Using Requirements Metrics to Guide Project Management and Assess Process Improvements

Using Requirements Metrics
Session #1900

Topic Category: “Measuring what you’ve accomplished”

It is well known that fixing requirements errors which escape into later phases of the software development phases can be expensive and time-consuming. Measuring requirement processes and quality early can help project managers and requirements analysts better understand requirements-related risks and address the potential impact to the project. This presentation describes our experiences and challenges in defining and applying Requirements Engineering (RE) measurements in four categories: quantity metrics, quality metrics, volatility metrics, and process metrics.
Using Requirements Metrics
Goals of this Session: Learner Outcomes

1. Learn how we applied **Goal – Question – Metric** to define requirements metrics in four categories;
2. Share in lessons learned from applying basic requirements engineering metrics to assess the impact of changes in requirements processes;
3. Understand how measuring requirements can help in effectively predicting problems and managing projects.

Using Requirements Metrics
Topics

- Presentation Topics:
  - Requirements Engineering (RE) overview
  - RE in business and research at ABB
  - Applying Goal-Question-Metric (GQM)
  - GQM results / selection of subset of RE metrics
  - RE Metrics Guide contents
  - Lessons learned in using RE metrics
  - Next steps at ABB
- Q&A / Contact Information
- References
Using Requirements Metrics – Overview

Requirements in Development Lifecycle


Using Requirements Metrics – Overview

Requirements Effort During Lifecycle

Figure from Wiegers 2003, Fig. 17-2; see References for full citation.
Using Requirements Metrics

ABB Overview

“ABB (www.abb.com) is a leader in power and automation technologies that enable utility and industry customers to improve their performance while lowering environmental impact.”

- Headquarters: Zurich, Switzerland
- About 120,000 employees in around 100 countries
  - 10,000+ in USA (ABB Inc.)
- 2008 Orders: $38.3 billion; 2008 Revenues: $34.9 billion
  - Over $5 billion from software systems
  - Strong and growing service business
- Listed on Stockholm, Swiss, and New York exchanges; traded on SWX Europe

Motivation/assumption:

Higher RE artifact quality and better RE practices will improve results (both delivered product quality and development project efficiency)

Objective: Improve requirements engineering proficiency in software development throughout ABB

- Raise the quality of our requirements
- Increase effectiveness of our RE processes

Result measures: Reduced defects in test and in the field, and lower cost of rework or additional work, attributable to poor requirements (wrong, incomplete, extra, missing).

- Test and field defects (results) are lagging indicators.
- In addition to in-process defect data, are there other early indicators for artifacts or practices which we can use to guide quick corrective actions? → RESEARCH!
Using Requirements Metrics
ABB Research Perspective: What To Measure? (and what not to measure?)

Some RE Research Questions:

- How can requirements measures (e.g. volatility, quality) be usefully applied on agile/iterative and conventional development projects?
- When can high volatility be good, and when might it be bad? Which changes should ‘count’ when measuring volatility?
- What are the earliest points at which we can detect whether our requirements are good enough, and if corrective action is needed?
- Which measures of RE work and work products are most meaningful for different RE activities in product development?
- Which representations of functional and non-functional requirements are most effective at different phases of software product development?
- Can requirements measures be usefully applied in defining leading indicators to guide decision-making during product development?
- How can RE measures guide selecting the requirements practices and tactics that will offer quickest benefit and highest ROI for software development projects and organizations?

Goal: Find EARLY measures which are good PREDICTORS in practice

Using Requirements Metrics
Requirements Engineering at ABB

Measure requirements Practices, Artifacts, and Results to analyze and improve quality and efficiency:

- Projects
  Use requirements metrics as predictors, to guide early corrective action

- Processes
  Select, pilot, and measure the impact of improved requirements engineering methods
  - Before- and after- measurement when new RE methods are piloted and deployed
  - Inspect and adapt!

