



# Requirements Engineering Tools: An Evaluation

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## From the Editor

Requirements engineering (RE) is the key success factor for any product and project. Missing, wrong, and changing requirements are major failure points. RE tools facilitate professional engineering by specifying, organizing, and tracing requirements along the lifecycle. This article provides an overview on popular RE tools in various scope and price ranges. Practical guidance is provided from our worldwide RE projects. I look forward to hearing from you about this column and the technologies that matter most for your work.—*Christof Ebert*

**“IF YOU DON’T** know where you are going, any road will get you there.” Alice from *Alice in Wonderland* was told this obvious piece of wisdom when she asked for directions. We all know this wisdom from navigating through the fog of insufficient requirements when working on projects. Clear goals can be achieved; unclear goals are sure to be missed. Requirements engineering (RE) is the disciplined and systematic approach (i.e., “engineering”) for elicitation, documentation, analysis, agreement, verification, and management of requirements while considering market,

technical, and economic goals. “Disciplined” is about culture, and “systematic” demands process and tools, which is our focus here.

Requirements matter. As a business process, RE is pivotal yet challenging. Many companies fail with their projects and products due to insufficient RE. A seminal article, published 20 years ago, has already provided the reasons and recipes for success.<sup>1</sup> Missing, wrong, and changing requirements pave the way to project hell. Business success depends on good RE. Many different stakeholders and interfaces among clients, suppliers, internal organizations, and teams highlight that RE is much more than a set of use cases or UML diagrams.

RE is a business process with a high cost if done wrong. The return on investment of RE is one of the highest in the entire software and IT value chain. Rework, delays, and missed market opportunities are just a few examples of why insufficient RE is the major root cause of project failure. To evaluate your own perspective, spontaneously and honestly answer the following five questions.

- Are your requirements documented in a structured and testable way?
- Is there a brief rationale for each requirement that describes the benefits and value?

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- Did you ever deliver a product with a forgotten or wrong functionality?
- Are your test cases optimized to a minimum-viable set that is traceable to market requirements?
- Do you keep requirements consistent along the project/product lifecycle?

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

an entire lifecycle. Most companies struggle with RE, because they are not considering the transformation of artifacts and traceability needs to requirements along the entire lifecycle. Figure 1 presents the different dimensions of introducing and improving RE. It displays how RE tools are mandatory for organizing requirements.

### Tools Evaluation

Bearing in mind the continuously emerging needs of users of RE tools

major RE activities.<sup>2-4</sup> In 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.<sup>5</sup>

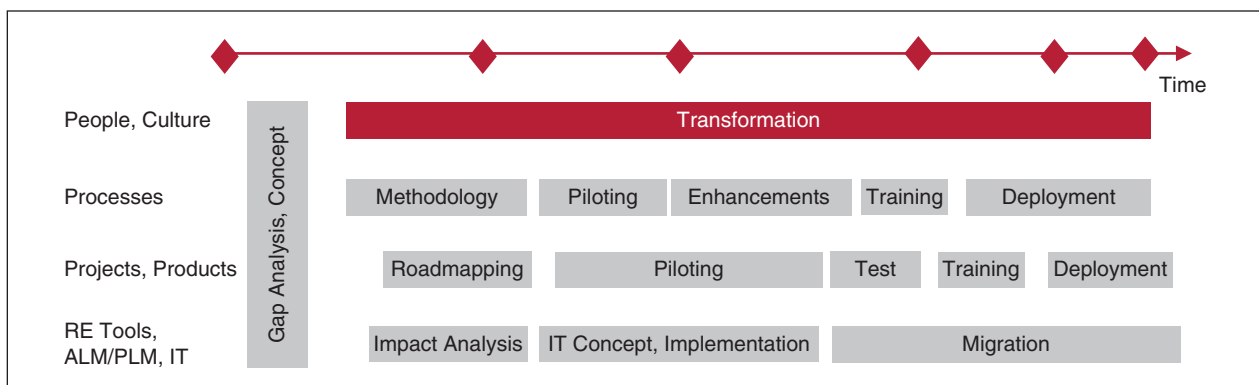
A short description of the RE tools evaluation criteria is presented in Table 1. Some of the topics are basic and belong to the core capabilities that any software practitioner would expect from this type of tool. For example, “Organization of requirements,” “Reports, database queries, open interface 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 are increasingly found in most tools. This is the case for “Variant management,” “Collaboration, workflow management,” “Federation and notification with ALM/PLM tools,” “Agile, CI/CD and DevOps,” and “Intelligent support.”

