisfaction with delivered systems (Macaulay 1996).

The problem of creating the requirements document is reinforced through geographical distance between the different people involved in the RE process. Not only the distance between customers or users and the engineers constitutes a problem, often the engineers themselves are distributed all over the world, e.g. due to outsourcing decisions and offshoring projects. Carmel and Agarwal (2001) describe that only a decade ago, the number of firms participating in global software development was low, but today 203 of the US Fortune 500 engage in offshore outsourcing endeavors. Today, more than 50 nations participate in collaborative software development projects internationally. The reasons are cost advantages and a large and well-educated pool of labor—India is a famous example. Although RE is always distributed in some way due to the distance between the different stakeholders, the term distributed RE is used to emphasize the distance between them, e.g. in global RE processes.

Instead of using simple text files or diagrams for communicating both requirements and possible changes to them, nowadays a lot of tools from different vendors exist to help mastering the RE process. These tools belong to the class of so-called computer-aided software engineering (CASE) tools. Many tools support a multi-user environment that is needed for distributed RE. These tools are intended to help overcoming some of the problems mentioned before.

Therefore, the aim of this paper is to give an overview over existing RE tools on the market and to evaluate how they support the different phases of RE—especially a distributed RE process. The paper is structured as follows: In chapter 2 the generic phases of the RE process are shortly described, followed by a short market overview of tools

in chapter 3. The four market leading tools are evaluated in detail in chapter 4, supplemented by a short description of some interesting other tools, especially from smaller German providers. Finally, chapter 5 summarizes the results of the evaluation.

2 The Requirements Engineering Process

Sommerville (2004) divides the RE process in the following phases:

0. Feasibility study
1. Requirements elicitation and analysis
2. Requirements specification
3. Requirements validation
4. Requirements management

These phases are passed through iteratively until the final requirements document is created. The management phase can be seen as an accompanying phase to all other phases. This paper bases on this division of phases, that is, especially phase one to four, to evaluate the different software tools for RE. These four stages are described further in the following sections and are mainly based on the remarks of Sommerville (2004).

2.1 Requirements elicitation and analysis

Sommerville describes the stage after initial feasibility studies as requirements elicitation and analysis. At the beginning of the RE process the requirements are mostly incompletely and not precisely defined. This is due to a number of reasons: End-users and stakeholders often don't know what they really expect from the software or they cannot precisely articulate the desired functions the system should provide. Often different stakeholders have different opinions and interests that may lead to requirements that contradict each other. Some stakeholders express their requirements with implicit knowledge of their work and the requirements engineers must understand them without experience (Sommerville 2004).

In the elicitation phase the aim is to identify actors, objectives and use-cases and their descriptions. The information about desired functionalities and features for the software have to be identified. This requires an intensive collaboration between the engineers and the end-users of the system.

One technique to describe real-life examples is scenarios. Often use-cases, which are a scenario-based technique, are used for requirements elicitation. They are easy to read

and understandable for most people without special knowledge. Further techniques for elicitation are interviews, prototyping[1] or brainstorming (Sommerville 2004).

In the analysis phase the aim is to reveal requirements that contradict each other. The engineer gets a better understanding of the system and the requirements can be defined more precisely and more suitably. In case of contradictions, requirements are modified, new requirements can emerge, others vanish or they get priorities. One technique is the viewpoint-oriented analysis where the problem is seen from viewpoints of different stakeholders to analyze it (Sommerville 2004).

2.2 Requirements Specification

According to Sommerville, the requirements specification phase deals with organizing the collected requirements to a formal specification. This requirements document is the agreed statement of the system requirements between customer and contractor. Hence, the document is used by different stakeholders, for example end-users, system engineers or managers. Due to different know-how different elements should be included in the document. One important part for example are the user requirements, which are intended for use by people involved in using the system. They should be described in natural language and diagrams that are understandable by customers. Another part are the system requirements, which are intended to communicate precisely the functional and non-functional elements the system should provide. They may be written in formal or semi-formal language to reduce ambiguity and enable automatic creation of source-code. The IEEE for example have agreed standards (for example (IEEE 1998)) for requirement documents (Sommerville 2004).

2.3 Requirements Validation

Boehm (1984) defines validation as building the right product. As shown in (Sommerville 2004), requirements validation deals with showing that the gained requirements describe the system that the customer actually wants. It has much in common with the requirements analysis phase but deals with the complete requirements document. The requirements have to be tested before they are used in the design or implementation phase of the software engineering process. This is an important step because the cost of changes resulting from a requirements problem are much greater than for example coding errors, because system design and implementation changes are the consequence. In

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[1]New or changed requirements can emerge through prototyping where early versions of the software are given to the customer to find out if the development goes into the right direction or if some functionality is missing.

the validation phase different checks should be done, for example validity checks, realism checks, verifiability, consistency checks or completeness checks. Different requirements validation techniques can be used, for example requirements reviews, prototyping or test cases. In a formal requirements review, the client and the development team together inspect the requirements. Important checks are for example traceability, that is, checking if the origin of a requirement is clear or adaptability, that is, checking if the requirement can be changed without large side effects on other requirements. If the requirements are specified as a system model in a structured or formal notation, consistency can be automatically checked by a CASE tool (Sommerville 2004).

2.4 Requirements Management

Requirements for a system are never stable; they are always changing. Reasons for this are:

- Conflicts or inconsistencies that are discovered during analysis or validation have to be corrected (Kotonya and Sommerville 1998).

- Problems often cannot be fully defined, so the requirements are bound to be incomplete (Sommerville 2004).

- Better understanding of the system by the end-users often lead to more precisely defined requirements (Wirsing 2003).

- Changes in system environment can lead to changed system requirements (Wirsing 2003). Requirements that are likely to change are called *volatile requirements*, in contrast to *enduring requirements* (Sommerville 2004).

Requirements management is the process of managing these changes in requirements. Activities in requirements management cover changing requirements, managing the relationships between requirements and managing relationships between the requirements document and other documents in the software engineering process (Wirsing 2003). According to Sommerville (2004) the basic pre-condition is the traceability of the requirements. It has to be traceable who of the stakeholders has proposed the requirement and why it exists (source traceability), which other requirements are linked or dependent on a requirement (requirements traceability) and how requirements are linked to the design modules where they are implemented (design traceability). Traceability information is often represented through a traceability matrix, where the different relations are stored. Especially in this phase of the RE process CASE tools are required to support these activities in larger projects. They are required for requirements storage, change management and traceability management (Sommerville 2004).

3 Requirements Engineering Tools – A Market Overview

A document-based requirements specification has some limitations. It can be difficult to keep it current and changes that are made often are hard to communicate to different stakeholders. Additional information for each requirement cannot be stored easily and links between requirements and to design elements, for example use-cases, are hard to define.

A requirements engineering tool (or often called: requirements management tool) that stores requirements and related information in a multi-user database often provides a better solution. These tools can be used, for example, to change and view the database contents, import and export requirements, connect requirements and establish links between requirements and other software development tools. Wiegers (1999) names seven reasons to use a requirements management tool:

- Manage versions and changes, for example baselines[1]
- Store requirements attributes, for example author and creation date
- Link requirements to other system elements
- Track status, that is, knowing which percentage of the requirements have already been implemented
- View requirements subset, that is, filtering or sorting requirements with specific attributes
- Control access, for example setting access permissions for individuals and groups or using web access for geographically distributed users
- Communicate with stakeholders, for example discussing requirements issues electronically

At the moment a lot of RE tools exist on the market, which fall into two categories: on one side the established tools, which exist since many years and on the other side the new tools. Even a third category exists: tools, which are used for RE, but are not designed for it, for example word processors like Microsoft (MS) Word or spreadsheets like MS Excel. But these are not the focus in this paper; it lies on the professional RE tools. Also not regarded in this paper are tools that can be used for distributed work but cannot be categorized as real "RE tools", like normal groupware for example. The

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[1]Baselines allow labeling a set of requirements at specific versions.

Figure 3.1: Market share of requirements management tools
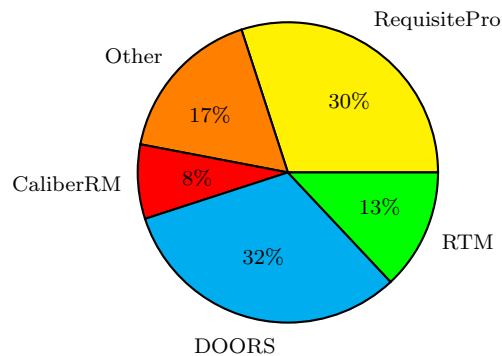
established and most famous RE tools are DOORS from Telelogic, RequisitePro from IBM, RTM from Serena and CaliberRM from Borland[2]. The market leaders are DOORS and RequisitePro (Mühlbauer 2006; META Group 2003), but still normal office tools like MS Word are hard competitors (The Standish Group International 2003), because people believe that the professional RE tools are only needed for extremely complex engineering projects. In Germany there are three companies which have developed a RE product: Polarion Software with Polarion, SOPHIST with CARE and Arcway with Arcway Cockpit (Mühlbauer 2006).

