

Alternative Analysis for Requirements Management

Leah Goldin / Golden SoLutions / l_goldin@computer.org
Gloria Kinrot Comverse Network Systems / gloria_kinrot@icomverse.com

Abstract. The utmost challenge in Requirements Management (RM) introduction is to really identify and admit the requirements problems and their repercussions, which the RM solution is going to solve. Furthermore, criteria based on the RM problem domain are important to evaluate the solution. Moreover, the criteria, retrospectively, help to better understand the problem at hand.

The paper describes the RM alternative analysis that was executed at Comverse Network Systems, according to an existing formal alternative selection procedure. The alternative analysis compared manual methods, i.e. Microsoft Word, and the RTM like tool for implementing the RM enterprise process.

The alternative selection process did indeed help in gaining a better perspective of the scope of RM in the company. The company's decision-makers became aware of existing problems in terms of requirements traceability activities, revealing inter-departmental synchronization gaps, which convinced them to invest in the RM solution.

As with any process change, RM introduction into the organization involved change management issues.

Thus, we found that having a clear problem definition along with evaluation criteria helped to keep a balance between the real-world problems and tool issues during the RM deployment.

Our main conclusion is that the process maturity level of the organization tremendously affects the rate of RM deployment and success. The main obstacles to success of RM are the lack of basic project management norms along with requirements norms.

1. INTRODUCTION

1.1 Purpose. The objective of this paper is to assist the business decision-makers, i.e., R&D managers, RE/Process managers, company management, etc. in the introduction of Requirements Management (RM) into the organization. The utmost challenge in RM introduction is to really identify and admit the requirements problems and their repercussions, which the RM solution is going to solve. Furthermore, criteria based on the RM problem domain are important to evaluate the solution. Moreover, the criteria, retrospectively, help to better understand the problem at hand. This paper, in addition, provides a mapping of RM activities to the RM problem definition. These activities provide the framework for the RE managers to integrate RE into the project management plans.

1.2 Scope The paper describes the requirements management alternative analysis that was executed at Comverse Network Systems, according to a systematic alternative selection procedure [1]. The alternative analysis compared manual methods and the RTM tool [2] for implementing the requirements management enterprise process. The procedure includes the following steps: problem definition

1. Evaluation criteria and threshold definitions
2. Alternative solutions to problem discussion
3. Alternative analysis including assumptions, comparison and pros/cons
4. Recommendation, including cons and sensitivity analysis

2. PROBLEM DEFINITION

Alternative selection usually means reaching decisions under adverse conditions resulting from lack of knowledge and time pressure. These conditions increase the probability of an erroneous decision. Thus, it is vital to begin with a concise, clear, and unequivocal definition of the problem that we are trying to resolve.

Requirements management is a non-trivial process involving all aspects of the organization, people, activities, and work products. Therefore, as a first step in problem definition, the questions from each stakeholder's viewpoint must be stated from the perspective of requirements management as a black box.

The following questions have been identified via the requirements management process:

1. Are all the customer requirements covered? (Customer → SLRS¹ → SRS².)
2. What is the development status of the requirements? (implemented, tested)
3. What is the impact of a requirement change? (other affected requirements?)
4. Are all customer requirements complied to? (compliance table)
5. What are all the requirements found in customer release Y? (complete and *not* delta)
6. Which product version contains feature X? What features or requirements are found in product version X?

The information needed to answer the requirements management questions is found in the work products generated by the requirements management activities. These activities are executed throughout the organization. The activities are formalized, as follows:

1. **RM infrastructure setup and maintenance** including formal definition of the company's RM process and procedures, tool choice, tailoring, and deployment
2. **Requirement elicitation** from all formal or informal project or product documents to obtain a requirements list to be used as basis for requirement changes
3. **Requirement impact analysis** of requirement changes to obtain an affected requirements list and system impact list (i.e., features, capabilities, and scenarios)
4. **Formal document generation and update** to obtain an SLRS, an SRS, etc. from the requirements
5. **Requirements coverage validation** via compliance table, traceability matrix, test verification matrix, to ensure all product or customer requirements are being handled by development groups
6. **Requirements status verification** to review the development group's status of expected requirements
7. **Requirements baselining** to classify requirements by configuration version

3. EVALUATION CRITERIA AND THRESHOLDS

Since RM aims towards improving decision making concerning requirements, criteria implying confidence and integrity are crucial to evaluating RM alternatives. In addition, criteria for requirements management tool acceptance are identified for performance and effort which affect tool deployment in the organization. Thresholds are defined for each evaluation criteria. Non-compliance with thresholds may invalidate an alternative. Where possible, units of measure are defined.