Traceability support has emerged as a key need for RE.<sup>4,5</sup> RE tools

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RE is a culture change.<sup>1</sup> It is like moving from ad hoc projects toward project management. RE is often misunderstood as “collecting requirements,” when, in fact, it means to “engineer” systematic work along

in recent years, we propose a set of features that are relevant for industry. Ten years ago, we started systematically evaluating RE tools based on a classification framework for RE tool capabilities during



**FIGURE 1.** Good RE means a culture and technology change. ALM/PLM: application lifecycle management/product lifecycle management.

Table 1. A list of categories of RE tool capabilities.

Number	Label	Topic	Description
1	OR	Organization of requirements with metadata, attributes, and 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, and 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 it offers an extension language, API and/or REST API (+++).
3	IC	Internal checks, that is, consistency, dependencies, and history	The tool offers mechanisms for conflict detection and resolution among requirements and/or consistency checks (+), supports dependency analysis (++), and includes requirements version control and requirements change management functionality (+++).
4	TS	Traceability support, that is, drag and 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 it 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 (that is, word specification, table, and so on) (+), 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 and asynchronous and/or synchronous communication; includes granular access control and security (+); provides predefined and flexible, customizable workflows (++); and supports multiple devices (for example, web browser, mobile app) (+++).
10	IBP	Easily adapted and integrated into your business processes	The tool is customizable and flexible 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 pre-existing tools and processes within the organization (+++).
11	FN	Federation and notification with ALM/PLM tools	The tool offers 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) (++), and ReqIF (+++).
13	MaC	Macros for repeated commands	The tool includes macro creation and management functionality (+) and 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 (+), and courses and/or certifications (++), and it is easy to use and/or learn (+++).

(Continued)

Table 1. A list of categories of RE tool capabilities. (Continued)

Number	Label	Topic	Description
15	DevOps	Agile, CI/CD, and DevOps	The tool is conceived for or easily adaptable to agile methodologies and DevOps pipelines (+) and allows the management of requirements in agile, lean, scaled agile frameworks (++) 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 (for example, 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) (+++).

The "Description" column includes a short summary of the items under consideration and indications of the specific values assigned to them (that is, "+," "++," and "+++"). REST: Representational State Transfer; API: application programming interface; CSV: comma-separated values; DevOps: development and operations; SaaS: software as a service; OSLC: Open Services for Lifecycle Collaboration; CI: continuous integration; CD: continuous delivery; ReqIF: Requirements Interchange Format.

are not only expected to support the management of relationships between requirements and system tests (that is, horizontal traceability), but also between requirements and other software artifacts (that is, vertical traceability). Scalability of RE tools

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 variations that may exist

RE tools must fit and federate with existing business processes, particularly 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, which results in a 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 into an ALM/PLM as a solution for managing the software and product lifecycle. On first view, its drag and drop functionalities are nice, but, along the lifecycle, it will be a burden due to lock-in with the vendor. Thus, based on many customer projects, we recommend that you ensure that your tools are federated rather than integrated, offer open interfaces, and provide the export and import of requirements with the ReqIF standard.