Figure 3.1 shows the market share of the RE tools[3] and an almost complete market overview is given in table A 1 in the appendix.

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[2]See chapter 4
[3]Source: The Standish Group International (2003)

4 Evaluation of Requirements Engineering Tools

In this section the biggest tools are introduced and evaluated in a non-specific order on how they support the four requirements phases described in chapter 2 and especially, how they support a multi-user environment and distributed RE[1]. In this part user communication is of special importance because misunderstandings between different stakeholders lead to problems with the requirements (Kotonya and Sommerville 1998). Because of this, documents are no good substitution for interpersonal communication, even more, if they lack consistency(Al-Rawas and Easterbrook 1996). Herlea and Greenberg (2000) go even further and describe that only synchronous communication, like teleconferencing with teledata is the only adequate way to communicate requirements. Edwards and Sridhar (2005) found out, that voice and video communication among distributed teams can improve the coordination of the projects. Thus, the tools are evaluated which form of user communication is supported.

It is obvious that the tools cannot support all the things that a developer normally does. For example, a tool cannot check if a requirement is realistic, like it is done in the requirements validation phase. But the tools can support the developer at least in some of the activities done in each phase. To make a comparison, all tools are evaluated for the same features, however, partly additional information is mentioned, too. Multi-user functionality is evaluated in an own section. In the section of IBM RequisitePro it is explained in each case why the described functionality is put into the particular phase. In the sections of the other tools only the functionality is evaluated because the reasons stay the same. It is often difficult to put a feature into only one phase because they are often used in several phases. Then the feature is put into the phase to which it seems to apply more. The evaluated information is not based on own tests, because evaluation versions were not available or the provided versions could not be started due to operating system incompatibility. Because of this, the information is mainly based on telephone interviews with the corresponding firms, partly on (Hood et al. 2005) and partly on product documentation and information from the tools website. To avoid misunderstandings, it should be mentioned again that even if it is not explicitly remarked, only the product facts in the following sections are taken from the interviews and documents, but not the interpretation, comparisons to other products or the assignment to the requirements phases, which all stem from the author of this paper.

In section 4.5, some other interesting RE tools are introduced, especially German providers.

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[1]A complete overview of the evaluated functionality shows table A 2 in the appendix.

4.1 IBM RequisitePro

IBM[2] with headquarter in Armonk, New York, USA is the worlds biggest provider for IT in hardware, software and services. The Rational product series offers tools for managing the whole software lifecycle. The requirements management tool is called RequisitePro. It can be integrated with many other products from the Rational series, for example with Rational ClearQuest, which is a tool for change management in the software lifecycle (IBM 2005). The newest version of RequisitePro is 2003.06.15, on which the following sections are based.[3] RequisitePro is document-oriented with a strong integration with MS Word. It could be used without Word, but loses much of the usability.[4] An API called RPX is also available (IBM 2006).

4.1.1 Support for Requirements Elicitation and Analysis

Requirements can be created in RequisitePro or in MS Word and are managed in a database. Documents can be searched for special key words, which are automatically imported into RequisitePro[4] what facilitates the work if requirements were elicited in Word. As shown in (IBM 2006), they can be structured in different levels (hierarchical requirements). Graphics can also be used as requirements (IBM 2006), which supports the elicitation from graphic tools, too.

The IT specialist mentioned that user and system requirements can be created and an software development process called Rational Unified Process (RUP) can be used. The RUP is supported through project and document templates. The project templates define the types and structure of requirements like user requirements for example. The creation and reuse of own information architectures is also possible.[4]

Arbitrary attributes can be stored for better description of the requirements (IBM 2006). In RequisitePro, every requirement automatically gets a unique ID as a standard attribute for example.[4] Defining attributes is especially for analysis interesting, because the developer can for example create an attribute like priority and then search how many requirements in the project exist that have highest priority.

Requisite Pro does not support mandatory attributes (IBM 2006). Mandatory attributes can be very important in a project. Some attributes can be fundamental so that the administrator wants to define them mandatory to force them to be filled out when a requirement is created.

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[2] http://www.ibm.com
[3] The information about RequisitePro was mainly taken from a telephone interview with an IT specialist from Rational Software, IBM Germany.
[4] Taken from the telephone interview with the IT specialist from Rational Software, IBM Germany.

However, RequisitePro allows assigning attributes subsequently (IBM 2006). If a developer gets a better understanding of the requirements, this feature may be used to better describe a requirement. Especially in the requirements analysis phase, when the structure is not definite, requirements are often moved between different levels of the structure. Thus it is important that a tool supports fast moving of requirements by drag & drop.

This feature is supported by Requisite Pro[5], in contrast to the information in (Hood et al. 2005).

4.1.2 Support for Requirements Specification

A basic feature for requirements specification is spell checking because requirements that will be used for a formal specification should be formulated in correct language so that no ambiguities can emerge.

The IT specialist mentioned that a spell checker is integrated in RequisitePro. He also remarked that RequisitePro supports the import from MS Word, MS Excel and MS Access, xml and csv files. The import of pdf files is not supported. Graphics can also be used in RequisitePro through MS Word but they cannot be stored in the database. Thus all MS Word compatible graphic formats are supported.[5] If the engineers want to include for example diagrams to specify the requirements precisely, such an import function for different formats is very useful.

In the requirements specification and also in the elicitation phase it is also advantageous when the tool supports interfaces to modeling tools where the developer can design for example use-case diagrams. It is even better if the tool itself supports use case modeling.

RequisitePro supports bi-directional interfaces to IBM Rational Rose, Rational Software Modeler, Rational Software Architect and Rewritten Software Use Case Studio (IBM 2006). Use cases can be modeled only in a textual way in RequisitePro, a graphical modeling is only possible through the use of the external tools.[5]

Just as important are interfaces to products that are often used in user departments, like the MS Office Tools. The IT specialist enumerated bi-directional interfaces to MS Word, MS Excel, MS Access and MS Project, but not to MS Visio.

Especially important in the requirements specification phase and even in the validation phase is the generation of reports, which can contain different elements according to the point of interest. A report wizard which can help to produce such reports does not exist in RequisitePro, but it supports the generation of some standard reports through the print function, for example a report over all requirements and their attributes or the

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[5]See footnote 4.

complete requirement hierarchy with traceability. It is also possible to print out user configurable views.[6]

Besides that, it is useful if some predefined reports exits that comply to a certain standard, like the IEEE/ANSI 830-1998 standard (see IEEE 1998). Here RequisitePro only offers the RUP document templates that were already mentioned in section 4.1.1. A tool should also offer a scripting language that allows the user or firm to adapt the reports to its own needs. In RequisitePro this is possible by the API RPX (IBM 2006).

4.1.3 Support for Requirements Validation

The requirements validation is a critical phase that can hardly be supported by tools because it consists of many activities that cannot be done by a machine. For example, a machine cannot check if a requirement is complete or if it is comprehensible. However, the tools can facilitate the developers' work in some of the activities.

A basic aspect for requirements validation and also for change management is versioning. Here, every time a requirement is created or changed, RequisitePro automatically stores in a non-editable history the version number, a version label, the user name, date and time, changes in the requirements text and an automatically created entry what was changed by the user.[6] So it is possible, if an error is discovered in the requirements specification or questions emerge, to find out the user who has created or changed the requirement.

The use of structured or formal methods for expressing requirements as a system model is often important where errors in the requirements can have severe consequences like in aerospace. Formal methods have not become mainstream software development techniques because often time-to-market is more important than an error free software product (Sommerville 2004). However it is favourable if a tool supports a formal method for designing critical systems.

RequisitePro does not support any textual or graphical form of formal language.[6]Although more related to the test phase of the software development process, the generation of test-cases for requirements is also a validation technique because if test cases are hard to define, often missing or ambiguous information in the requirements is discovered (Kotonya and Sommerville 1998). Thus, a RE tool should provide the generation of test cases for a requirement or at least an integration to a testing tool. RequisitePro supports integration to IBM Rational TestManager and to Mercury TestDirector, but no internal function for generating test-cases is available.[6]

RequisitePro provides a detailed search function that supports the user in the validation phase but also in other phases. It is possible for example to search in requirements or

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[6]See footnote 4.

documents and even in attributes[6] as already mentioned in section 4.1.1.

