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Requirements Engineering Tools: An Evaluation

Juan M. Carrillo de Gea, Christof Ebert, Mohamed Hosni,
Aurora Vizcaíno, Joaquín Nicolás and José L. Fernández-Alemán

Requirements engineering (RE) is a major success factor for any product and project. Missing, wrong and changing requirements are major failure points. Requirements tools facilitate professional RE with organizing, specifying, and tracing requirements along the life cycle. This article provides an overview on RE tools in various scope and price ranges. Practical guidance is provided from our many RE projects. Looking forward to hearing back from you about this column and technologies that matter most.

—Christof Ebert

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"If you don't know where you are going, any road will get you there." Alice in Wonderland was told this obvious piece of wisdom when she was asking for directions. We all know it from our projects when navigating in fog with insufficient requirements. Clear goals can be achieved, unclear goals are sure to be missed. Requirements engineering (RE) is the discipline to clarify and communicate value, goals, and their transformation to a product.

Requirements engineering matters. As a business process is pivotal yet challenging. Many companies fail with their projects and products due to insufficient RE. A seminal article twenty years ago already had the reasons – and the recipes for success [1]. Missing requirements, wrong requirements, and changing requirements pave the way to project hell. Business success depends on good requirements engineering. Many different stakeholders and interfaces with clients, suppliers, internal organizations and teams highlight that RE is much more than only a set of use cases, or UML diagrams.

RE is a business process, with high cost if done wrong. ROI of RE is amongst the highest in the entire software and IT value chain. Rework, delays, and missed market opportunities are just few examples why RE dominates each project risk assessment. To evaluate your own perspective, just answer the following five questions spontaneously and honestly:

- Are your requirements documented in a structured and testable way?
- Is there a brief rationale for each requirement that describes the benefits and value?
- Did you ever deliver a product with forgotten or wrong functionality?
- Are your test cases optimized to a minimum viable set which is traceable to market requirements?
- Do you keep requirements consistent along the project and product life cycle?

If there is at least one “No”, this article is for you. Improve your RE and use appropriate technology to manage requirements.

RE is a culture change [1]. It is like moving from ad-hoc projects towards project management. Often RE is misunderstood as “collecting requirements”, while in fact it means “engineering” – systematic work along the entire life cycle. Most companies struggle with RE, due to home-grown solutions and not considering the transformation need along the entire life cycle. Fig. 1 shows the different dimensions of introducing and improving RE. We will here look to RE tools because they are mandatory for organizing requirements.

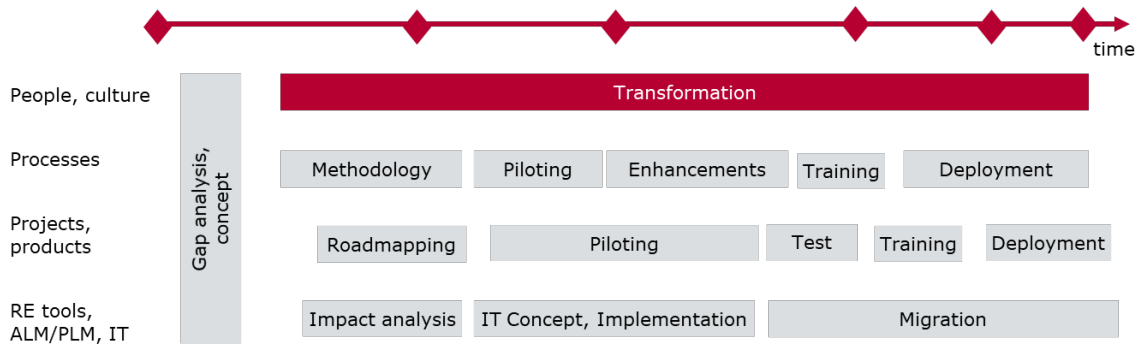

Fig. 1: Good RE means a culture and technology change

Tools evaluation

Bearing in mind the continuously emerging needs of the users of the RE tools in recent years, we propose a set of features that are relevant for industry. Ten years ago, we have started systematic RE tools evaluation based on a classification framework for RE tool capabilities along the major RE activities [2,3,4]. For this updated study, we mapped the former categories of the classification framework to new topics and added categories to meet current trends in the RE tool market, such as agility, collaboration and test-driven RE [5].

The short description of the RE tools evaluation criteria is shown in Table 1. Some of the topics are basic and belong to the core capabilities that any software practitioner would expect from this type of tool. For example, “Organization of requirements”, “Reports, database queries, open interface language”, “Internal checks” and “Traceability support” refer to key functionality areas when dealing with requirements information. Subpar support in these areas could have a negative impact on the effectiveness of the tool and user productivity. Other features are more unusual but also desirable – especially in certain use scenarios – and increasingly found in most tools. This would be the case of “Variant management”, “Collaboration, workflow management”, “Federation and notification with ALM/PLM tools”, “Agile, continuous X, and DevOps” and “Intelligent support”.

