Improving the Exchange of Requirements and Specifications between Business Partners

Authors

Manuel Reis Monteiro
Extessy
Wolfsburg, Germany
m.monteiro@extessy.com

Christof Ebert
Vector Consulting Services
Ingersheimer Straße 24
70499 Stuttgart, GERMANY
christof.ebert@vector.com

Matthias Recknagel
Daimler
Stuttgart, Germany
matthias.recknagel@daimler.com

Abstract

Increasingly complex supplier-relationships dominate product development, independent of industries and products. Mostly the primary source of risks and later problems is insufficient coherence with requirements engineering methodology and collaboration between different business partners during the project. This article based on experiences from various industries and projects provides insight into how to effectively collaborate in requirements engineering. The Requirements Interchange Format has quickly moved forward over the past two years first in automotive and currently starting in domains such as medical and aerospace. This paper describes typical RE collaboration scenarios and what we recommend in order to mitigate risks and thus effectively manage complex supplier relationships.

Copyright

1 Introduction

Increasingly complex supplier-relationships dominate product development, independent of industries and products. Distributed software engineering is the consequence of the rather friction-free economic principles of the entire software industry. Software can be exchanged easily and collaborative development is something most students learn today in school. Often the supply chains are not even limited to software development but might involve hardware suppliers which need to exchange interface specifications to adjust their firmware in line with operating systems or middleware.

Many companies engage into supplier relationships with distributed software engineering due to lack of own competences, an effective work-split across architectural functions and building blocks and of course perceived cost differences. Most of these companies engage globally active sourcing companies for components, subsystems and services to achieve fastest ramp-up of their distributed sourcing targets. With time they realize that savings are much smaller and problems are more difficult to cure than before. Necessary changes in product features do not arrive in time from their suppliers, and quality issues and the risks of insufficiently implemented functionality increases with each supplier added. Disillusioned many pay a high price in their supplier management and still miss their own deadlines or face quality penalties in tight schedules.

What went wrong? Supplier relationship management and collaborative development bear many challenges, specifically if external suppliers have shared responsibility on some features which architecturally overlap with system components done by yet another party. Working with companies around the world in industries such as automotive, ICT, aerospace, medicine, industrial automation and transport we realize that frequently the problems start out with insufficient requirements engineering. Often requirements are developed by the OEM or product responsible and then partitioned and distributed to their many business partners, such as suppliers. The project is started and along the way changes become necessary. Those are again partitioned and distributed to business partners. When finally the components arrive, integration is difficult and the product responsible (or integrator) realizes that there was too much room for interpretation, and that many engineering decisions were taken without synchronizing across the multiple stakeholders.

Insufficient stakeholder management is not primarily due to “politics” and “insufficient communication” as it is often argued by engineers. Mostly the primary source of risks and later problems is insufficient coherence of requirements engineering methodology and collaboration during the project.

From surveys across companies we found that especially the “divide and conquer” approach does not work. Requirements specify needs and solutions. Data from the evaluated projects showed that only 52% of the originally allocated requirements appear in the final released version [2,3,4,5]. We can identify several supplier-oriented challenges:

- Overlooking requirements which impact distributed functionalities
- Inadequate supplier representation during system analysis
- Communicating only functional requirements
- Not inspecting requirements before they are allocated to a supplier
- Not looking to requirements across sourced components
- Representing requirements in the form of designs thus over-restricting the supplier
Insufficient change management with all stakeholders along the product life-cycle
Not sharing necessary specifications and not keeping those being shared consistent

We will look in this article to lessons learned from collaborative RE to effectively and successfully manage relationships across several business partners. Both experiences and practical guidance result from our work with clients in different industries. Specifically we will show how to effectively and efficiently manage requirements interchange.