3.1 Alternative Evaluation Criteria. Table 1 contains the criteria to evaluate RM activities that are independent of any alternative solutions. Criteria are ranked on a scale of 1-7, having the appropriate meanings for each one.

Most of the requirements management activities are based on checking conflicts, redundancy, compliance, etc. Therefore, the **RM Confidence Level** criterion is very important to evaluate the outcome of the activities. A scale of 1-7 was defined, among which 1 indicates, "No confidence" and 7 indicates "full confidence".

The emphasis of requirements work is another important criterion. The **Work Emphasis** criterion is defined from 1-7 to indicate the shift from purely clerical work (1) to purely intellectual orientation (7).

Usually requirements data are held by people or in documents. Therefore, the **Human Knowledge Dependency** criterion indicates the shift from dependence on humans only (1) to on a knowledge base (5), to on an expert system (7).

The accompanying documentation of the requirements process is usually very cumbersome and hard to maintain. Therefore, the **Document Integrity** criterion measures the correct content of both formal and informal documents, varying from non-reliable (1) to fully updated (7).

Another criterion relating to documentation is the **Doc Production Effort**. This criterion measures the ability to generate full document updates vs. delta documents, revealing only requirement changes.

The initial and crucial step of capturing all customer and marketing requirements is measured by the **Elicitation Performance Level** criterion, varying from none (1) to full requirements list (7). The tendency is to skip this very first step of distilling the actual requirements list from the customer and marketing specifications before jumping to formal development documents.

¹ SLRS - System Level Requirements Specification

² SRS - Software Requirements Specification

The purpose of the **Overall RM Effectiveness** criterion is to evaluate the ability to actually execute the RM activities, varying from “RM activity OK” (7) to “No RM activity” (1).

The **Overall RM Complexity** criterion is to evaluate the difficulty of executing the RM activities.

The thresholds have been set to realistic values, indicating the expectations of the organization in the requirement management process.

#	Alternative Evaluation Criteria	Measurement Units	Threshold
c1.	RM Confidence level <ul style="list-style-type: none"> Conflict analysis Redundancy analysis Req compliance Req development coverage Specific viewpoint (keyword) 	1=No confidence → 7=Full confidence	4
c2.	Work emphasis	1=Clerical → 7=Intellectual	5
c3.	Human knowledge dependency	1=Human → 5=Knowledge base → 7=Expert system	5
c4.	Doc integrity (correct content)	1=Non reliable → 7=Fully updated	6
c5.	Doc production effort (vs. delta)	1=Cumbersome → 7=Simple	4
c6.	Elicitation performance level	1=None → 7=Full list	7
c7.	Overall RM effectiveness	1=No RM activity → 7=RM activity OK	7
c8.	Overall RM complexity	1=Complicated → 7=Simple	6

Table 1: RM Alternative Criteria

3.2 Tool Evaluation Criteria. Requirements management activities are eventually supported by tools. Therefore, the human computer interaction (HCI) of the supporting tools is an important factor in the success of requirements management deployment into the organization.

Table 2 contains the criteria to evaluate RM tool usage. These criteria include performance, capacity, multi-user access, ease of use, effort, and specific requirements management functionality, e.g., spec production, req hierarchical support. Additional criteria concern tool cost and support, establishment effort (NRE³), and the ability to integrate and tailor to the development environment.

Criteria are measured by several unit types. The **Use** measure indicates the ease of use reflected by the number of user actions required to execute a requirements management action. The **Performance** measure indicates the throughput of a requirements management activity (e.g., pages/hour). The **Effort** measure indicates the time in person-months (PM) needed to accomplish an activity. The **Schedule** measure indicates the chronological time needed to accomplish an activity.

