Preprint: Krzysztof Wnuk, Lech Madeyski, Waleed Abdeen, Sneha Penmetsa and Navya Lingampalli, "An Empirical Analysis of the Usage of Requirements Attributes in Requirements Engineering Research and Practice". In: Nguyen, N.T., et al. Computational Collective Intelligence. ICCCI 2024. Lecture Notes in Computer Science, vol 14811, pp. 29–40, Springer, Cham. 2024. DOI: 10.1007/978-3-031-70819-0_3 Preprint: https://madeyski.e-informatyka.pl/download/WnukMadeyskiAbdeenPenmetsaLingampalli24.pdf

An Empirical Analysis of the Usage of Requirements Attributes in Requirements Engineering Research and Practice

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Abstract. Requirements attributes play an important role in storing and managing meta-information about requirements. This paper presents the results of a literature review and two industrial case studies performed at two large organizations developing software-intensive products for a global market. We performed seven snowballing iterations and identified 18 studies where we extracted requirements attributes. Next, we compare these identified attributes with those of two large companies developing software-intensive products for a global market. We found common attributes that describe stakeholders and roles, support change management, tracing and communication, tracking the status, and estimating the business value of requirements.

Keywords: requirements attributes · case study · literature review · empirical study · requirements management

1 Introduction

Requirements attributes are defined as descriptive properties attached to each requirement and help to gain a clear understanding of both intrinsic and external aspects of requirements [11]. Information that requirements attributes carry helps to track the status of requirements implementation, risks involved, possible impacts on cost and schedule, and the conditions of operations that apply to a requirement [21]. Attributes help companies trace and maintain requirements at various stages of requirement engineering processes (requirements elicitation, analysis, documentation, and validation) [7]. Despite that, there is a shortage of studies on how requirements attributes are used in industry and in academic publications.

This paper fills this gap by identifying research related to requirements attributes and conducting industrial case studies on the use of requirements attributes in practice. We performed seven snowballing iterations and identified 18 studies, where we extracted and semantically clustered 53 general attributes. Next, we compared these identified attributes with the 28 general attributes

used by two large companies that are developing software-intensive products for a global market. The result is that a set of 25 attributes was found in both research papers and case studies.

Our main contribution from this study is the set of 25 attributes divided into 5 areas: roles, status, traces, value and intrinsic. Following the status of requirements, roles and changes dominate among the attributes. We also discovered a lack of guidelines on how and when to populate these attributes in the requirements flow, depending on the selected requirements process. What is also surprising is the under-representation of requirements quality attributes in our results and the focus only on internal business value. As requirements are the objects carrying customers and business value into the development organization, we believe that attributes should better support that transition in software development processes. Finally, most of the identified attributes are manually populated, leaving a significant potential for automation to support requirements management.

2 Background and Related Work

Requirements attributes represent a subset of more general software development and project management attributes, summarized below:

- *Requirements attributes:* store requirements meta-information, with the main goal of supporting traceability and maintainability of a large pool of requirements [6]. Hence, each requirement is stored in the repository with some attributes attached to it.
- *Project attributes:* represent the collection of descriptive characteristics and parameters of a project and help to define key information about the project and can communicate the project status to stakeholders [19], e.g., project size, requirement volatility, time and cost constraints.
- *Product attributes:* are the characteristics that define a particular product and will affect a consumer's purchase decision. These attributes include both tangible (e.g., size, colour, quantity, etc.) and intangible (e.g., price, quality, reliability, etc.) attributes [3].
- *Decision attributes:* represent the decisions related to the selection of the requirements. The storage of such attributes is necessary to examine and improve the release planning process. Examples of decision attributes include decision-rationale, inter-dependencies, and requirements triage criteria [10].
- *Business attributes:* capture the business needs of an organization is implementing in projects. Examples of business attributes include cost production and maintenance [19].
- *Requirement process attributes* characterize the requirement process used by a software company. For example, the duration of the process, the type of the process (e.g., waterfall or agile requirements process), the number and nature of the process steps (e.g., requirements elicitation, validation), the nature of interaction with potential stakeholders and customers, and the methods used to identify, analyze, and document requirements (e.g., brainstorming). Some of these attributes could have been captured as requirements attributes.