Chapter 2 will briefly highlight why existing solutions don’t work in industry and how the requirements interchange format (RIF) was started as a global initiative [1]. Chapter 3 will show how the technical solution with RIF and requirements exchange has been technically solved. Chapter 4 provides a concrete case study from the automotive industry which shows that with RIF effective and efficient requirements exchange and collaboration are feasible. Chapter 5 briefly discusses this approach, and Chapter 6 summarizes the conclusions.

2 Business Needs and Solutions

2.1 Document-based solutions

A common practice is to transfer requirement specs in an office document format either HTML, word processing or spreadsheet format [7,8]. These documents are primarily extracts from the Requirements Engineering (RE) tools. Extracting more than one specification is generally not possible. Traceability is hard to support. The partners must agree on a template format so that partners subscribing to an exchange have a chance to import documents into their respective RE tools. Conflict detection and resolution are often not possible since most RE tools consider documents as new imports into the database, or because a merge cannot be performed on a given view. Alternatively, PDF reports make it impossible for most RE tools to import the requirements albeit for a set of transformations which results in loss of data.

Other approaches merely extend existing tools with specific “bridges” to collaborate in specific environments and to ease the copy/paste of information from one tool to the other [8,9]. For instance, major ERM vendors evolved their environments to support engineering document management. CRM environments since recently integrate with change and requirements tools. However, such IT-centric approaches don’t go beyond interface management and don’t integrate with systems and software engineering processes. Their scope is limited to interfaces and front-end processes. More recently enterprise data management is used to connect different engineering tools [10]. Such PLM environments have big impact in providing a connected tool-chain with consistent engineering, calibration and production data along the life-cycle, but need approaches such as RIF as a language with a defined syntax and semantics to make sure that specific values or attributes have the same meaning independent whether it is on contractor or supplier sides.

2.2 Current solutions

In general, all RE tools offer the ability of file-based archive-and-restore of specifications. The file format for archives is proprietary to a tool vendor and cannot be used if exchange partners use different RE tools. Archiving solutions may not be tailored to export a subset of requirements reducing its usability when views are needed for each partner.
Some tool vendors do provide exchange features based on proprietary formats, and are designed either to process a single specification at a time, or to exchange specifications with a single partner. As mentioned above, such exchange formats do not have industry acceptance.

2.3 Requirements Interchange Format-based solutions

With the sponsorship of the German “Hersteller Initiative Software” (HIS) – a joint standard initiative of the German automotive industry – the “Simulation and Tools” working group was tasked with the job of specifying a standard to resolve the problem of exchanging requirements and specification documents between Car manufacturers and their tier suppliers; the resulting Requirement Interchange Format (RIF) is based the Extendible Markup Language (XML) and defines a tool independent exchange format that is specifically defined to address the needs of requirements representations; the RIF specification structures requirements, their attributes, types, access permissions and relationships between requirements. Additionally text requirements can be exported together with multimedia content, e.g., pictures or embedded documents. Containers are also available to transport complete or part requirement hierarchies.

After its successful introduction and the requests of international companies in different industries to also use RIF on a broad scale, the RIF specification has been handed over to the ProSTEP iViP Association for a future standardization by the OMG.

3 Requirements Exchange

3.1 Requirements Exchange

Requirements exchange is the process of establishing consistency among requirement specifications and requirements traceability on remote locations and the continuous harmonization of the requirement specifications and requirements traceability over time.

The content to be exchanged is typically a set of requirements specifications and the traceability among requirements. Most commercially available RE tools offer the possibility of partitioning requirements in so-called views; a view may maintain both a vertical partitioning, which involves selection of attributes or columns, or a horizontal partitioning, which involves selection of filters or queries.

It is common practice for requirements specifications to be assigned several views with horizontal and/or vertical partitioning; each view contains the requirements that a given partner is authorized to see.

However, industrial partners developing systems need to work on shared requirements specifications. For instance, nonfunctional requirements such as functional safety or security need a system perspective and typically suffer from premature partitioning as is often done.