#	Tool Criteria	Measurement Units	Threshold
1.	Document and report production (including traceability)	Use: # actions Performance: production time	Use: 3 user actions Performance: < 1hr / 200 pages
2.	Interactive requirement update	End-user wait time	< 1 second / requirement
3.	Elicitation Performance (batch)	Use: # actions End-user wait time	Use: 3 user actions Performance: < 1hr/100 pages
4.	Requirements hierarchical support (i.e., familiar requirement access and not just one by one)	Yes/No	Yes
5.	Multi-user integrity (prevent more than one user’s access to same requirement at same time)	Yes/No	Yes
6.	Concurrent operation capability	# Concurrent sessions	>= 10 sessions

³ NRE - Non Return Engineering

#	Tool Criteria	Measurement Units	Threshold
7.	Requirements capacity	# Requirements in database	>= 100K requirements
8.	Cost	\$	(per budget)
9.	Incremental NRE for Infrastructure setup	PM	<= 12 PM
10.	Legacy document capture	Effort: PM Schedule: finish date	Effort: 12 PM Schedule: Month/Year
11.	Tool support <ul style="list-style-type: none"> • external (RTM) • internal (system administration) 	Response Time	none

Table 2: RM Tool Criteria

4. ALTERNATIVES IDENTIFICATION AND DESCRIPTION

The requirements management activities and process may be solved by several alternative solutions, differing in several aspects. Identification of these aspects via the requirements management actions helps in differentiating between solutions and clarifying the pros and cons of each alternative during alternatives analysis.

The two alternatives that are compared are a *manual requirements management method* and the *RTM (Requirements and Traceability Management) tool*. The manual alternative includes executing all requirements management activities with support of a word processor and spread sheet. The RTM alternative is a commercial requirements management tool, based on an Oracle database, and a requirements management application that can be tailored to the organization's requirements management process.

The RM problem has been defined by the list of seven RM activities, RM infrastructure setup, requirements elicitation, requirements impact analysis, formal document generation, requirements coverage validation, requirements status verification, and requirements baselining. During alternatives analysis, each RM activity has been further decomposed into the specific actions needed to accomplish the RM activity, regardless of the solution. Each alternative solution, manual or RTM, is then systematically correlated to the particular implementation required to achieve the resulting RM action.

5. ALTERNATIVES ANALYSIS

The alternative analysis and comparison is complex and problematic. It is composed of data collection, identification of missing information and assumptions, comparison of the alternative solutions, summary of advantages and disadvantages, and recommendation.

The RM activities are analyzed for both alternatives against the criteria. Missing information is replaced by assumptions since the acquisition of the missing information is time consuming, and acquisition of information either prolongs the decision-making or is unavailable. The following assumptions have been made for analysis:

1. Personnel dealing with RM have know-how in system analysis.
2. The RTM tool is sufficient for use (See tool acceptance criteria).
3. All requirements data, e.g., requirements content, traceability, are available, i.e., thinking has been done and documented somewhere!!!

5.1 Alternative Comparison. The alternatives are compared to illustrate how each alternative complies with the different evaluation criteria.

The *RM confidence level* criterion shows that with the RTM solution, which is based on a database, a better awareness is achieved for each of the RM activities. For example, during requirements impact analysis, awareness of requirements redundancy, conflicts, and specific viewpoints is better revealed with RTM than with manual methods. Therefore, the manual alternative is marked with 2 and the RTM alternative is marked with 6.

In any case, the two scale extremes have not been used since human strengths and weaknesses are taken into account. All other RM activities receive the same marks, i.e., manual-2, RTM-6, due to the fact that awareness of each activity is better achieved with RTM.

The *Work emphasis* criterion, in a similar manner, shows that with the RTM solution the ability to think is provided versus the emphasis on data collection with the manual solution. For example, during document generation and requirements elicitation, the use of a tool reduces the tedious and clerical side of the activity, due to database automation, enabling concentration on analysis resulting in the production of better work products. On the other hand, the manual method consumes most of the human's resources on data mining. Therefore, the

manual alternative is marked with 2 and the RTM alternative is marked with 7. Notice that for this criteria, RTM was marked with 7 because with RTM automation, full intellectual work is enabled! As for the manual alternative, a 2 mark has been given due to use of the Microsoft Office suite. All other RM activities receive the same marks due to the fact that the work emphasis of each activity is more intellectual with RTM.

The **Human knowledge dependency** criterion shows that although expert system level has not yet been reached, with RTM, a knowledge-based level is achieved, i.e., a mark of 5, for all RM activities. However, with manual methods, all the RM activities are dependent on human memory even for searching in an electronic document!

The **Document integrity** criterion illustrates the fact that by using the RTM tool, once data have been entered into the database, the formal document for each RM respective activity, e.g., compliance table, SRS, etc., can be generated automatically as a database report. This criterion is most demonstrated upon requirement change where the full document is generated at the click of a button. Therefore, the manual alternative is marked with 3, i.e., the human must be given some credit, and the RTM alternative is marked with 7.