It also contains a traceability feature (IBM 2004), which is besides requirements management also important for requirements validation. In this phase it can be used to check the origin of information, called trace analysis or assess the impact of a change, called impact analysis, which shows the connectivity of a requirement.Traceability for change management is further described in the following section.

4.1.4 Support for Requirements Management

An efficient requirements management can only be done with a database management system. As shown in (IBM 2004), the storage in RequisitePro happens in Oracle, MS Access, MS SQL Server or DB2 from IBM.

In RequisitePro it is only possible to integrate a change process by using an external tool; Rational ClearQuest is preferred (IBM 2006). However, every change and comments ever made during the whole lifecycle of a requirement can be displayed.[7] As mentioned in section 4.1.3, it is possible to do a trace analysis and an impact analysis. RequisitePro is also able to display suspect links, that is, identifying information where elements in the relationship have changed. It is also possible to create a baseline to freeze the actual state of the requirements. Two baselines can then be compared to differences (IBM 2006).

As mentioned in section 2.4, a basic activity in the requirements management phase is managing the relationships between requirements. To display these dependencies, RequisitePro offers a tree view, a trace matrix and a tabular view. They can be created through putting a reference ID, marking a cell in the traceability matrix or creating an information by copying the original information.[7] It is also possible to establish dependencies between requirements and imported graphics (IBM 2006).

Often it is not very useful to allow every connection between the requirements. The IT specialist mentioned that in RequisitePro links can be limited to special groups of requirements, like user-requirements, or to certain user roles. It supports m:n dependencies, 1:1 or 1:n cannot be defined and it is not possible to give these dependencies attributes.[7] Requirements can also be connected to requirements from other projects (IBM 2006), but not to an older baseline.[7]

If changes are made to requirements, sometimes an undo has to be done because the modification was wrong or something was deleted by mistake. Thus it is of advantage if a tool supports an undo function so that a modification can be undone without being displayed in the change history. RequisitePro does not offer such an undo function where

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[7]See footnote 4.

older version of requirements can be restored. The only undo supported is the normal MS Word undo.[7]

4.1.5 Support for a Multi-User Environment and Distributed Work

It is not assumed that every user of a RE tool works on a system that uses the same hardware and software. So the first thing a tool should provide is a broad basis of operating systems the tool should run on. There are differences between the server and client components of the tools, but only the client side is of importance for a multi-user environment.

RequisitePro only supports MS Windows operating systems on the client side, namely Windows XP, Windows NT, Windows 2000 and Windows 2003 Server. Linux or Unix systems are not supported (IBM 2004).

For managing users, it provides an integrated role concept. The administrator can assign different roles to the users and it is possible to set different access rights for these roles.[8] This is often necessary because not all users are allowed to access or change all the data or use all functions provided by the tool.

Access rights can be defined on the basis of menu options and a user that is assigned to a certain role inherits the access rights of this role.[8] Although mentioned as not supported in (Hood et al. 2005), in RequisitePro it is possible to change these rights subsequently for a special user.[8]

In distributed work security is also of high importance. In RequisitePro, every user gets an own password, but it is not possible for the administrator to force the users to change their passwords regularly[8], what may lead to a security vulnerability.

In large projects, where many users may create or change requirements, it is often not necessary that every person works with a full version of a requirement management tool. It is economically wise to use a web client instead, that is often cheaper than a full version of a tool. Another reason is the small and uncomplicated installation on client platforms. Furthermore the web client should run on many operating systems to support best the collaboration between the different stakeholders.

RequisitePro provides a separate web client that was originally designed for use in an intranet. Now it can also be used in the internet (IBM 2006) and does not use ActiveX[8] what is important for security reasons. The client can be set read-only[8], so that users can only read requirements but cannot change it, what is extremely important in a multi-user environment because not every person is always allowed to change them.

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[8]See footnote 4.

Like in the normal client it is not possible to use the web client offline, a user can only edit documents offline and bring them online later.[8] A not-supported offline work can be very disturbing when users want to work with Laptops in places where no connection is possible or when they want to work at home and only got a slow internet connection and maybe even have to pay for it.

The web client RequisiteWeb which is based on Java is not fully functional. It has many restrictions in document editing, project administration and integrations with other tools. For example it is not possible to modify the project structure or cut, copy and paste requirements in a document (IBM 2006). However, it runs on all platforms like Windows and Unix and supports MS Internet Explorer, Netscape Navigator, Mozilla Firefox and Mozilla as web browsers but a license for it is not cheaper than a license for the normal client.[9]

For concurrent access RequisitePro offers the standard functions of MS Word. That means that if a user opens a document all the requirements included are locked and other users can only open a read-only copy. Therefore it is recommended that only small documents are used. If only requirements sections have to be edited, the extended editing feature can be used where for example the requirements text can be changed without opening the document. The changes will be updated in the document the next time a user opens it. Only the edited part is set read-only then (IBM 2006). Since many stakeholders are involved in the RE process, it is important that a requirement tool supports the native language of the users. Although English is often well accepted in the IT departments, other departments complain about it and prefer the native language. For global collaboration this means, that a tool should support as many native languages as possible. RequisitePro only supports English[9], no other European or Asian language, what could limit its scope above all in the Asian market.

This could be reduced through the integration into the Eclipse IDE. For these integration additional languages are supported.[9] Such an integration into the Eclipse IDE can also be useful for distributed work because Eclipse is a platform independent IDE.

A project specific glossary, that includes all the words that have a certain meaning, is very useful for distributed projects. In the glossary words can be defined that should be used for example to describe a requirement. This is very helpful where daily meetings are not possible. Even more important is the possibility of defining forbidden words that cannot be used to describe a requirement, because they are not unequivocal, like *fast* or *good*. The IT specialist mentioned that RequisitePro provides the definition of a glossary but does not support the definition of forbidden words.

If a user is not permitted to change a requirement, nevertheless he could contribute good proposals to it. Thus, a tool should provide a function where these users could

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[9]See footnote 4.

remark their comments. In RequisitePro this is possible by commentary attributes or discussion contributions.[9] It could also be used for discussing reviews in the validation phase, for example. As shown in (IBM 2006), discussions can be be stand-alone or tied to a requirement and the integrated e-mail function in RequisitePro can be used to participate in the discussion. Chats, live meetings or a function for presenting teledata for brainstorming for example are not supported.[9]

If a requirement is changed, it is of importance that everybody who is concerned with it will be informed. Otherwise it could lead to confusion, if a lot of requirements are changed but nobody recognizes it. Thus, a tool should provide an e-mail function for informing the users of changes. The e-mail mechanism in RequisitePro allows automatically sending an e-mail to subscribers and other persons when a requirement is changed. The sender who did the change can also customize the recipients, subject and content of the email.[10]

Finally, if many stakeholders, especially non-informatics, are working with the tool, it should be possible to configure the menu and the layout to the user's needs. The layout can be configured partly in RequisitePro[10], but only add-ins can be added to the menu (IBM 2006).

4.2 Serena RTM

Serena Software[11] with headquarter in San Mateo, California, USA is the worlds biggest independent software firm with focus only on change management in IT-environments. Besides products like ChangeMan for application lifecycle automation or TeamTrack for enterprise process management, Serena provides a broad solution for requirements management called RTM (Requirements Traceability Management). RTM stood out in the category lowering the cost of application maintenance in the Yphise Software Product Assessment and the Yphise Certification was awarded to Serena in 2005 (Hood GmbH 2006; Yphise 2005).

To the question if RTM is document-oriented, a Technical Solution Manager from Serena Software answered *"Partly yes and partly no..."* because on one side the requirements are stored in a database and referenced documents are only registered but not stored there but on the other side a bi-directional synchronization for MS Word, Adobe Framemaker and Interleaf exists.

An API is also available for RTM but the Technical Solution Manager mentioned that it is not very welcome because it often affects the stability and the ease of maintenance of the program.

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[10]See footnote 4.
[11]http://www.serena.com

The following information describes version 5.6 of RTM.[12] Information from (Hood et al. 2005) could not be taken because it seemed out of date due to major version changes from version 5.3.6 to 5.6. These were for example a better integration with other Serena products, better password security, an improved GUI and enhanced web-client functionality (Clarke and Vyridi 2005; Serena Software 2006c).