One possible solution is to replicate requirements specifications between remote locations (see Figure 1). Synchronization is then based on snapshots that can be exchanged occasionally. To perform such “lazy synchronization”, a partner must first generate of snapshot of the requirements specifications (often referred to as an export); each requirement and link must be assigned a globally unique identifier, which is valid for the lifetime of the require-
ment. This ensures that the same requirement can be matched at every remote location, independently of RE tools.

Secondly, a partner must be able to merge a snapshot with the specification in the local RE tool often referred to as an import. The original specification and its replica may have been modified concurrently, leading to conflicts when trying the merge the requirements specifications. Decision must be made as to which change must be updated; such decisions are called conflict resolutions.

Figure 1: Lazy synchronization for requirements exchange between business partners.

3.2 Exchange Strategies

Because each partner may change the requirements concurrently, partners involved in the same project need to apply proper conflict resolution to ensure that the system as a whole settles down into a consistent state (so-called convergence problem).

Before an exchange between partners can take place, partners must agree on an update strategy. Two strategies can be distinguished: atomic updates and concurrent updates.

The atomic update strategy (rotating master) allows a single partner to perform changes to the requirement specifications. All other partners keep the specifications frozen until one of them receives a snapshot and is then authorized to perform changes. This strategy relies on the consistency of a single-copy and avoids the occurrence of conflicts. However, this strategy does not scale up: as the number of partners increases, so does the time required to synchronize replicas at all partner sites.

The concurrent update strategy (multi-master) allows all partners to update requirement specifications concurrently. One or more partners may hold so-called primary copies, with which other partners can synchronize to. A concurrent update strategy offers scalability and flexibility, but requires that partners devise an exchange plan to ensure timely convergence of specifications at all partner locations.
3.3 Exchange File Format (RIF)

The Requirements Interchange Format (RIF) uses so-called information elements to describe individual or groups of requirements. Information elements represent either simple or complex data types. Complex data types may depict XHTML fragments, with which rich formatted text can be transported including images or embedded objects.

All requirements in RIF are assigned a globally unique identifier which helps identify throughout the requirements lifecycle and also enable merging the concurrently modified requirements.

RIF keeps information about requirements (SpecObject) and requirement containers separately. Two schemes are provided to organize requirements: a hierarchical container (SpecHierarchyRoot) recursively aggregates elements of type SpecHierarchy; each element has pointers to the actual requirement. A list container (SpecGroup) can also be used to group requirements with pointers to the actual requirement. These containers may exist in parallel and offer the possibility of organizing different views on requirements.

RIF provides additional structures for modeling relationships between requirements. A relationship (SpecRelation) is a directional, typed link between requirements, which can also maintain a set of attributes. To ensure wide usability across functional and nonfunctional requirements and between different companies in a supplier network, RIF provides all necessary data models to flexibly represent requirements and requirements traceability.

Figure 2 shows a simple requirement as we can find it in a variety of specifications. Figure 3 then shows how this very requirement is represented in RIF.

![Figure 2: Example requirement.](image)

4 Industrial case study

4.1 Process Overview

To highlight the challenges related to requirements exchange, a case study involving exchange of specifications on an actual industrial project is provided in this section. It describes succinctly the request for proposal process used by the customer.

In the first phase of the RFP (request for proposal), the customer develops his requirements. For this purpose he specifies the artifact to be designed. Today mostly state-of-the-art RE
A tool is used for documenting requirements. For this particular project of the case study, 67 specifications with a total of 10,000 requirements are part of the SOW (statement of work) that is to be examined by the bidders. At this stage there is little need to exchange requirements with third parties.

In the second phase, the customer selects a number of suppliers to submit proposals based on the SOW. The suppliers receive the specifications and check their understanding of the statement of work by reviewing/commenting the requirements. At the end of this phase, the customer makes a formal request for quotation to each supplier.