The reasoning for the **Document production effort** criterion is very similar to the Document integrity criterion. However, the manual alternative is marked with 1 since the effort required to produce a document manually speaks for itself. The RTM alternative is marked with 6 because some minimal effort is required to update the requirements data in the database, i.e., there is no free lunch.

The **Elicitation performance level** criterion is fully achieved with RTM, marked 7. The actual requirements list results from capturing isolated requirements data into the database. With manual methods marked 5, the requirements are spread out in a pile of documents and in peoples minds.

Analysis of the **Overall RM effectiveness** and the **Overall RM complexity** criteria ultimately differentiated between the RTM and manual alternatives with respect to each RM activity. Table 3 details the marks and reasoning of the alternatives per each RM activity.

RM Activity (+I/O)	c7) Overall RM effectiveness	c8) Overall RM complexity
0) RM Infrastructure Setup (and maintenance) Input: tools Output: environ	Doc templates and <u>ad-hoc</u> method for each product version vs. CM requirements DB and framework for <u>all next versions</u> <i>man:</i> 2 <i>RTM:</i> 7	<u>Short-term</u> solution with min overhead and preparations vs. <u>long-term</u> requirements framework incl. formal definition of requirements versions (product version vs. customer project) <i>man:</i> 5 <i>RTM:</i> 1
1) Requirements elicitation Input: SLRS, SRS, Output: requirements	Requirements <u>documents</u> containing requirements plus vs. <u>full list</u> of standalone requirements <i>man:</i> 2 <i>RTM:</i> 7	<u>Highlight</u> document vs. automatic <u>batch</u> capture <i>man:</i> 2 <i>RTM:</i> 7
2) Requirements impact analysis Input: requirements. Output: requirements. +Keywords	Human <u>intuition</u> vs. <u>analyze</u> impact wrt relevant sub-tree of requirements <i>man:</i> 2 <i>RTM:</i> 5	Paging <u>spaghetti</u> documents vs. <u>graphical browsing</u> in tool <i>man:</i> 1 <i>RTM:</i> 7
3) Formal document generation (and update) Input: requirements. Output: SRS	<u>Write delta</u> (incremental) documents vs. <u>get full</u> document via database report including delta requirements change <i>man:</i> 2 <i>RTM:</i> 7	<u>Write</u> document vs. <u>update</u> delta and get full database report <i>man:</i> 3 <i>RTM:</i> 7
4) Requirements coverage validation Input: SLRS, SRS Output: compliance table	<u>Manual</u> traceability matrix vs. <u>full</u> traces of requirements <i>man:</i> 1 <i>RTM:</i> 7	<u>Manual</u> built from deltas vs. <u>automatic</u> DB trace report of full version <i>man:</i> 3 <i>RTM:</i> 7
5) Requirements status verification Input: requirements. + "param" Output: sub-req	<u>People</u> knowledge vs. <u>database</u> reports on requirement list <i>man:</i> 1 <i>RTM:</i> 7	<u>Ask</u> people vs. database requirements list <u>report</u> <i>man:</i> 1 <i>RTM:</i> 7
6) Requirements baselining Input: requirements. Output: req ver	<u>Document</u> deltas vs. <u>configuration</u> management of requirements <i>man:</i> 3 <i>RTM:</i> 7	<u>Manual</u> delta requirement version vs. <u>full</u> <u>configuration</u> management version <i>man:</i> 1 <i>RTM:</i> 7

Table 3: RM manual vs. RTM analysis

5.2 Alternative Pros and Cons. This section lists the advantages and disadvantages resulting from the alternative comparison via the different criteria.

1. Manual approach has minimal infrastructure development, (just documents templates and compliance scripts), whereas RTM requires building a database infrastructure.
2. Once the RTM infrastructure exists, requirements activity focuses upon analytical work, whereas manual focuses on clerical work.
3. Once the RTM database is populated, for any delta requirement change, a complete requirements product version is available, whereas in manual only incremental documents exist.
4. With RTM, impact analysis is based upon graphical views that may be systematically browsed,

whereas with manual traceability is hard to follow by paging manually through the requirements “spaghetti”.