4.2.1 Support for Requirements Elicitation and Analysis

As mentioned before, RTM provides the user a well-known MS Word-interface, where requirements can be elicited. The created requirements get own IDs and can be structured into different levels. Since requirements are objects in RTM, it is also possible to treat graphics as requirements, but it is not possible to move requirements between different levels of the structure by drag & drop, which hampers fluid working in the analysis phase.

In RTM different information architectures can be defined, like user and system requirements. Own architectures can be created by a graphical editor and reused in other projects. In contrast to the information in (Hood et al. 2005), RTM delivers predefined information architectures which don't comply with a certain standard but nevertheless could help in the early phase of a project.

Requirements can be equipped with additional attributes, which can also be documented and changed afterwards. In contrast to RequisitePro mandatory attributes can be defined that have to be filled out. The mandatory attributes can even be defined after the creation of the requirement. This provides the developer with a better control over the attributes of requirements, which can help him in the requirements analysis phase.

An interesting new feature in version 5.6 is polling, where votes over requirements can be done. It is described in section 4.2.5.

4.2.2 Support for Requirements Specification

The basic feature for the specification phase, spell checking, is supported by RTM. It supports the import from MS Word, MS Excel, Interleaf, Adobe Framemaker and MS Access over csv. The import of xml files is not supported but will be included in the next version. Pdf files also cannot be imported what can partly form the specification of requirements to be a bit more long winded. However, the import of any graphic formats is supported.

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[12]If nothing else is mentioned in the text, the information about RTM was taken from a telephone interview with the Technical Solution Manager from Serena Software.

For specifying requirements more precisely, RTM supports an interface to IBM Rational Rose and to Artisan RTS but not to Borland Together, like CaliberRM for example. From the MS Office Tools, RTM supports a bi-directional interface to MS Word, MS Excel, MS Project and even MS Visio. Since requirements are objects in RTM, they can be defined as use cases an their description can be used as the use case description, but RTM offers no function for modeling them graphically.

For printed specifications through reports, RTM provides a report wizard (Serena Software 2006b) which can produce some predefined MS Word reports like traceability matrices or multi-level-reports over requirements and it is also possible to adapt the reports to special purposes by a Meta-SQL language. Predefined reports that apply to a certain standard like IEEE are not included.

4.2.3 Support for Requirements Validation

For versioning, RTM stores a complete object of a requirement with all its attributes in a history which cannot be manipulated by a user. In addition, the ID, the time modified and the user name who made the changes are also stored. Thus, a basic function for validation is given.

The detailed search function lets the user search in requirements and attributes, what is often needed in the validation phase. Attached documents cannot be searched by the search function.

RTM also supports traceability features (Serena Software 2005) that can be used for requirements validation, like an impact analysis or a trace analysis. Further traceability features are described in the following section.

A support and checks for compliance with a formal language are not given but it supports integration to Mercury TestDirector for the generation of test cases from objects stored in it (Serena Software 2006a).

4.2.4 Support for Requirements Management

The database used for storage is Oracle. Other database systems are not supported (Serena Software 2005), what can lead to complicated installations if a firm normally uses another database system. For managing changes in requirements, a role-based change process called Change Request is already integrated in RTM. A user can pose a change proposal and a discussion can be lead. If the person in charge agrees, he can allow the change. It is also possible to create an own change process with an integrated workflow-mechanism. All changes ever made to a requirement can be displayed in a graphical representation. RTM provides a lock-mechanism to protect a requirement from possible

changes. As mentioned in section 4.2.3, it is possible to analyze the impact of a change and to do determine the origin of a requirement trough a trace analysis. Suspect links can also be identified. Like in the other tools baselines can be set and compared to each other.

For displaying dependencies, RTM provides a graphical and a textual view (Erchinger 2005). The dependencies can be created in many ways: through drag & drop in the graphical view, marking start and end-point, setting a reference ID, marking a cell in the traceability matrix or automated through filter and link criteria. Automated linking can also be done using a command line link tool. Hence, it provides the most functions of the tools in this point and especial the automation is an interesting feature. Dependencies between requirements and imported graphics can also be established. RTM allows every type of connection between requirements, it can be limited to 1:1, 1:n and m:n. Thus the developer is not restricted in formulating dependencies. Attributes can also be assigned to dependencies in RTM. To restrict useless connections between requirements, the links can be limited to special requirements groups and user roles. The direction and the cardinality can also be limited. Requirements from other projects can be integrated and even requirements from older baseline. The latter is shown by links to objects that are marked as replaced.

An undo-function in RTM, that sometimes is of high importance in a project, protects the developer of changes made by mistake that have to be undone. It can be done using the database or using a replace function in the history to restore earlier versions of requirements.

4.2.5 Support for a Multi-User Environment and Distributed Work

Working on different platforms is possible through RTM's client support for MS Windows XP, MS Windows 2000 and MS Windows 2003 Server. Linux and Solaris as mentioned in (Hood et al. 2005) are only supported by the web client.

RTM provides an integrated role concept for user administration (Serena Software 2005). The administrator can assign roles to users and every user gets an own password. A function for a mandatory regular change of the password is now supported by RTM. Access rights can be set according to the different roles and every user inherits the access rights of his role. Access rights can be changed subsequently and are not strictly bound to a role. Thus, the creation of special accounts is possible without creating new roles. Access rights can also be defined on the basis of menu options.

RTM includes an additional web client at no charge. It supports a read only function and it does not use ActiveX components, which is a pro for security. It can be run on all platforms with a web browser. Like the normal RTM client it is not possible to work with it in an offline mode but Word documents can be edited offline and synchronized later.

Another restriction of the web client is that it cannot show the traceability graphically. It supports Mozilla Firefox, MS Internet Explorer and Netscape Navigator as web browsers (Serena Software 2005).

If multiple users want to edit a requirement, the first user gets the access right and for the rest it is shown *in processing* and set to read-only. Eclipse integration is not supported yet but Serena is working together with the Eclipse developers at the moment to develop such integration. Like RequisitePro or DOORS, RTM only offers English as language, other European or Asian languages are not supported. This can be a reason for not using this tool in a project where many stakeholders insist on the support for native language. The Technical Solution Manager mentioned that Serena is working at additional language support.

RTM provides a glossary for defining project-specific words but in contrast to the information in (Hood et al. 2005) no function to define forbidden words which cannot be used. Through the use of the new polling function, votes can be send to different users which can then pick from customized answers and have the possibility to comment them. It is graphically shown how many users already voted and the percentages of the chosen alternatives. Deadlines for polls can also be set. This feature supports well collaboration and the requirements elicitation and analysis phase.

Besides the polling function RTM offers a function to directly connect comments to a requirement so that users that are not allowed to change requirements can communicate their ideas to others. In addition, discussion objects, which can be used as a discussion forum, can be created. Chats or the like are not supported.

The e-mail mechanism, which notifies the users on changes of requirements, can be detailed configured. It is possible to configure for every user on which event he is notified, for example a change of the state of a requirement. It is also possible to configure the subject and content of the e-mail, like attached attributes of the requirement.

In RTM it is possible to define special views for different roles, which can be configured down to the attribute levels. Menus and layout can be configured to user needs and roles. The three different GUIs that are integrated also support different roles: the web client for restricted usage for reviews in the validation phase for example, a Word interface for specifying requirements and the full client for developers.

4.3 Borland CaliberRM

Borland Software Corporation[13] with headquarter in Scotts Valley, California, USA is leading in the development of platform independent solutions for software delivery op-

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[13]`http://www.borland.com`

timization. The solutions from Borland cover the whole application lifecycle, from requirements management to the deployment of the finished product. Besides the core product for requirements management, CaliberRM, Borland provides CaliberRM Datamart for analyzing the effectiveness and efficiency of the requirements management process and CaliberRM Estimate Professional for managing for example time schedules and the extent of a project (Borland Software Corporation 2006a). In the newest version, CaliberRM 2005 Release 2 SP1, both components are delivered with CaliberRM at no additional charge (Borland Software Corporation 2005a, 2006b). Also available is a software development kit (SDK) that can be used by developers to enhance the functionality of CaliberRM. Besides CaliberRM, Borland distributes Core::Analyst, a package of CaliberRM and the modeling tool Together[14], for integration in its Core SDP application lifecycle platform. CaliberRM is not document-oriented like RequisitePro for example; documents are integrated through references. At the moment Borland is developing new products for the Caliber series. According to the Technology Consultant, the new products will be announced in May 2006. It will be a package called Caliber Analyst, which includes CaliberRM and the new product Caliber DefineIt. Caliber DefineIt will focus on the phases requirements elicitation and analysis and it will allow visual capturing of scenarios (Lobeck 2004). *"For the themes elicitation und analysis you can use CaliberRM and Caliber DefineIt. Caliber DefineIt has some nice functionality, which stronger supports these two phases.",* so the Technology Consultant in an e-mail. But also the specification and validation will be better supported.[15]

Sections 4.3.1 to 4.3.5 are based on information from (Hood et al. 2005), datasheets, websites and a telephone interview with a Technology Consultant from Borland. In (Borland Software Corporation 2005a, 2006b) it can be seen that the information that was taken from (Hood et al. 2005) where the earlier version CaliberRM 2005 was tested was not affected by the Release 2 SP1.