3 Research Design

This paper investigates the following research question:

RQ1: What are the requirements engineering attributes published in the literature? *Motivation:* The motivation behind RQ1 is to obtain a summary of publication trends regarding requirements attributes.

RQ2: What attributes are used/documented in two large software-intensive companies operating in a global market? *Motivation:* The reason is to know what requirements attributes are used by the requirement engineers of software companies.

3.1 Research Methodology

We used a case study research methodology for conducting the two case studies [18] and a snowballing method for finding the relevant literature, following the guidelines presented by Wohlin [23]. We conducted a database search to find the start set of the papers, in Google scholar and Scopus using the following terms ("requirements engineering" OR "requirements specification" OR "market-driven requirements engineering") AND ("requirements attributes"). We identified 9 papers formed the start set, denoted by P1 [17], P2 [11], P3 [21], P4 [7], P5 [15], P6 [12], P7 [14], P8 [8] and P9 [20].

3.2 Iterations

Table 1 presents the summary of the iterations and the papers identified in each iteration. We have performed 7 iterations of snowballing, finding an additional 9 papers, denoted as P10 to P18. In each iterations we analyzed citations and references.

Iteration	References analyzed	Citations analyzed	New papers
1	201	563	P10-P4Cit10 [5], P11-P4Cit70 [9], P12-P5Cit30 [4]
2	193	843	P13-P9Cit29 [6], P14-P10Cit21 [10]
3	123	79	P15-P13Ref14 [2]
4	15	197	P16-P15Ref4 [1]
5	17	227	P17-P16Cit9 [16]
6	297	211	P18-P17Cit129 [13]
7	63	644	

Table 1: The number of references and citations screened in each snowballing iteration and the identified papers.

4 Case Studies

We conducted two case studies at two large companies developing software-intensive products and services.

Company A: develops a software-intensive product for the open market with about 1400 employees. The product combines hardware and software, but the software is of the main value and the source of competitive advantage. Hardware development projects typically run over 12-18 months and include around 400-500 individuals, while software features are developed in smaller sub-projects consisting of around 3-15 software developers and architects over a period of 2-8 weeks. We have been granted access to the requirements database, which contains the history of managing features since 2010. We have extracted all the attributes and associated values from the database.

We have identified 122 attributes in the database and over 10000 features that were handled during the analysis time, 57 had values for less than 10 percent of all features, and thus we excluded these attributes, considering them obsolete. Out of the remaining 65 attributes, 6 were describing various states (see attribute 26 in Table 3), and another 6 were recording the dates when these states last changed (see attribute 22 in Table 3), so we clustered all states into one attribute and all dates into one date attribute. The remaining 57 attributes were analyzed (and are presented in the *Supplementary Material* [22]) and classified into the following categories:

- Intrinsic - build-in characteristic of requirement. Most are present when a requirement is created but are also clarified during the requirements engineering process.
- Value - attributes describing what value a requirement offers to end customers and to the internal business.
- Traces between requirements and traces to other artifacts.
- Stakeholders/Connections/Communication - these attributes describe what roles/organizations get involved in the work on a requirement.
- States and changes - these represent in what state a requirement is like entered, analyzed, implemented, released, rejected, accepted, under investigation, and changes to that requirement.

Company B: develops software-intensive products and services. The company has over 100000 employees and develop solutions within the Telecom business. We have extracted requirements attributes from a requirements database that contains general product requirements for 2 software-intensive products. The database contained 243 requirements and 31 attributes. Out of them, we removed 5 attributes that did not contain any data: 1) attachments, 2) child requirements, 3) issue links, 4) comments, and 5) resolution. The remaining 26 attributes were analyzed and added to the common set presented in Section 6.

Semantically similar attributes were clustered together, resulting in 28 attributes only from the case studies, see Tables 2, 3, 5, 6. We identified only 4 attributes that were unique to the case study and we could not find similar

attributes in the literature. These attributes were deployment target (what hardware a software feature is deployed to), the last person who changed a feature, open source contribution strategy (if a feature is contributed to an open source community), and the name of a sub-contractor delivering the requirement.