The combination of artificial intelligence (AI), heuristics, and natural language processing facilitates semi-automatic traceability and

Scalability of RE tools toward volume, product variants, engineers, and locations is pivotal, yet often neglected when comparing different RE tools.

toward volume, product variants, engineers, and locations is pivotal, yet often neglected when comparing different RE tools. 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 are putting more emphasis than before on necessary capabilities, such as sharing,

among products. This requires applying 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"—which are any requirements that make a system different from another in the product line.

lots of consistency checks.<sup>5,6</sup> We have delivered such machine learning mechanisms to retrieve traceability in legacy requirements and to implement agile testing with a minimum-viable test suite based on semi-automatic horizontal traceability. These mechanisms can be used in customer and system requirements and system test cases. AI also helps the RE tool learn from past requirements (and their defects and insufficiencies) and foster the reuse of 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.<sup>3</sup> Various RE tool market reports are available,<sup>7,8</sup> but they are often unclear in their independent assessments. The scope of the individual tools collected in the databases is broad and diverse. It ranges from tools with 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.<sup>3</sup> Some of them are specific while others are multipurpose and offer many functionalities. We have consulted up-to-date online resources and have identified a total of 156 candidate tools for evaluation. Here we evaluate widely used RE tools that cover the major RE activities.<sup>3</sup> Tools that are fully integrated to ALM/PLM suites and domain-specific tools, such as prototyping environments for gaming apps, were not considered.

We selected 12 tools that continuously rank high in usage from current market studies and from our own

projects at Vector Consulting. Microsoft Office was added since it is still the most widely used tool for requirements, with its spreadsheet and documentation support. These 13 tools were evaluated using the previous list of topics presented in Table 1. To avoid bias, we used the tools with practical use cases and also observed their use in client projects through conducting interviews. Table 2 displays the full evaluation.

The RE tools under study offer a high level of support to the set of capabilities. Four tools lead in the ranking (Siemens Polarion, DOORS DNG, Enterprise Architect, and Jama Connect), followed closely by two other tools, namely PTC Integrity and PREEvision. The tools with the highest scores share the ability to provide full support to the RE process and enable high degrees of innovation. They offer cutting-edge features to the user, which are

were. We have evaluated the major current RE tools according to criteria as defined by current standardization. According to the results of this survey, many tools have obtained high or very high scores in requirements. Figure 2 provides the summary. The horizontal axis uses a white-box perspective, diving into technology, complexity, and prizes which are obviously correlated. The vertical axis takes a black-box perspective and ranks tools according to user experience. Even if a tool has a low ranking on the vertical axis, it does not mean that the 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, there is some correlation of both axes that shows that a good tool typically has a higher price tag.

“A fool with a tool remains a fool” is conventional wisdom. Yet we observe with many clients that, in a

Here we evaluate widely used RE tools that cover the major RE activities.

not yet common and, therefore, are a challenge for vendors. They also offer integrated solutions for complete software lifecycle management, cloud computing licensing models to simplify adoption, and maintenance processes.

### 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

rush, a requirements tool is introduced with the assumption that it will improve performance, culture, and process. Wrong! RE tools demand investment and good coaching to generate an ROI. Here are some hints from our projects at Vector.

- First work on the methods and process, then the tool. Never consider the RE tool as a sufficient solution to RE problems. It is a necessary condition for good RE and nothing more.

Table 2. The ranking of tools.

Tool name	DOORS DNG	DOORS	Jira	Siemens Polarion	PTC Integrity	Reqtify	Quality Center	in-STEP Blue	PREEvision	Enterprise Architect	Jama Connect	RMTrak	Microsoft Office
Version, date	7.0.3, December 2020	9.7.2, July 2020	8.14.0, November 2020	20 R2, October 2020	12.2.1.0, October 2019	2020x, November 2019	15.5, September 2020	6.5, January 2020	9.5, 2021	15.2, October 2020	8.56.1, November 2020	5.3.22, 2017	365, January 2021
Vendor name	IBM	IBM	Atlassian	Siemens	PTC	Dassault	Micro Focus	Micro-TOOL	Vector	Sparx Systems	Jama Software	Pro-meteo	Microsoft
Cost	High	High	Low	High	High	Middle	High	High	High	Middle	Middle	Middle	Low
OR	+++	+++	0	+++	++	+	+	+	++	++	+++	+	++
RDOIL	++	+	+	++	++	+	++	+	++	++	++	+	+
IC	++	++	+	++	++	+	+	+	++	++	++	+	0
TS	+++	+++	+	+++	+++	+	+	+	++	+++	+++	+	0
VM	+++	++	0	+++	++	0	0	+	+++	+	+++	0	0
RWC	++	+	+	++	++	0	+++	++	+++	+++	++	0	++
IMV	+++	++	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

Values include "0", "+", "++", "+++" (from minimum/no support to full support).