4.3.1 Support for Requirements Elicitation and Analysis

Although managing documents as requirements is not the focus of CaliberRM, besides the creation of requirements inside it, requirements can be created from information which was elicited with MS Word for example. Like in the other tools, every requirement gets an own ID as standard attribute (Borland Software Corporation 2005d). CaliberRM provides a detailed structuring of the requirements into different levels (Lobeck 2004). Graphics can also be used as requirements.[15] A very helpful feature for the analysis phase is that requirements can be moved in the structure by drag & drop (Borland Software Corporation 2005d). This accelerates the work in early phases and saves time.

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[14] A Technology Consultant from Borland was interviewed to get the information about CaliberRM.

[15] Taken from a telephone interview with the Technology Consultant from Borland.

In CaliberRM, it is possible to create own information architectures. In contrast to the information in (Hood et al. 2005), CaliberRM does not deliver the V-Modell 97 and the V-Modell XT as predefined information architectures, but gives the possibility to create information architectures, that conform to these two models.[15]

Like in the other tools, additional attributes for requirements can be defined and changed subsequently. It is possible to define mandatory attributes and even to define them subsequently (Borland Software Corporation 2005d). This gives the administrator the possibility not to prescribe all attributes at the creation of a requirement.

4.3.2 Support for Requirements Specification

CaliberRM supports spell checking for a correct specification. It supports only three import formats, MS Word, MS Excel and xml files. Xml files are used to import a glossary for example (Borland Software Corporation 2005d). In contrast to RequisitePro, the import from MS Access is not supported, but with the free tool CaliberRM Import Factory, comma-separated files and MS Access files can also be imported.[15] Wmf, bmp, jpg, xbm and art graphic formats can be imported (Hood et al. 2005).

The support of use cases is given in a textual way, requirements can be use cases themselves, but CaliberRM provides no integrated function for modeling these use cases graphically, for example in UML.[16] Thus, external tools have to be used. For this CaliberRM supports a bi-directional interface to the modeling tool Borland Together and in contrast to the information in (Hood et al. 2005) also to IBM's Rational XDE. To the MS Office tools, bi-directional interfaces exist to MS Word and MS Excel. CaliberRM provides an open interface where it is also possible to create own import functionality with the SDK. Attachments for requirements can be linked to all file formats.[16]

The report wizard in CaliberRM provides some standard reports, like a status report where all requirements are sorted by status. It is possible to generate MS Word reports, HTML reports or reports for use in CaliberRM Datamart. With the so-called Document Factory it is possible to generate any type of customized specifications documents using MS Word templates (Borland Software Corporation 2005d). Predefined specification documents, like the IEEE/ANSI 830-1998 standard (see IEEE 1998) for requirements documents, are not integrated.[16]

4.3.3 Support for Requirements Validation

As the other tools CaliberRM offers a complete versioning where every creation or change of a requirement is documented in a history. The version, date and time of the change,

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[16]See footnote 15.

the user who made the change and an additional comment is stored (Borland Software Corporation 2005d). The history cannot be manipulated by a user (Hood et al. 2005).

CaliberRM provides a limited search function where it is possible to search for text in names or descriptions of requirements. A detailed search for attributes is also possible. The content of referenced documents cannot be searched.[16]

The origin of a requirement can be analyzed through a trace analysis (Borland Software Corporation 2005d) and an impact analysis (Borland Software Corporation 2005d) shows the connectivity of a requirement for analysis and validation aspects. CaliberRM does not support a formal language that could be used for consistency checks for example, but it could theoretically be integrated by using the SDK.[16]For generating test cases, CaliberRM supports integration to Mercury TestDirector (Borland Software Corporation 2005d).

4.3.4 Support for Requirements Management

CaliberRM supports the database systems Oracle and MS SQL Server. MS Access is not supported as a database.[16]A change process like in the other tools is not included in CaliberRM but could theoretically be integrated through an external workflow component (Hood et al. 2005). The whole lifecycle of a requirement with all changes can be displayed in a history. As mentioned in section 4.3.3, an impact analysis and trace analysis is possible and like the other tools, suspect links can be identified. The definition and comparison of baselines to freeze a state of a project is also possible (Borland Software Corporation 2005d).

Dependencies between requirements can be displayed in a tabular view or graphically (Lobeck 2004). These connections can be established in three ways: by drag & drop, by marking a cell in the traceability matrix or by creating information by copying the original information (Hood et al. 2005).
It is also possible to establish dependencies between imported graphics and requirements.[17]

CaliberRM only supports m:n connections, a restriction can only be done through user roles. Restrictions through cardinalities or directions of links cannot be set. It is also not possible to allow only links between certain groups of requirements, like user and system requirements (Hood et al. 2005). Attributes for dependencies between requirements cannot be set[17], but cross-project dependencies (Borland Software Corporation 2005d) and even dependencies to older baselines can be displayed (Hood et al. 2005).

CaliberRM supports an undo function in contrast to the information in (Hood et al. 2005). It is possible to undo changes and restore older versions of a requirement through

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[17]See footnote 15.

the history.[17]

4.3.5 Support for a Multi-User Environment and Distributed Work

The client of CaliberRM runs on MS Windows XP, Windows 2000 and Windows 2003 Server (Borland Software Corporation 2005c). Linux and Unix are not supported anymore, like it is mentioned in (Hood et al. 2005). CaliberRM is designed for a work in a multi-user environment with an integrated role concept (Borland Software Corporation 2005d). Every user who gets an assigned role inherits the access rights of this role and gets a password for security reasons. In contrast to RequisitePro, it is possible to force the users to change their password regularly (Borland Software Corporation 2005d). This is of high importance in large projects where many users have access rights and the security vulnerability therefore is higher. An individual adaptation of the access rights of a user is also possible (Borland Software Corporation 2005d) but access rights cannot be defined on the basis of menu options (Hood et al. 2005).

The web client of CaliberRM does not use ActiveX components and allows a read only function where it is not possible for the user to change requirements (Hood et al. 2005). It has full functionality except the MS Office integration. It can be run on the same platforms like the normal client and supports MS Internet Explorer as web browser (Borland Software Corporation 2005c). For use on other operating systems, the integration into the Eclipse IDE is recommended.[18] In contrast to the information in (Hood et al. 2005), it is not possible to run the web client in offline mode, but according to the Technology Consultant it should be supported in the future by the new product Caliber DefineIt. The normal CaliberRM client also cannot be run in offline mode.[18]

If multiple users are working with CaliberRM and a user edits a requirement, the program automatically locks it and an icon displays that other users only have read access until the editing user has finished his operation (Lobeck 2004). CaliberRM offers support for more languages than RequisitePro, DOORS or RTM. It supports English, Japanese and since Release 2 SP1 also French and German (Borland Software Corporation 2005b). This will definitely increase its usefulness in France and Germany.

It offers a glossary to store project-specific vocabulary, which can also be exported and reused (Borland Software Corporation 2005d). A function for defining forbidden words is integrated. If a user uses a forbidden word, it is marked in a special color and sometimes a hint is given, for example for abbreviations (Lobeck 2004).

Every requirement has got an own item where a discussion can be lead and users that are not allowed to change requirements can write down their comments. Unread contributions are marked so that the user can see them directly (Lobeck 2004). Live meetings

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[18]See footnote 15.

or chats are not supported.[18]

CaliberRM supports an e-mail mechanism for informing users on changes of requirements. The e-mail is send to the owner of the requirement, the user who changed it and other interested persons, which can be configured individually. In the e-mail itself the content can be configured (Borland Software Corporation 2005d).

For different kind of users, different views can be created which can be configured by filters. Menus and layout of the GUI can also be configured (Hood et al. 2005).