No.	Label	Topic	Description
1	OR	Organization of requirements with metadata, attributes, reuse	The tool allows the user to add metadata to the requirements in different formats (+), includes predefined requirements attributes and user-defined attributes (++), and provides predefined and user-defined requirements and requirements document templates (+++).

2	RDOIL	Reports, database queries, open interface language	The tool is able to generate structured, sophisticated and/or standardized reports from the data (+), its functionality can be easily extended (++), and offers an extension language, API and/or REST API (+++).
3	IC	Internal checks, i.e., consistency, dependencies, history	The tool offers mechanisms for conflict detection and resolution between requirements and/or consistency checks (+), supports dependency analysis (++), and includes requirements version control and requirements change management functionality (+++).
4	TS	Traceability support i.e., drag & drop, horizontal and vertical	The tool offers visual traceability support and/or different types of traces (+), supports traceability links to requirements and other artifacts (++), and offers complete traceability to manage requirements across the development lifecycle including external traceability to other tools (+++).
5	VM	Variant management	The tool includes explicit support for reuse (+), variant creation and management (++), and software product lines and/or reusable requirements catalogs (+++).
6	RWC	Remote working, cloud only	The tool can work without connectivity (+), its functionality when not connected is complete (++) and allows the user to work offline and synchronize when connectivity is available (+++).
7	MV	Multiple views	The tool includes database and document-oriented views of the requirements (i.e., word specification, table, etc.) (+), offers different views of the traceability relationships (textual, tree, matrix) (++), and allows the user to visualize requirements dependencies and their evolution (+++).
8	Perf	Performance	The tool can manage big projects with large amounts of data (+), is optimized to load large models (++), and offers adequate performance and is responsive, even if there is remote work without connectivity (+++).
9	CWM	Collaboration, workflow management	The tool provides collaborative and/or distributed work support, offers review, discussion and/or vote functionality, asynchronous and/or synchronous communication, includes granular access control and security (+), provides predefined and flexible, customizable workflows (++), and supports multiple devices (e.g. web browser, mobile app) (+++).
10	IBP	Easily adapted and integrated into your business processes	The tool is customizable and flexible in order to adapt to project conditions, stakeholders or the nature of the requirements (+), can easily fit with any type of business process or industry (++), and can be easily integrated into or adapted to preexisting tools and processes within the organization (+++).
11	FN	Federation and notification with ALM/PLM tools	The tool offers application lifecycle/product lifecycle management (ALM/PLM) functionality (+), offers the possibility to integrate into third-party ALM/PLM solutions (++), and has OSLC support (+++).
12	EI	Export/import with standard formats	The tool offers complete import/export functionality and support for standard formats: CSV (+), others (except ReqIF) (++), ReqIF (+++).
13	MaC	Macros for repeated commands	The tool includes macro creation and management functionality (+), provides a scripting language (++), and/or other automation mechanisms (+++).
14	TLC	Training and learning curve effort	The tool includes adequate documentation, tutorials, training materials and resources (+), courses and/or certifications (++), and it is easy to use and/or easy to learn (+++).
15	DevOps	Agile, continuous X, and DevOps	The tool is conceived for or easily adaptable to agile methodologies and DevOps pipelines (+), allows the management of requirements in agile, lean, scaled agile frameworks (e.g. SAFe, S@S) (++), and CI/CD and DevOps (+++).
16	IS	Intelligent support	The tool facilitates the processing, grouping or classification of requirements by using natural language processing or other automatic methods based on artificial intelligence and data analytics (+), offers code generation functionality (++), and provides recommendations about the project assets (e.g. stakeholders, requirements) to facilitate monitoring and decision making (+++).

17	Scal	Scalability	The tool offers basic support to large projects (+), can appropriately scale with the size of the project and team (++), and is offered within a cloud service model (SaaS) (+++).

Table 1. List of categories of RE tool capabilities. Column "Description" includes a short summary of the items under consideration and indications on the specific value assigned to them (i.e. "+", "++", "+++")

Traceability support has emerged as key need for RE [4,5]. RE tools are not only expected to support the management of relationships between requirements and with system test (i.e., horizontal traceability), but also between requirements and other software artifacts (i.e., vertical traceability). Scalability is an important feature to consider when comparing different RE tools, but one that is not usually addressed. This concept refers to the ability of the RE tool to accommodate many user requirements, considering the needs of the project. With increasing agile and collaborative work, we put more emphasis than before on the necessary capabilities, such as sharing, collaborative editing, and flexible architectures.