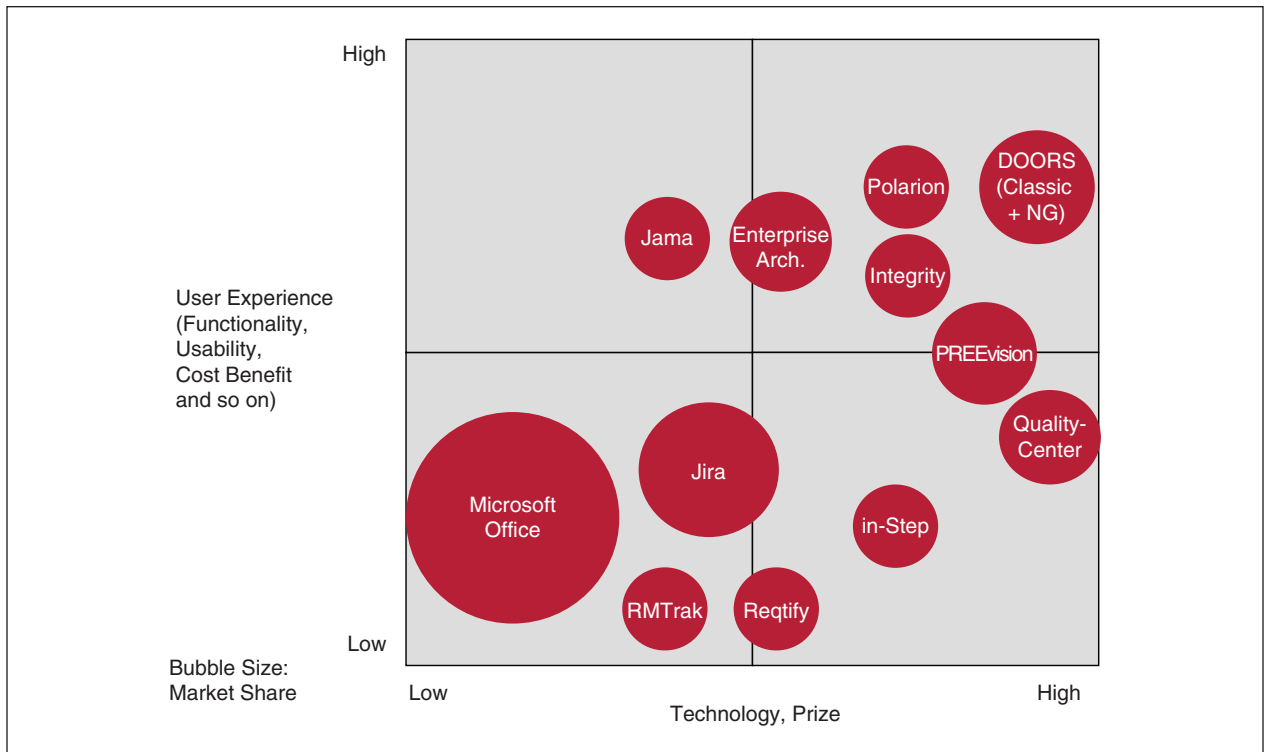


FIGURE 2. RE tools and the state of the practice.

- 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, using resources such as templates, complete requirements, traceability, and a systematic workflow for all project stakeholders.
- Federate your RE tool with configuration tools (for example, CVS) and change management (for example, 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.

**R**E tools have big benefits if they are carefully introduced. Take the time and do not underestimate the learning curve, especially if the RE tool is introduced on top of an already challenging project. Without careful introduction, it might otherwise be the final nail in the project's coffin. ☹

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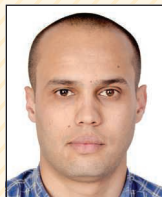
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