4.4 Telelogic DOORS

Telelogic[19] is a worldwide leading provider for solutions for sophisticated software and systems. Its headquarter lies in Malmoe, Sweden. Telelogic's tools support the whole software development lifecycle. Telelogic recently acquired I-Logix, which also provides a solution for RE. Telelogic's requirements management tool DOORS (Dynamic Object Requirements System) is the market leading product since the last years (The Standish Group International 2003; Versteegen et al. 2004). It got the Yphise Award in 2005 for best requirements management software (Yphise 2005). Telelogic offers four different components of DOORS. The DOORS core product, DOORS/ Analyst for additional description of requirements by UML 2.0 diagrams, DOORSnet, a web-client and DOORS XT for increased performance in distributed projects.

According to a Presales Engineer from Telelogic Germany, DOORS is database-oriented but provides the user a document-oriented view for an easier change from text processors like MS Word. An extension language called DXL is available for creating own components for the use with DOORS and a so-called Test Tracking Toolkit for small-scale test environments is included. The following remarks base on the newest version 8.0 of DOORS. Information from (Hood et al. 2005) could not be used due to major version changes from 7.1 to 8.0. Version 8.1 will be likely released in May 2006.[20]

4.4.1 Support for Requirements Elicitation and Analysis

DOORS provides a document-oriented view of information and requirements can be directly elicited and created in it. If the elicitation happened in text files or in MS Word documents for example, the information can also be imported. Graphics can be used as requirements and every requirement gets a unique ID. They can be structured into different levels like in the other tools (Telelogic AB 2006b). The helpful feature to move

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[19]http://www.telelogic.com

[20]If nothing is explicitly mentioned, the following information about DOORS was taken from a telephone interview with the Presales Engineer from Telelogic Germany.

requirements by drag & drop like it is supported by CaliberRM or RequisitePro is also available in DOORS.

DOORS distinguishes different information architectures and delivers the most predefined information architectures from the four tools. By default it offers for example IEEE standards, the RUP, standards of the defense industry like DoDAF (Department of Defense Architecture Framework) or MoDAF (Ministry of Defence Architecture Framework) etc. The creation and reuse of own architectures is also supported.

Attributes for requirements can be defined and changed subsequently. Mandatory attributes can only be defined in DOORS XT (see section 4.4.5), but not in DOORS. It is not possible to create mandatory attributes subsequently.

4.4.2 Support for Requirements Specification

Like the other tools, DOORS includes a spell-checker for the requirements. Although (Hood et al. 2005) only mentions two import formats, DOORS supports some more import formats: Adobe Framemaker files, MS Project files, spreadsheet files (tsv, csv) and MS Word documents. MS Access or pdf files cannot be imported. Although it is mentioned in (Hood et al. 2005), eps graphics files cannot be imported. Only two graphic formats are supported, wmf and bmp files. The common and space saving jpg format is not supported, what can enlarge the data in the database and lowers the data transfer over the network if much bmp graphics have to be used as requirements. Besides that, references to all file formats can be set. These files can be stored in the database for better protection against unintentional changes or can be left outside the database for better access.

A function for describing use cases is not explicitly given but can be done through the requirements description. A graphical use case description is not included in DOORS, but this can be done by integrating another product of Telelogic called DOORS/ Analyst, which is especially designed for that.

DOORS supports interfaces to the two established modeling tools Borland Together and IBM Rational Rose. It also supports interfaces to Artisan RTS[21], IBM Rational Software Modeler, IBM Rational Software Architect, MathWorks Simulink[22], Telelogic TAU, Kennedy Carter's iUML[23] and to Rhapsody, a product of the newly acquired firm iLogix[24], which can also be used for requirements management. It also provides interfaces to tools that can be used for modeling safety-critical software, like Esterel Technologies'

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[21]http://www.artisansw.com
[22]http://www.mathworks.com
[23]http://www.kc.com
[24]http://www.ilogix.com

SCADE[25] or eNGENUITY Technologies' VAPS[26] for modeling applications that require high quality graphics such as cockpit avionics. As mentioned before, Telelogic provides DOORS/ Analyst, a component for DOORS for modeling requirements graphically based on UML. From the MS Office series, it supports bi-directional interfaces to MS Project, Word and Excel.

DOORS supports the generation of reports of different views through a report wizard. Word templates can be integrated to format the report. Through the support of many information architecture standards and the document-oriented view the reports can be directly used as requirements specification documents. A scripting language called DXL (DOORS Extension Language) is also available. The reports can only be stored, viewed and printed in DOORS.

4.4.3 Support for Requirements Validation

For controlling creation and changes in the lifecycle of requirements, DOORS provides a complete versioning in a history. The history shows for example the user who changed the requirement, date and time and the modification. Details of a record can also be displayed. The history cannot be manipulated, but a direct restore function to restore older versions is included. A detailed search function can be used to find or replace entries even in attributes of requirements, but not for searching attached documents.

The trace analysis in DOORS helps the user to find the source of an information in the validation phase and the impact analysis can be used to show which requirements are affected by others. Like in the other tools, a formal language is not supported by DOORS. For small scale-test environments, DOORS provides the Test Tracking Toolkit. It allows defining test instructions, link them back to the requirements and record and compare the results of different tests for example. For large scale-test environments an integration with Mercury TestDirector exists (Telelogic AB 2006a).

4.4.4 Support for Requirements Management

For storage of requirements, DOORS includes an own repository. Other database systems are not supported. Only DOORS XT optionally supports the database management system Oracle. DOORS includes a change process called CPS (Change Proposal System) where users without write authorization can create change proposals to a requirement. They are marked as in review and the responsible user for that requirement can approve or decline the changes. If they are approved, the changes can be automatically adopted. An external integration with the change management tool Telelogic SYNERGY/ Change

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[25]http://www.esterel-technologies.com
[26]http://www.engenuitytech.com

is also supported. As mentioned in section 4.4.3, the changes are stored in a history for every requirement, an impact and trace analysis is supported and also the identification of suspect links between requirements that have been changed. Baselines can be stored and compared with a diff function.

In DOORS, links between requirements can be shown in a tabular or graphical view. The links can be created by drag & drop, marking start and end point, creating new information by copying from the original information and by inserting a reference in an attribute (Link-by-Attribute). Marking a cell in a traceability matrix like in the other tools is not supported by DOORS. Links between imported graphics are also possible.

DOORS provides the most features in connecting requirements and restricting the links between them. 1:1, 1:n and m:n connections can be defined. It is possible to restrict them to links between certain groups of requirements, the direction and the cardinality can be restricted and also a restriction through user roles is possible. Attributes for links can also be set, as opposed to the information in (Hood et al. 2005). Dependencies on requirements in other projects and baselines can be represented. A normal undo-function and an undo over the history to restore older versions of requirements is also included in DOORS.

4.4.5 Support for a Multi-User Environment and Distributed Work

Working with the client of DOORS on different platforms is possible through the support of MS Windows XP, MS Windows 2000, MS Windows 2003 Server, RedHat Linux, HP-UX and Solaris (Telelogic AB 2006c). The integrated role concept is the basis for a multi-user working environment. The administrator can set access rights for every role and assign them to users who inherit the rights of their role. In addition it is possible to change the access rights for individual users afterwards. Every user gets a password which can be set to a minimum length and it is possible to set that the users have to change their passwords regularly just like in CaliberRM or RTM. Setting access rights on the basis of menu options is not possible.

DOORSnet, the webclient of DOORS, is an additional product and not included in DOORS. It is not fully functional because it was originally designed for read-only customer reviews. For example, it is not possible to create links between requirements and it only provides rudimentary edit functions. It does not support an offline work and can only be used when connected to the internet, but for better security it does not use ActiveX components. MS Internet Explorer and Netscape Navigator are supported web browsers (Telelogic AB 2006d). It runs on the same platforms like the normal client (Telelogic AB 2006c, d). A DOORS integration into the Eclipse IDE is not supported. However, the normal DOORS client supports an offline work. It is possible for a user

to mark the data that he wants to edit offline. This data is locked in the database for other users until it is brought back online and synchronized.

Telelogic offers another product, DOORS XT, which is specially designed for better support of distributed work. In DOORS always a whole document is transferred over the network if a user accesses it so the performance is only good on a fast connection and if the documents are not too large. This problem is dealt by DOORS XT by using xml for transferring data and only transferring those parts of a document that are actually used. DOORS XT uses a three-tier architecture with an Oracle database, a WebLogic application server and a thin client. On a client machine, only the thin client has to be installed and patches and installation can be done online over the server. Since DOORS XT is a relative new product it does not provide all the functionality that is provided by DOORS. For example, DOORS XT does not support integrations to other products. It has to be individually decided which product better fits to the working environment of a firm.