Variant management refers to the ability to move from the production of a single product to an assembly line that efficiently and effectively manages the different variations that may exist between products. This implies the application of the principles of mass production to software. This approach results in improvements in both efficiency (reduced time-to-market) and effectiveness (improved software quality). When implementing a reuse strategy, it is required to define the so-called "variation points", or in other words, any requirement which makes a system different from another in the product line.

RE tool must fit and federate with existing business processes, in particular with ALM/PLM. The norm is to provide a REST API. As each REST API is different, however, it is necessary to build an integration layer, with the consequent waste of resources. To mitigate this problem and avoid the need to implement point-to-point integrations, the Open Services for Lifecycle Collaboration initiative has emerged to create standard REST APIs to connect data. Some vendors offer RE tools integrated to an ALM/PLM solution for managing the software and product lifecycle. On first view it is nice with drag and drop functionalities, but along the life cycle it will be a burden due to lock-in with this vendor. We thus recommend from the many customer projects to ensure that your tools are rather federated than integrated, offer open interfaces and certainly provide export and import of requirements with the ReqIF standard.

AI and heuristics together with natural language processing facilitates semi-automatic traceability and lots of consistency checks [5,6]. We have delivered such ML mechanisms to retrieve traceability in legacy requirements and to instrument an agile testing with minimum viable test suite based on semi-automatic horizontal traceability from customer requirements and system requirements to system test cases. AI also helps in making the RE tool learning from past requirements (and their defects and insufficiencies) and foster the reuse of the knowledge that the company has acquired.

Tools ranking

There are almost 200 stand-alone RE tools available in the market. Many of them can be found in online RE tool databases [3]. Various RE tool market reports are available [7,8], but often are unclear in their independent assessment. The scope of the individual tools collected in the databases is broad and diverse. It ranges from limited support for requirements practices in agile methodologies with issue tracking and management, to project management, up to high-end tools covering all RE disciplines [3]. Some of them are specific, while others are multipurpose and offer tons of functionalities. We have consulted up-to-date online resources and identified a total of 156 candidate tools for evaluation. This list was filtered for this study towards dedicated RE tools that are widely used in practice and able to cover all the activities of the RE process [3]. Tools which are fully integrated to ALM and PLM suites and domain-specific tools such as prototyping environments for gaming apps are not considered.

Twelve tools are selected which continuously rank high in usage from current market studies and from our own projects at Vector Consulting. Microsoft Office has been added, being still the single most widely used tool for requirements, with its spreadsheet and documentation support. These 12+1 tools are evaluated with above list of topics presented in Table 1. To avoid bias, we have used the tools with practical use cases and also observed their use in client projects where we directly get into interview situations. Table 2 shows the full evaluation.

The RE tools under study offer a high level of support to the set of capabilities. Four tools lead the ranking (i.e. Siemens Polarion, DOORS DNG, Enterprise Architect and Jama Connect), followed closely by two other tools, namely PTC Integrity and PREEvision. Tools with highest scores share the ability to provide full support to the RE process and high degrees of innovation. They offer the user cutting-edge features, which are not yet common and therefore remain a challenge for vendors, as well as integrated solutions for complete software lifecycle management, cloud computing licensing models to simplify adoption and maintenance processes.

Tool name	DOORS DNG	DOORS	Jira	Siemens Polarion	PTC Integrity	Reqtify	Quality Center	in-STEP Blue	PREEvision	Enterprise Architect	Jama Connect	RMTrak	MS Office
Version, date	7.0.3, 2020/12	9.7.2, 2020/07	8.14.0, 2020/11	20 R2, 2020/10	12.2.1.0, 2019/10	2020x, 2019/11	15.5, 2020/09	6.5, 2020/01	9.5, 2021	15.2, 2020/10	8.56.1, 2020/11	5.3.22, 2017	365, 2021/01
Vendor Name	IBM	IBM	Atlassian	Siemens	PTC	Dassault Systèmes	Micro Focus	Micro-TOOL	Vector	Sparx Systems	Jama Software	Pro-meteo	Microsoft
Cost	High	High	Low	High	High	Mid	High	High	High	Mid	Mid	Mid	Low
OR	+++	+++	0	+++	++	+	+	+	++	++	+++	+	++
RDOIL	++	+	+	++	++	+	++	+	++	++	++	+	+
IC	++	++	+	++	++	+	+	+	++	++	++	+	0
TS	+++	+++	+	+++	+++	+	+	+	++	+++	+++	+	0
VM	+++	++	0	+++	++	0	0	+	+++	+	+++	0	0
RWC	++	+	+	++	++	0	+++	++	+++	+++	++	0	++
MV	+++	++	0	+++	+++	+	+	+	+++	+++	+++	+	+
Perf	++	+	++	++	++	+	+	0	++	++	++	0	+
CWM	+++	+	++	+++	++	+	++	+	+++	+++	+++	+	++
IBP	++	+	++	++	++	+	+	+	++	++	++	0	++
FN	+++	+++	++	+++	+++	0	+	+	+++	+++	+++	0	+
EI	++	++	+	++	++	+	+	++	++	++	++	+	+
MaC	++	++	++	++	++	0	+	0	++	++	++	+	++
TLC	+	+	+	+	+	+	++	+	+	+	+	+	++
DevOps	+	+	++	++	+	+	++	+	+	+	+	0	0
IS	+	0	0	+	0	0	0	0	0	++	0	0	0
Scal	+++	+	+	+++	+++	+	+++	+	++	+++	+++	+	++
Total	38	27	19	39	34	12	23	16	35	37	37	10	19