In the third and last phase, the customer takes official receipt of all bids and starts formal assessment of each bid. If a bid fails the supplier is allowed to re-submit. When a choice is committed, the customer awards the contract to a supplier by selecting a single bid, and issues the purchase order.

For the customer in this case study it was important that several restrictions were met by the exchange process:

- The suppliers should not be able to change the original customer requirements
- All suppliers should be able to comment on the requirements concurrently
- The suppliers should not be able to see the comments of the other suppliers

EXERPT [11], a RIF-based exchange platform, was used to exchange requirements between partners. Similarly RIF interfaces or filters could be used as they are increasingly offered by major tools vendors.

We will describe in the following sections how the requirements exchange process meets the requirements of the customer.

Figure 3: Example requirement from Figure 2 “translated” to RIF.
4.2 Requirements Analysis

The main objective of the requirements analysis phase is to ensure that the potential suppliers fully understand the requirements so that bids have a higher rate of compliance with the customer requirements. For this purpose, the customer initiates two rounds of requirements exchange with the suppliers; each supplier can return comments on the requirements. No requirement can be changed directly by suppliers. The customer consolidates the comments into a set of actions that will refine or modify some of the requirements in terms of wording, definitions, etc (see Figure 4).

![Figure 4: Requirements Analysis Phase.](image)

The RIF-based exchange process had to consider the customer’s restrictions. To ensure that these restrictions were met, the customer requirements and supplier’s comments had to be dealt with in certain ways:

**Partitioning.**

The customer created a single view in his RE tool for each supplier which contained only the original customer requirements and a supplier specific comment attribute by partitioning the requirements document vertically. This partitioning ensured confidentiality of supplier comments, and that all suppliers were able to write their comments concurrently, as supplier comment attributes are assigned to each supplier (see Figure 5).

**Conflict resolution.**

The exchange process demanded that only the customer is authorized to change or delete requirements while allowing the suppliers to update their comments concurrently. This was enforced by the update policy of the customer for all commented RIF files sent by the suppliers. The update policy that was defined in the update tool only allowed the update of changes made to the comment attribute values of the respective supplier.

The main activity of the team on the customer side is to analyze the comments of each supplier and consolidate the comments and requirements.

The document-based exchange that was used on previous projects, involved dealing with office or PDF documents; the step of importing the comments into the RE tool was outsourced; the assessment team was left to realize the verification and consolidation steps. Verification means that the imports are checked against the actual documents received from the supplier, i.e., that the comments are assigned to the correct requirements and that the
syntax of comments are identical, and is normally performed as part of the consolidation step.

The manual verification of the requirements document in previous projects took about half a person-day in total to complete and was prone to error. Considering that the comments are consolidated twice for all 7 suppliers, the customer has to deal with 14 separate exchanges requiring 469 person days to verify the documents. This project phase is assigned a capital of 1,980 person-days.

The RIF-based exchange as it is performed today eliminates the need for manual verification, as the RIF-based files synchronize requirements directly into the RE tool; effort savings using the RIF-based exchange represent about 24% of overall resources need by the manual verification process.

![Diagram of exchange process]

Figure 5: organization of comments / views in the customer database.

### 4.3 Tender Analysis and Proposal Selection

After completion of phase II, the customer makes a formal request for proposal to each supplier and requests the submission of at least three different bids (Figure 6). Each bid represents a reply to the statement of work in terms of a technical solution. The objective of this phase for the customer is to compare bids in terms of compliance and costs. This is achieved by generating appropriate metrics to measure each proposal.
In the document-based exchange approach, the process started by composing a traceability matrix in a word processor which lists the requirement in the customer specification with the proposed technical solution from the proposal in the form of a table.

This table was then transferred to a spreadsheet and handed over to analysts. The job of the analyst is to comment and score the proposal. The result, the compliance matrix, is sent back to the supplier, who may take the opportunity to change and resubmit the proposal. The final step is to consolidate all final proposal scores into a single metric and select the winning bid.