Through the document oriented view DOORS supports two edit modes if multiple users are editing requirements. In the exclusive edit mode a document is locked for other users and marked as read-only, in the shareable edit mode parts of the document can be marked by a user as locked and other parts can be edited by other users. DOORS is only available in English with the possibility to manually translate the menu entries in ASCII files. A German version is not available.

A glossary can be created in a project specific or global dictionary, which can be used for the whole database. Forbidden words can be defined and a user-configured alternative is displayed if such a word is used. In some cases an alternative for the word is proposed by the program. Users that have no rights to change a requirement can create so called *change proposals*. So they have the possibility to communicate their ideas without the need for more access to the requirements. Live meetings, chats or the like are not planned.

In the context of the CPS, the automatic e-mail script sends an e-mail to all DOORS users when a requirement is changed. The layout of the GUI cannot be changed in DOORS, but user-specific views can be configured through filters. Menus can also be adapted to user needs.

4.5 Other tools

Besides the market leaders, a lot of other tools for RE exist on the market. The main reason for these products is that they are often cheaper than the products from the market leaders. This can be an important decision criterion for small or medium sized firms.

IRqA (Integral Requisite Analyzer) from TCP Sistemas e Ingenieria[27] that is distributed in Germany by QA Systems[28] is one of these products. Its mature technology seems even better than that from the market leaders (Mühlbauer 2006). It provides an attractive usability and since 2005 a German GUI, which considerably increased its use in Germany. As mentioned in section 4.1.5, the support of the native language is very important for stakeholders, which do not work in IT-departments. The interesting feature of IRqA is the integrated modeling component. IRqA supports graphical elements of UML 2.0 to directly model requirements. The advantage lies in the fact, that the requirements can be modeled without using external tools. Other requirement tools have to use interfaces, which is always a question of compatibility. It is criticized that the UML tools are not working together very well with the requirements management tools (Mühlbauer 2006). In requirements based testing IRqA also provides a solution.

Polarion from the German provider Polarion Software[29] is fully web-based and disposed to development across distributed locations. There exist two versions of Polarion: one bases on the open source product Subversion, the other on SAP NetWeaver. An interesting feature of Polarion is called Live Documents. The Live Document Technology facilitates the collaborative work between the developers and the users. The information in documents that are stored in Polarion is recognized and can be managed in Polarion. The information in the document is automatically updated when the requirement is changed in Polarion and vice versa, so the documents and the requirements are always in sync (Polarion Software GmbH 2005, 2006; Rizzo 2006). The benefits are obvious, users that are not familiar with the requirements management tool can use for example MS Word files for specifying their requirements, the engineers can work with the complete requirement tool and the documents are always synchronized.

SOPHIST[30], also a German provider, provides its tool CARE (Computer Aided Requirements Engineering). The tool provides a wide range of features and is based on the groupware Lotus Notes, what on one hand restrains its market but on the other hand excellently supports distributed development. SOPHIST does not see CARE as a direct threat to the market leading products like DOORS, Caliber or RequisitePro. They categorize CARE not as mass product, but as a product individualized for every project (Sophist Technologies 2005). Especially attractive is the very low price for a license[31], which can be up to 50 times lower than the price of other RE tools.

Arcway Cockpit from Arcway[32], a young corporation from Germany, can be seen as a Swiss knife for a software development project. It is based on the Fundamental Mod-

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[27] http://www.irqaonline.com
[28] http://www.qa-systems.de
[29] http://www.polarion.com
[30] http://www.sophistgroup.com
[31] 150 € per license. (see Sophist Technologies 2005)
[32] http://www.arcway.com

eling Concepts, a modeling language, which is more system-related than UML (which is more software-related) (Apfelbacher and Curth 2004). The so-called Big Picture, a visual diagram, shows the connection between processes and architecture. This helps to communicate and coordinate the requirements between the users and the engineers. The focus of Cockpit lies on improving the cooperation and accelerating the coordination process between the user departments and IT in elicitation, analysis and specification of requirements (Arcway AG 2006a, b; Keller 2006).

4.6 Tool Classification

According to the evaluation in the sections 4.1 to 4.4, the support of the different RE phases of the four market leading tools is classified as follows:[33]

Table 4.1: Classification of the requirements management tools

	Elicitation & Analysis	Specification	Validation	Management	Distributed Work
CaliberRM	★★	★★	★	★★★★	★★
RequisitePro	★	★★	★	★★★★	★
RTM	★	★★	★	★★★★	★★
DOORS	★	★★★	★	★★★★	★★

This classification is based only on the features described in this paper; features that are not described here are not included. The better classification of CaliberRM in the phase elicitation and analysis comes from the support of the most features assigned to this phase. This position will probably be strengthened if the new product Caliber DefineIt is released which will even better support this phase. Also the other phases will be affected through this release. A really good support is not given by any of the tools. DOORS can set itself apart a little in the support of the requirements specification phase through its major support of integration to modeling tools and document standards. The support of the other tools for this phase is roughly equal. None of the tools can excel in the requirements validation phase. The support of this phase can be seen as very low. The evaluation showed that the activities of this phase are not the target of these tools. In contrast to that, all tools excellently provide the support of the requirements management phase. Finally, all tools support distributed work basically. RequisitePro was originally not designed for work over the Internet and the web client has many restrictions in functionality. This will probably change due to IBM is planning to build

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[33]Legend for table 4.1: ★ = minor support, ★★ = basic support, ★★★ = good support, ★★★★ = excellent support

up the whole application on Eclipse basis. In contrast to the other tools, its focus lies mainly on smaller projects. In fact, Telelogic provides DOORS XT for distributed work, but the functionality is smaller than in DOORS. It remains to be seen how it will be further developed and if it reaches the functionality of DOORS one day. Overall, DOORS itself provides not more features for distributed work than CaliberRM or RTM. The only innovative feature of all tools in this area is the polling function of RTM.

5 Summary and conclusion

After describing generic phases in RE, this paper evaluated the four market dominating RE tools in terms of their support for these phases. Furthermore, their support of distributed work was evaluated for assessing their applicability for distributed RE. A classification was created and some smaller tools were introduced as well. Not regarded in this paper were tools that are designed for distributed work but cannot be categorized as "real" RE tools, i.e. groupware and project collaboration platforms. Despite the fact that this paper does not evaluate the whole functionality of the four tools, it shows that the strengths of the tools lie in different areas:

DOORS gives the user a MS Word feeling due to its document-like view. It also provides the most overall functionality. At the same time, this makes the introduction of this tool often more difficult especially in non-IT departments. This is the strength of RequisitePro, because it provides a simple usability but also a strong integration with MS Word. RTM excels through its almost fully functional web client and many possibilities in terms of managing the links among requirements. Finally, CaliberRM provides a good support through all phases with an appealing graphical user interface, support of many languages, and its instant applicability. Therefore, each firm that wants to use such a tool has to decide individually which tool fits best to its needs. Versteegen et al. (2004) for example give hints how to proceed in this selection process.

The evaluation also shows that the providers of the four tools could learn from some smaller providers. None of the four tools includes a possibility to model use cases graphically without external components. This was apparently recognized at Borland and will be integrated in Caliber DefineIt. Polarion shows that a tool can be fully web-based and thus support distributed work.

Finally, this paper reveals that none of the tools provides innovative features for distributed work and user communication, which is very important in the RE phase of the software development process. RTM takes a first step into that direction with its polling function. No synchronous form of communication like chats, live meetings with cameras, or brainstorming functions are supported by any of the tools. The technical solution manager from Serena Software mentioned that such a live meeting functionality would make the tool dependent on a certain technology what would not be favourable.[1]

But maybe in this very area the tool providers should rethink because these are important features that are needed for an effective and efficient RE which often has to be

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[1]Taken from the telephone interview with a Technical Solution Manager from Serena Software.

conducted in practice. Even a simple chat function or instant messaging that could be used in addition to the normal discussion function could reduce ambiguities and errors in requirements that emerge from misunderstandings and asynchronous communication. This is especially important in distributed projects where face to face meetings are not always possible or economical. If such a function was integrated in a requirements management tool it could be used immediately and was no need for external tools. Further research could show which of those groupware functions could be interesting to be included in a requirements management tool and to which extent it would be used and increase the quality of requirements.