5 Results of the literature review and the case study (RQ1 and RQ2)

Tables including the attributes associated with 1) stakeholders, roles, and organizations involved in managing and working with requirements, 2) changes and the status of requirements, 3) traces between requirements and traces to other artifacts, and 4) the value of a requirement and other business or market aspects, can be found in the *Supplementary Material* [22]. This section discusses the attributes that we identified both in the case study and in the literature review (25 attributes), which correspond to 40% of all attributes. For each attribute, we judge if it can be filled in automatically or manually and if it covers the intrinsic aspects, the communication, or the decision.

We identified 7 attributes related to stakeholders, roles, and organizations involved in working with requirements, but only 5 were found both in the literature review and the case studies (only two in case study B), see Table 2. What is noticeable here is the distinction between the originator of a requirement (a person who wrote a requirement), the owner of a requirement (a person who often sponsors the development of a requirement), and stakeholders. We believe that this distinction is important for proper handling requirements decisions. We observe here that attributes support requirements communication by recording the roles related to handling requirements. These attributes can be used to create notifications for changes or other actions to the relevant roles and stakeholders.

	Attribute Name	Description	**M**any/ **A**uto[1]	**I**ntrinsic/ **D**ecision/ **C**ommunication[2]	Refs
13	Originator / Author	P3: Person responsible for entering the requirement into the database. P5: Who issued it? P8: The person who suggested the requirement P10: Submitter - who suggests the requirement CS1: Creator CS1: Submitter CS2: The person reporting the issue	A	C	[21,15] [8,5]

	Attribute Name	Description	**M**any/ **A**uto[1]	**I**ntrinsic/ **D**ecision/ **C**ommu-nication[2]	Refs
15	Owner	P3:The person that maintains the requirement and reports the status of it P4: Requirements owner: a person that is responsible for the follow-up P8: The person who is responsible for that requirement CS1: Feature owner - owns the budget for implementing the feature P16: The person who is responsible CS1: Requirements Scope owner - a person responsible for decision-making P3: Responsible for status and delivery P4: Requirements Manager - a Product Manager responsible for the specification and work-up of the requirement P7: Ownership: A person ensuring that the work is finished CS1: Leading Feature Analysis Team CS1: Feature lead - person or team responsible for leading the discussion, decision, implementation, delivery of this feature CS1: Technical area team responsible CS1: Analysing architect CS2: Requirement Owner CS2: Assignee	M	C	[21,7] [8,5,14]
16	Stake-holders	P3: Stakeholders: List of key stakeholders that have a stake in the implementation of the requirement and who will be involved in the review and approval of the requirement as well as any changes to the requirement. P8: Who needs the functionality in their work (intended users) P8: Which scanner groups have an interest in the requirement P6: Description of the stakeholders P7: Any user who had an account in the Jazz project repository. CS1: Stakeholder	A	C	[21,8,14]
42	Business Unit	P3: A business unit that produces the product CS1: GSM Review site CS1: Development site / App Dev site	M	C	[21,15]
43	Business Line	P3: A specific brand or line of product within a given business unit. P8: Who needs the functionality CS1: Platform CS1: Requirement Stream (product line) CS1: Proposed products that a requirement applies to CS1: Requested products for a given requirement CS1: Lead product	M	C	[21,8]

Table 2: The attributes associated with stakeholders, roles, and organizations involved in managing and working with requirements.

We have identified 12 attributes associated with handling changes to requirements. Out of them, only 4 were identified in both the literature review and case studies (3 in case study B and 4 in case study B), see Table 3. Of the common attributes, we have 2 that track the entry and last change of a requirement and two that track the requirements status and the implementation status. Our con-

[1] An attribute have to be filled **M**anually or could be filled **A**utomatically.

[2] A category of requirement attribute can be: **I**ntrinsic, **D**ecision or **C**ommunication.

clusion here is that the evolution of requirements should also be tracked beyond requirements stats and include verification and delivery.