The RIF-based exchange approach provides several advantages for both customer and supplier. The customer “shifts” responsibility for traceability back to the supplier and concentrates on producing the compliance matrix. The supplier typically traces the technical solutions of a bid back to the customer requirements in its RE tool. A supplier proposal is composed of technical specifications and traces to customer requirements, and requires from the supplier no additional efforts. Additionally, suppliers have a better opportunity to correct and resubmit a bid.

At the time of writing, the project has not entered this phase, but the projected savings are assumed to be high.

![Proposal Analysis and Selection Phase.](image)

**Figure 6: Proposal Analysis and Selection Phase.**

## 5 Discussion

Requirements exchanges are not simple exports and imports; users tend to think of requirements exchange as a form of export / import operation as available in many RE tool. This leads to failure in dealing adequately with conflicts; for example if one supplier makes a modification to a requirement attribute whilst another supplier modifies the same requirement attribute, the customer is confronted to an update-update conflict. An automated resolution of this conflict means that one of the suppliers change will not be updated; to prevent this loss of information the customer must resolve the conflict by manually merging the requirement attribute changes. If this type of conflict is frequent, manual intervention is prohibitive in terms of the time required to update the requirements specification. A generally accepted solution to deal with conflicts is to avoid them or at least keep them to a minimum.

Drawing and agreeing to an exchange plan between partners is important to avoid complex conflict resolution. In previous pilot projects, RIF-based exchanges were unsuccessful because they failed to properly plan what parts of the documents could be modified by a given
party; this led to so-called ‘lost-updates’ whereby partners made modification concurrently to the same requirements and overwrote one-another.

Access policy assignment was found to be an adequate mechanism to help enforce the exchange plan and improve overall performance. The RIF access policies should not be mistaken with the control access policies built-in in most commercially available RE tools, although the access policies can be imported as control policies in some RE tools. Their main purpose is to indicate to the exchange partners the intent defined in the exchange plan for a given phase of a project (i.e. which attributes can be modified). Because RIF-based requirements are uniquely identified it is possible to reduce the size of snapshots being exchanged; the initial exchange must contain the entire snapshot, i.e., the full attribute set of a requirement. Subsequent exchanges can be limited to attributes that are writable, i.e. attributes that are likely to have changed. This leads to a significant improvement of performance for the import / export operations.

The design of RIF focused primarily on the representation of requirement structures; little attention is paid to the difficulty of identifying and managing exchanges; in the case study, phase III requires the exchange of at least 1407 separate technical documents divided into the 21 supplier offers. Current experience in the automotive industry shows that exchanges can also occur on a weekly basis. It is easy to make a mistake in spite of process support. A RIF–based exchange tool should include features to adequately manage the complexity bound to real business scenarios found in customer-supplier relationships. This issue could be easily addressed by enhancing the RIF specification with the assignment of unique exchange identifiers to each requirements exchange; RIF only foresees unique identification for individual exchange files.

The assumptions and savings will vary with the specific project. The savings exposed in section 4 estimate the potential realized by eliminating manual requirements exchange, and only the savings realized in the acquisition process. If additionally the savings in product development, series production, after-sales service, (lost) market share, or potential liability issues are estimated, greater savings can surely be realized. Also the case study focuses primarily on the customer activities during the request for proposal process. All suppliers involved are Tier I suppliers, which call upon their own supplier chain to prepare the proposals in a spoke-and-hub manner. Savings can also be realized on the supplier side by adopting an RIF-based exchange.

Finally, this paper focused primarily on the exchange process on the customer-side during the request for quotation phase. Once the contract is awarded specifications are normally frozen, but may still change during the development phase. Such changes are normally associated with costs to be incurred by the customer. A RIF-based exchange can help pinpoint which requirements have been changed; an impact analysis can be executed to assess which functional requirements at the supplier site are impacted by changes. Tier I supplier can take advantage of this mechanism to transfer requirements changes down the supplier chain. However, the current use of RIF exchanges requires that complete snapshot to be exchanged; since contractual changes are not frequent, the RIF format could be improved to only transmit the actual changes (deltas) rather than the complete snapshot.