5. With RTM reports, requirement status and coverage can be verified objectively and independently at any time, whereas with manual, the requirements status depends on people’s observational skills (stating that “80% ready”) and manual coverage verification is scheduled over long intervals of time, e.g., once every year.
6. Manual can provide compliance and coverage for the first product version, but deltas and changes are hard to maintain in documents, whereas RTM provides built-in traceability, automatically maintained with requirement change.
7. Once the RTM database is populated and infrastructure exists, documents are generated automatically, whereas with manual documents are re-written, remain as increments, or grow out of date.
8. RM with RTM provides a reproducible method while RM with manual requires constantly “re-inventing the wheel”.

6. RECOMMENDATION

After evaluating the alternatives according to the criteria, the marks given to each alternative are the basis for the recommendation. In our case, the alternative analysis marks speak for themselves. RTM tool was the recommended alternative.

7. VALIDATION OF THE RECOMMENDATION

7.1 Cons Analysis. Validation of the recommendation includes two important activities: evaluation of weak points, and assumption sensitivity analysis. Evaluation of weak points is performed by an additional thorough analysis of the recommended alternative’s disadvantages, to verify a reasonable resolution for each disadvantage.

1. RTM requires effort for establishing data base infrastructure including
 - Capturing requirements from existing documents
 - Adding traceability and attribute information (think!)
 - Supplementing the RTM environment (scripts)
2. At present, the RTM tool environment’s performance and ease of use is not satisfactory, (including server, PC, network, tool version).?????
3. However, it is assumed that the RM tool acceptance criteria can be achieved for RTM during Phase 1.

7.2 Sensitivity Analysis. Since some of the information leading towards the decision is based on assumptions, and not facts, it is imperative to perform a sensitivity analysis. In a sensitivity analysis, the assumptions are assigned values, which differ from the ones assumed during the alternative analysis process. The effect of the different values on the recommendation is then examined.

1. With the RTM database, the product requirements knowledge is less dependent on particular persons.
2. If the RTM tool is discovered to be unacceptable in the future, all data base requirements can be output to document format and all future RM work can proceed manually.
3. If requirements management data, e.g., trace are not available, the fundamentals for requirements management are missing, i.e., no RM exists in any alternative!

8. CONCLUSION

The alternative selection process did indeed help in gaining a better perspective of the scope of RM in the company. The company’s decision-makers became aware of existing problems in terms of requirements traceability activities, revealing inter-departmental synchronization gaps, which convinced them to invest in the RM solution.

As with any process change, RM introduction into the organization involved change management issues. Thus, we found that having a clear problem definition along with evaluation criteria helped to keep a balance between the real-world problems and tool issues during deployment. People in the organization tend to hold on to tool performance and ease-of-use issues, as part of resistance towards change. Therefore, having the proper criteria, in the problem domain, defined in advance did help to keep perspective.

During the planning phases of RM deployment, we found that the activities identified in this paper provided the RE framework necessary to delegate project responsibility. However, integration of these RE activities into the project management plans encountered the main difficulties. One major reason is that project personnel had to execute specific RM activities via the RTM tool, which either was not really done beforehand, or require

additional activities such as traceability. Unfortunately, sometimes it was realized that requirements were the lowest priority issue in the project interest and therefore no RM solution was expected, i.e., there was no real commitment to requirements management.

Our main conclusion is that the process maturity level of the organization tremendously affects the rate of RM deployment and success. The main obstacles to success of RM are the lack of basic project management norms along with requirements norms.

Two years after introducing the RM solution to the organization, we find that the ideas introduced in this paper must be constantly re-enforced and reviewed. This is due to the fact that after each step forward, process maturity is gained, enabling a new and better view of the requirements management process.

9. REFERENCES

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BIOGRAPHY

Leah Goldin / Golden SoLutions is an independent consultant specializing in Software Engineering, Process and Quality. She has accumulated over 20 years of experience developing embedded systems. During that period she has fulfilled various management and technical roles, including software development, SQA and process improvement, at Rafael, IAI, Comverse, and Nice. Dr. Goldin is currently dividing her time between consulting to high-tech companies, and teaching at the academia.

Dr. Goldin received her Ph.D. from the Technion Computer Science department, where her research focused on Requirements Engineering. She is a senior member of IEEE, and currently serves as the Chair of the Israeli Chapter of the IEEE Computer Society.

Gloria Kinrot / Comverse is a marketing manager specializing in product management, proposal management and technical and marketing documentation. She has worked for 20 years in defense, medical and telephony industries in software development, quality management, system engineering and marketing. At Comverse, Gloria has led an effort to establish and deploy knowledge management systems in the organization.