	Attribute Name	Description	**M**an/ **A**uto	**I**ntr / **D**ecision/ **C**omm	Refs
14	Date Requirement Entered	P3: Date of entering the requirement P4: Creation date P5: Submission date P7: User story creation date CS1: Created Date CS2: Created: created date and time	A	C	[21,7] [15,14]
22	Date of Last Change	P3: Date of Last Change P4: When the last change was performed CS1: Last changed date CS1: Last consolidation state change date CS1: Last description change date CS1: Last stakeholder state change date CS1: Last scope owner state change date CS1: Last architecture state change date CS1: Last development state change date CS2: Revisions a list of revisions (identified by id, timestamp, change set, information) that was made to this requirement, including previous versions CS2: Updated: last update date time CS2: Change date: date only, when the FP was changed CS2: Revision: revision number (e.g. A,B).	A	C	[21,7]
26	Status	P3: Status of the requirement (draft, in development, ready for review, in review, approved) P4: Status of the requirement P5: Created / Approved / Specified / Discarded / Planned / Developed / Verified / Released P13: Requirements state (new, dismissed, specified, planned for release, released) P9: Working state of a requirement (initial, defined, agreed upon, released) CS1: Stakeholder state CS1: Scope owner (product owner) state CS1: Consolidated state (general state of a requirement) CS2: Status [backlog, selected for development] CS2: Requirement status [uncovered, ok, NOK, NOTRUN, UNKNOWN]	A	C	[21,7] [15,6,20]
27	Status of implementation	P3: Implementation status: Indicator of the status of the implementation or realization of the requirement CS1: Development state CS1: Configuration state	M	C	[21]

Table 3: The attributes associated with changes, and the status of requirements.

Next, we analyzed attributes responsible for helping trace requirements to other artifacts in the software development process. We found 4 attributes but only 2 in both selected papers and the case studies (only one for case study B), see Table 4. What is surprising is that the case companies do not maintain links to test cases, while the selected papers mentioned an attribute that links requirements and test cases. The selected papers also offer many attributes for links between requirements, while the case studies offer only 2 attributes describing the relations between requirements.

Next, we identified 7 attributes that were associated with the value of a requirement or other business-related aspects. Out of 7 attributes, only 2 were

used in case study A and only one in case study B, both were mentioned in the selected papers, see Table 5. These are internal business value (estimate) and the market segment to which a particular requirement is planned to be delivered. We believe that the market segment is used by the case company A as a proxy of the end customer value.

	Attribute Name	Description	**M**an/ **A**uto	**I**ntrinsic/ **D**ecision/ **C**ommunication	References
28	Trace to Interface Definition/ Architecture	P3: Trace to Interface Definition Document. P5: Links to design documents P6: Influence - Activities of the software process affected by the quality attribute CS1: Link to architecture rational description or rationale	M	C	[21,15] [12]
29	Trace to Peer Requirements Parent Requirements Dependencies	P3: Trace to Peer: Links to requirements on the same abstraction level. P3: Parent Requirements P6: Decomposition - link to parent requirement P6: Where - List of the actors influenced by the quality attribute and also a list of models (e.g. use cases and sequence diagrams) requiring the quality attribute P6: Contribution - positive or negative on product's quality attributes. P4 : Relation/dependency - one or several links to other requirements on the same abstraction level P5: Link to sales contract enforcing requirement P5: Links to Use Case, Textual Specification P5: Parent-of / Child-of – links to other req's P7: Links between user stories and defects P13: Dependency and type of dependency P14: IVALUEpendencies between requirements P15: Dependencies (and, or, require, temporal, value, cost) P17: Interaction between requirements - Iteration can be positive, negative or unspecificified P12: Does the requirement increase/decrease the value of other selected requirements? P12: Technical dependencies - functional and temporal dependencies between the requirements P11: Product level requirement - Representation of requirements that are used at product level P11: Feature level requirement - Representation of requirements that are used at Feature level P11: Function level requirement - Representation of requirements that are used at Function level			
29	Trace to Peer Requirements Parent Requirements Dependencies	P11: Component level requirement - Representation of requirements that are used at component level CS1: Feature Information Link - link to more information about the feature CS1: Outgoing links to other features CS1: IDs of other features associated with this feature CS2: Link to MR CS2: Origin: [front-runner, group commitment, market access]	M	C	[21,11,7,6] [10,2,16,4] [9,12,14,15]

Table 4: The attributes associated with traces between requirements and traces to other artifacts.