Appendix

Table A 1: Market overview of requirements management tools[1]

Product	Manufacturer	Website
Accept 360	Accept Software	http://www.acceptsoftware.com
Analyst Pro	Goda Software	http://www.analysttool.com
Arcway Cockpit	Arcway	http://www.arcway.com
CaliberRM	Borland Software	http://www.borland.com
CARE 3.2	Sophist Technologies	http://www.sophistgroup.com
ClearSpecs Composer	LiveSpecs Software	http://www.livespecs.com
CORE 5.1	Vitech	http://www.vitechcorp.com
Cradle 5.2	3SL	http://www.threesl.com
DOORS	Telelogic	http://www.telelogic.com
EasyRM 1.06	Cybernetic Intelligence	http://www.easy-rm.ch
Envision VIP	Future Tech Systems	http://www.future-tech.com
Gatherspace	Gatherspace.com	http://www.gatherspace.com
IRqA 3.3	TCP Sistemas e Ingenieria	http://www.irqaonline.com
KollabNet Editor 2005	KollabNet	http://www.kollabnet.com
Objectiver	Cediti	http://www.objectiver.com
PACE	ViewSet	http://www.viewset.com
Polarion	Polarion Software	http://www.polarion.com
QFD/Capture 4	International TechneGroup	http://www.qfdcapture.com
RaQuest 2.3	SparxSystems Japan	http://www.raquest.com
Rational RequisitePro	IBM	http://www.ibm.com
RDD.COM 1.2	Holagent	http://www.holagent.com
RDD-100 4.1.2	Holagent	http://www.holagent.com
RDT 3.0	Igatech	http://www.igatech.com/rdt
Reconcile 2.0	Compuware	http://www.compuware.com
Reqtify 2.1	TNI-Software	http://www.tni-software.com
RMTrak	RBC Product Development	http://www.rmtrak.com
RTM	Serena Software	http://www.serena.com
SoftREQ	Software Requirements	http://www.softreq.com
SpeeDEV Rel 4.0	SpeeDEV	http://www.speedev.com
SteelTrace	Steeltrace	http://www.steeltrace.com
TcSE 7.0	UGS	http://www.ugs.com

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[1]Partly taken from `http://www.paper-review.com/tools/rms/read.php` and `http://www.volere.co.uk/tools.htm`

Table A 1: Market overview of requirements management tools (continued)

Product	Manufacturer	Website
TRUEreq	Truereq	http://www.truereq.com
VeroTrace	Verocel	http://www.verocel.com
XTie-RT	Teledyne	http://www.tbe.com

Table A 2: Overview of the evaluated functionality

General functionlity				
Function	Borland	IBM	Serena	Telelogic
SDK/API	CaliberRM SDK	RPX	API	DXL

Elicitation/Analysis				
Function	Borland	IBM	Serena	Telelogic
Attributes	✓	✓	✓	✓
Mandatory attributes	✓	✗	✓	DOORS XT
Subsequent attributes	✓	✓	✓	✓
Subsequent mandatory attributes	✓	✗	✓	✗
Multi-level structuring	✓	✓	✓	✓
Graphics as requirements	✓	✓	✓	✓
Predefined information architectures	✗	RUP	✗	IEEE, IEEE 12207, RUP, ESA, DoDAF, MoDAF,...
Drag & drop requirements	✓	✓	✗	✓

Specification				
Function	Borland	IBM	Serena	Telelogic
Spell checker	✓	✓	✓	✓
Import formats	Word,Excel,xml	Word, Excel, Access, xml, csv	Word, Excel, Interleaf, Framemaker, csv	Framemaker, tsv, csv, Word, Project
Pdf import	✗	✗	✗	✗

Table A 2: Overview of the evaluated functionality (continued)

Function	Borland	IBM	Serena	Telelogic
Graphic formats	Wmf, bmp, jpg, xbm, art	All MS Word supported	any	Wmf, bmp
Interfaces to modeling tools	Together, Rational Rose	Rational Rose, Rational Software Modeler, Rational Software Architect, Use Case Studio	Rational Rose, Artisan RTS	Together, Rational Rose, Artisan RTS, Rational Software Modeler, Rational Software Architect, Simulink, TAU, iUML, Rhapsody, SCADE, VAPS, DOORS/ Analyst
Interfaces to MS Office tools	Word, Excel	Word, Excel, Project, Access	Word, Excel, Project, Visio	Word, Excel, Project
Reports	✓	✓	✓	✓
Report standards	✗	RUP	✗	cp. information architectures
Scripting language for reports	Word templates	RPX	Meta-SQL	DXL
Report wizard	✓	✗	✓	✓
Textual use case support	✓	✓	✓	✓
Graphical use case support	✗	✗	✗	DOORS/ Analyst
Report output formats	Word documents	✗	Word documents	✗

Validation				
Function	Borland	IBM	Serena	Telelogic
History content	version, date, time, user, comment	version, label, user, date, time, changes requirements text, changed element	complete requirements object, ID, time, user	date, time, user, changed element, details
Origin of information (trace analysis)	✓	✓	✓	✓

Table A 2: Overview of the evaluated functionality (continued)

Function	Borland	IBM	Serena	Telelogic
Search function	requirements, attributes	requirements, attributes, documents	requirements, attributes	requirements, attributes
Connectivity checks (impact analysis)	✓	✓	✓	✓
Formal language support	✗	✗	✗	✗
History content editable	✗	✗	✗	✗
Test cases	TestDirector	Rational Test-Manager, Test-Director	TestDirector	Test Tracking Toolkit, TestDirector

Management				
Function	Borland	IBM	Serena	Telelogic
Database	Oracle, MS SQL Server	Oracle, MS SQL Server, Access, DB2	Oracle	own repository, Oracle (DOORS XT)
Change process	only external	only external	Change Request, user defined, external	CPS, external
Suspect links	✓	✓	✓	✓
Baseline	✓	✓	✓	✓
Baseline comparable	✓	✓	✓	✓
Link display	graphical, tabular	graphical, tabular	graphical, tabular	graphical, tabular
Creation of links	drag & drop, trace matrix, copying information	reference ID, trace matrix, copying information	drag & drop, marking start/end, reference ID, trace matrix, auto-link function	drag & drop, marking start/ end, copying information, link-by-attribute
Links between graphics & requirements	✓	✓	✓	✓
Dependency types	m:n	m:n	1:1, 1:n, m:n	1:1, 1:n, m:n

Table A 2: Overview of the evaluated functionality (continued)

Function	Borland	IBM	Serena	Telelogic
Dependency attributes	✗	✗	✓	✓
Limit links	user roles	user roles, requirements groups	user roles, requirements groups, direction, cardinality	user roles, requirements groups, direction, cardinality
Links to older baselines	✓	✗	✓	✓
Links to other projects	✓	✓	✓	✓
Undo	normal undo, undo over history	only Word undo	over history	normal undo, undo over history

Multi-User				
Function	Borland	IBM	Serena	Telelogic
Operating system (client)	Windows XP, Windows 2000, Windows 2003 Server	Windows XP, Windows NT, Windows 2000, Windows 2003 Server	Windows XP, Windows 2000, Windows 2003 Server	Windows XP, Windows 2000, Windows 2003 Server, RedHat Linux, HP-UX, Solaris
Multi-user concept	role concept	role concept	role concept	role concept
Passwords for security	✓	✓	✓	✓
Mandatory change passwords	✓	✗	✓	✓
Additional acces rights definition based on menu options	✗	✓	✓	✗
Individual access rights definition subsequently	✓	✓	✓	✓
Webclient	✓, no ActiveX	✓, no ActiveX	✓, no ActiveX	✓, no ActiveX
Webclient fully functional	✗	✗	✗	✗

Table A 2: Overview of the evaluated functionality (continued)

Function	Borland	IBM	Serena	Telelogic
Webclient read-only function	✓	✓	dependent on user rights	✓
Webclient offline use	✗	✗, offline Word edit	✗	✗
Webclient platform independent	✗	✓	✓	✗
Languages	English, German, French, Japanese	English	English	English
Glossary	✓	✓	✓	✓
Forbidden words	✓, colored	✗	✗	✓, replacement proposal
User communication: Discussion	Discussion on requirements	Discussion on requirements with e-mail support	Discussion on requirements, Discussion objects	Discussion on requirements/ objects
User communication: Live-Meeting	✗	✗	✗	✗
User communication: Chat	✗	✗	✗	✗
User communication: Interview function	✗	✗	Polling	✗
E-mail	✓	✓	✓	✓
Menu configurable	✓	✗	✓	✓
Layout configurable	✓	✓	✓	✗
Multi-user access on requirement	read-only	read-only documents/ requirements	read-only	exclusive/ shareable edit mode documents, read-only requirements
Client offlline use	✗	✗, offline Word edit	✗, offline Word edit	✓
Eclipse integration	✓	✓	✗	✗
Supported browsers	Internet Explorer	Internet Explorer, Netscape, Firefox, Mozilla	Internet Explorer, Netscape	Internet Explorer, Netscape, Firefox

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