6 Conclusions

This article introduced RIF as a technical solution to facilitate and ease collaborative RE to effectively and successfully manage relationships across several business partners. We provided experiences and practical guidance resulting from our work with clients in different industries. A concrete industry case study was presented to highlight that with RIF effective
and efficient requirements exchange and collaboration have been made feasible. We showed how a RIF-based approach is practically adopted to the exchange of requirements in the context of a request for proposal.

Results from several companies along the supply chain (i.e., OEMs, suppliers, tier-2 suppliers) in different industries with whom we have worked over the past years have showed consequent cost and resource savings in the exchange between customer and suppliers. These cost reductions result from improved efficiency (i.e., less manual exchange many with small adoptions) and from less rework due to changes and misunderstanding by sharing insufficient requirements information. This holds even more in RFP situations, where in the final phase of the RFP process changes are facilitated and defects reduced by exchanging traces between customer requirements and proposals. Therefore, such collaboration not only makes supplier management more effective and less error-prone, but also tangibly and sustainably reduces cost along the product life-cycle – which these days certainly is of heavy impact in global competition.

Needless to say that RIF by itself will not solve problems entrenched in insufficient engineering and management processes. Therefore a typical introduction strategy will always start with analyzing and improving processes and improving product life-cycle management – specifically the supplier interfaces – and then proceed to using RIF interchange format for streamlining and automating the collaboration in requirements engineering and management from concept to production and maintenance.

The requirements interchange format (RIF) was started as a global initiative and is fast growing. It is today used across industries, having initially started in automotive supplier networks and now growing to domains such as transportation, industrial automation and medical devices.

Our ambition with RIF for requirements exchange is to enable cooperating engineering organizations to more effectively handle requirements and specifications within the daily operational activities. Often information is manually reused or simply extracted and transmitted, but with high redundancies and overheads. At times, the redundancies create rework with changing requirements and errors from inconsistencies that remain in the product. Being able to not only reuse information but also embed knowledge into integrated workflows for specific tasks independent which tools and workflows are used by each cooperating business partner, generates immediate returns by making engineers more flexible.

RIF and its practical implementation facilitate the single source concept of requirements across organizational boundaries thus ensuring consistency across different requirements artefacts, less defects from requirements to specifications to engineering work products, speed in exchanging information and collaborating on solutions, and cost reduction.

References


Company profile

Vector Consulting Services is the preferred partner for improving technical product development. We support our clients with powerful consulting solutions that cover the entire product life-cycle and its related processes and tools. Objective-driven consulting together with a pragmatic implementation have made us the esteemed partner of our clients. The consulting branch of the globally active Vector Group, we support clients from automotive, transport, aerospace, industrial systems, ICT and other domains in optimizing technical product development. Our vision: High-quality consulting with a lasting partnership with our clients. Our understanding of consulting is a results-driven implementation of hands-on solutions for your company. Our experience is global, but we deliver our services locally, specific to your needs. We cover all phases of successful change: Setting objectives, supporting and driving practical implementation, and assuring sustainable results.

Biographies

Dr. Christof Ebert is managing director at Vector Consulting Services. He is helping clients worldwide to improve product development and to manage organizational changes. Prior to that, he held engineering and management positions for fifteen years in telecommunication, IT, aerospace and transportation. As a business consultant and author of several books he has influenced numerous companies. His book on Requirements Engineering at dPunkt.Verlag has recently appeared in its second edition and is a leading practice reference. Dr. Ebert lectures at the University of Stuttgart, serves on the editorial committees of several industry journals and is a SEI authorized CMMI Instructor. Contact him at christof.ebert@vector.com