	Attribute Name	Description	**M**an/ **A**uto	**I**ntrinsic/ **D**ecision/ **C**ommunication	References
41	Market Segment	P3: Market segment for the product P5: Market segment for which requirement is important P5: Functional domain P8: The clinical areas for this requirement CS1: Target Market CS2: Impacted product/s: A list of impacted products for this requirement.	M	C	[21,15,8]
48	Internal Business Value	P2: Business Novelty - how novel is the requirement to existing business processes P8: Value from the product management perspective P12: ROI is expressed as a relationship between gain and cost, where: Gain is value presented by a requirement in terms of potential sales or cost savings. P12: Investment payback time, i, e. when and how fast the brake-even of the investment can be obtained? P12: Level of uncertainty in the value offering of a requirement P12: Can the requirement be delivered by the targeted market window? CS1: Justification: Value for the company	M	C	[11,8,13]

Table 5: The attributes associated with the value of a requirement and other business or market aspects.

Finally, we identified 26 intrinsic and other attributes, where 11 were mentioned in either of the case studies and the selected papers, see Table 6 below. Apart from the id, description, and name, we have risk, priority, and release date. One can argue that risk and priority help decide about requirements as well as the category of a requirement.

	Attribute Name	Description	**M**anually/ **A**utomatically	**I**ntrinsic/ **D**ecision/ **C**ommunication	References
1	Rationale	P3: Rationale: the reason for the requirement P13: The rationale/benefit of the requirement P8: The reason behind the requirement P10: The reason behind the requirement P4: Why the requirement is specified and its benefit CS1: Justification CS1: One slide presentation of a requirement (link)	M	I	[21,10] [8,6]
5	Condition of Use	P3: Operational conditions in which the requirement applies CS1: Customization Policy for a feature	M	I	[21]
11	Unique Identifier	P3: Can be a mixture of characters and numbers P19 Unique identifier of a requirement CS1: ID CS1: Unique link to the feature CS2: Unique ID - system name + numbers CS2: Focal point ID: a 14 digits numerical id CS2: Opportunity ID: 6 digits numerical ID	A	I	[21,11] [15,9] [6,16]

	Attribute Name	Description	**M**anually/ **A**utomatically	**I**ntrinsic/ **D**ecision/ **C**ommunication	References
12	Unique Name	P3: Unique Name: This is a unique name or title for the requirement. P4: The title reflecting the contents of the requirement P5: Label: descriptive name P8: Requirement title P11: Requirement title P13: Title for the requirement P17: Name CS1: Title CS2: A short title (couple of words)	M	C	[21,7] [15,8] [5,6,16]
30	Priority	P3: Requirements importance for the stakeholders P5: Importance category (1,2,3) P6: Priority - the importance of the quality attribute for the stakeholders (min, low, high, max) P6: Obligation - optional or mandatory P7: Priority P13: The priority of the requirements (1 to 5) P14: The selection and rejection criteria that drive the requirements triage P12: The cost of not implementing the requirement? CS1: Product Portfolio Priority - how important is a given requirement for planning a portfolio of products CS1: Technology priority (in a range from 0 to 1) CS2: Priority CS2: FP Priority: [0,1,2,3]	M	D	[21,15] [6,10] [4,12] [14]
32	Risk	P3: A risk value for each requirement P4: Restrictions/Risks The restrictions and/or risks with the requirement P12: Does a requirement introduce disturbance in system architecture or hampers system evolution plans? P1: Testing Risk: It reflects the impact of insufficient testing of this requirement CS1: Risk of changes in a development environment when implementing this feature	M	D	[21,7] [4,17]
34	Additional Comments	P3: Generic comment field that can be used to document possible issues with the requirement, such as any conflicts, status of negotiations, or actions. P11: Additional information that can be attached to the requirements CS1: Minutes from the meetings short summaries of what happened with this requirement on the meetings CS1: Comments from the software team	M	C	[21,9]
35	Type/ Category	P3: Type/Category of requirements include: a. functional/performance, b. operational: interactions with external systems, c. quality attributes, d. physical characteristics, e. standards and regulations, f. constraint—imposed on the project, g. business rule — imposed by the business unit, h. business requirement CS1: Feature type (new functionality, legacy systems) CS1: Requirement classification (e.g., hardware vs. software feature, quality improvement, development environment production, development environment testing, thermal improvement, power consumption) CS2: Issue Type: [ex. Requirement,Uber-initative,Test Execution, Bug] CS2: Labels: the name of the branch where the requirement is located (e.g., General Product Requirements) CS2: FP General Product Requirement Categories CS2: Path - the requirement path in the tree (as the requirements arranged in a taxonomy) CS2: Product Info, e.g. Product Quality, Security	M	I	[21]