Table 2. Tools ranking. Values in the range “0”, “+”, “++”, “+++” (from minimum/no support to full support)

Practical Guidance and Conclusions

Effective and efficient RE needs a suitable RE tool. Manual activities are inefficient and are rejected – no matter how good the intentions behind them were. We have evaluated the major current RE tools according to criteria as defined by current standardization. According to the results of the survey, many tools have obtained high or very high scores in requirements. Fig. 2 provides the summary. The horizontal axis uses a white-box perspective diving into technology, complexity and prizing which are obviously

correlated. The vertical axis takes a black-box perspective and ranks tools according to user experience. Even a tool with “low” ranking on the vertical axis does not mean that a tool is not useful. It just ranks lower than some other tools, which are all in the top range of what you can find in the market. Needless to say, that there is some correlation of both axes, i.e. typically a good tool has a higher price tag.

"A fool with a tool remains a fool." We all know this, and yet we observe in many companies that a requirements tool is introduced in the assumption that this will make everything better. Here some hints from our projects at Vector:

- First the methods and process, then the tool. Never consider the RE tool as sufficient solution to RE problems. It is a necessary condition for good RE. Not more.
- Begin with a simple spreadsheet to prototype your RE tooling needs.
- Tools need professional change management and resources for preparation, introduction, and coaching.
- Tune your RE tool to enforce discipline, such as templates, complete requirements, traceability, and a systematic workflow for all project stakeholders.
- Federate your RE tool with configuration tools (e.g., CVS) and change management (e.g., Bugzilla) for traceability and agile progress tracking.
- Always start with horizontal traceability from customer requirements to appropriate system test cases.
- Handling versions and variants demands a dedicated RE tool to achieve consistency and reuse.

RE tools have big benefits – if carefully introduced. Take the time and do not underestimate the learning curve, especially if the RE tool is introduced on top of a challenged project. It might be the final nail in the coffin.

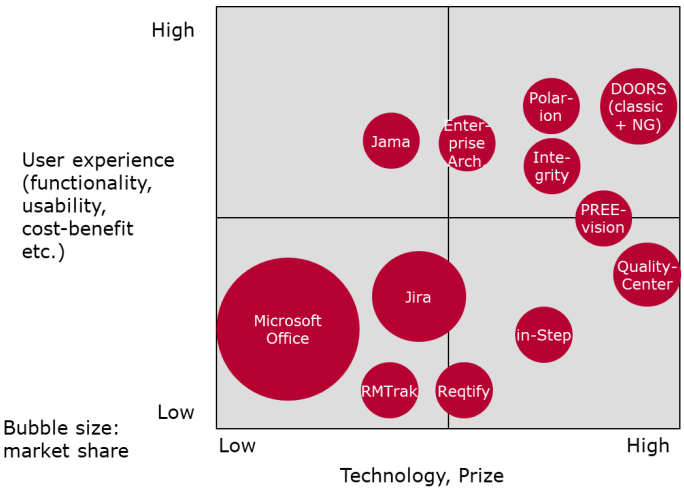

Fig. 2: Requirements Engineering Tools State of the Practice

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Authors

Juan M. Carrillo de Gea *is an associate professor at Software Engineering Research Group, Faculty of Computer Science, University of Murcia, Spain. Contact him at jmcdg1@um.es.*

Christof Ebert *is managing director at Vector Consulting Services. He's a senior member of the IEEE and the editor of Software Technology of IEEE Software. Contact him at christof.ebert@vector.com.*

Mohamed Hosni *is an assistant professor at MOSI Research Team, High School of Arts and Crafts Meknes, Moulay Ismail University, Morocco. Contact: m.hosni@ensam.ac.ma.*

Aurora Vizcaíno *is a professor at Alarcos Research Group, Institute of Information Technologies & Systems, Escuela Superior de Informática, University of Castilla-La Mancha, Spain. Contact her at aurora.vizcaino@uclm.es.*

Joaquín Nicolás *is an associate professor at Software Engineering Research Group, Faculty of Computer Science, University of Murcia, Spain. Contact him at jnr@um.es.*

José L. Fernández-Alemán *is an associate professor at Software Engineering Research Group, Faculty of Computer Science, University of Murcia, Spain. Contact him at aleman@um.es.*