	Attribute Name	Description	**M**anually/ **A**utomatically	**I**ntrinsic/ **D**ecision/ **C**ommunication	References
40	Application (Name / version)	P3: Application: The application of a specific product within a product line CS1: Which application within a product a feature belongs to	M	C	[21,11]
45	Description	P4: Not be more than about five sentences P5: Short textual description P13: Free description of the requirement P6: Quality requirements description CS1: Description CS2: Description A short description of the issue, written as natural language requirement (the product shall support.....) CS2: Requirement Details CS2: Rationale - a short description (one paragraph) explaining the rationale. The paragraph is structured into: 1) Short intro, 2) Motivation, 3)Applicability, 4) Quality attributes, 5) References	M	I	[7,15] [6,12]
51	Release due date	P9: The date that the requirement should be implemented and delivered P4: Customer's deadline for delivering a requirement P5: Release for which it is planned for P5: Official release name CS1: Estimation when the team delivers the feature with 90%/50% of certainty CS1: Execution end date (90% certainty)	M	C	[7,15] [20]

Table 6: The attributes mentioned in the case study and the selected papers.

Limitations and Threats to Validity: We have identified selection bias as one of the influencing threats to the internal validity of our literature study. To mitigate this threat, we constructed the start set comprising different publications from different authors. We also took certain precautions while selecting the papers, such as cross-checking the selected papers among the authors, and the same was persistently reassessed by the first author to avoid any bias. Still, the risk of missing papers remains. However, the intrinsic nature of snowballing minimizes this risk. To improve the reliability of our study, we followed the procedure proposed by Wohlin [23]. Every decision in this process is documented simultaneously to ensure reliability. The main limitation of our case study is the feature abstraction level used by the case companies. A higher abstraction level means some attributes and some details are not tracked, and therefore our analysis may be incomplete. Also, it is hard to generalize from two case studies, and we are aware that our results need to be complemented by other cases.

6 Conclusions

Understanding how to manage requirements and their attributes is an important step in making sure that software development organizations run smoothly and efficiently. Attributes also help comprehension of requirements by various stakeholders and enable them to be boundary objects in software development. This paper explores what requirements attributes are reported in the research liter-

ature and what attributes are used by software-intensive companies developing products for a global market.

Among the 53 semantically similar attributes that we identified from two studies and 29 attributes that we identified from the literature, we discovered 25 common attributes associated with stakeholders, roles, and organizations involved in managing and working with requirements support requirements communication and are mostly manually inserted, leaving the potential for automation.

Both case studies and literature track traceability between requirements and software design, while the literature also offers attributes that trace requirements with testing and many more attributes to track traces between the requirements. The value of a requirement is captured only from the internal business perspective, while the research papers also track the customer value of a requirement. Finally, we identified 11 intrinsic attributes that are both descriptive (id, name, rationale, comments, description) and supportive in decision-making (risk, priority, type, release date).

In the next steps, we plan to analyze more requirements databases from other companies operating in other contexts and markets. We also plan to work on creating a meta-model for requirements attributes that supports populating requirements attributes at various stages of the requirements process, e.g. integrate attributes with value stream mapping and requirements flow processes.

Acknowledgements Lech Madeyski worked on the paper during his research internship at BTH at Prof. Mattsson's invitation.

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