Two perspectives for both uses: Business and Research

Requirements Engineering Metrics Guide
Using Requirements Metrics
Goal-Question-Metric (GQM) Overview

Well-respected, widely-used software engineering method for defining and implementing metrics

GQM defines a measurement model on three levels:
- Conceptual level (Goal)
- Operational level (Questions)
- Quantitative level (Metrics)

Pattern / Example:

<table>
<thead>
<tr>
<th>Goal</th>
<th>Purpose</th>
<th>Issue</th>
<th>Object (process)</th>
<th>Viewpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve</td>
<td>the timeliness of change request processing</td>
<td>from the project manager’s viewpoint</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question</th>
<th>Metrics</th>
</tr>
</thead>
</table>
| What is the current change request processing speed? | • Average delta time from submission of a new change request to its disposition  
• Standard deviation  
• % cases outside of the upper control limit |

<table>
<thead>
<tr>
<th>Question</th>
<th>Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the performance of the processing improving?</td>
<td>Delta time in hours from submission of a new change request to its disposition, tracked over time</td>
</tr>
</tbody>
</table>

Using Requirements Metrics
Goal, Questions, Metrics – RE Practices (Excerpt)

Business perspective is relevant to Practices as well.
Artifacts are also important to Research.
Using Requirements Metrics
Goal, Questions, Metrics – RE Artifacts (Excerpt)

<table>
<thead>
<tr>
<th>Goal : Purpose</th>
<th>Evaluate the quality of requirements artifacts (documents + data in repository) from BUSINESS perspective (project manager)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issue</td>
<td></td>
</tr>
<tr>
<td>Object</td>
<td></td>
</tr>
<tr>
<td>Viewpoint</td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>How good are the requirements?</td>
</tr>
</tbody>
</table>
| Metrics        | • product requirements-related defect density, by phase  
|                | • percentage of requirements that are not prioritized  
|                | • percentage of requirements that do not have a source  
|                | • percentage of requirements that are ambiguous  
|                | …                                                                                                                |

| Question       | How well are the individual non-functional requirements defined?                                                 |
| Metrics        | • percentage of NFRs that are complete (including having quantifiable and verifiable measures)                   |

| Question       | Are the non-functional requirements complete enough to warrant starting architectural analysis?                   |
| Metric         | • percentage of the relevant quality concerns of the system which are covered by the defined NFRs  
|               | • … ?                                                                                                           |

Using Requirements Metrics
GQM Brainstorming Session Results

57 proposed metrics in four categories

- Quantity, 6
- Quality, 16
- Process, 31
- Volatility, 4
Using Requirements Metrics
RE Metrics Guide: Selecting by <Importance, Effort>

- Discussed and clearly defined what H, M, L mean for effort, and for importance (Business + Research)
- Ran workshop to assign <importance, effort> to all candidate metrics, and select a manageable subset
  - Chose all 17 metrics ranked <H, L>
  - Chose 5 of 6 metrics ranked <H, M>:
    - Excluded metric for the RE experience level of the person responsible for requirements
  - Chose 2 of 9 metrics ranked <H, H>:
    - Number of defects due to requirements errors
    - Percentage of incorrect requirements

Total: 24 metrics included in “RE Metrics Guide”, v1.0
(business units select metrics from it for their needs)

Using Requirements Metrics
RE Metrics Guide: Classifications and Structure

- Level: Beginning, Advanced
- Target: Minimize, Maximize, N/A
- Objective: Adherence, Improvement, Other
- Effort/Cost: High, Medium, Low

Each Guide entry also describes:
- data source(s),
- update frequency,
- motivation,
- how to calculate,
- possible causes of bad data,
- examples,
- how to analyze the metric.
### RE-M1 Total Number of Requirements By Type

<table>
<thead>
<tr>
<th>Level</th>
<th>Target</th>
<th>Objective</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Other-quantify the requirements or normalizes other metrics</td>
<td>Low</td>
</tr>
</tbody>
</table>

**Data Source(s):**
- Requirements Management System
- Market Requirements Specifications (MRS) document
- Product Requirements Specifications (PRS) document

**Update Frequency:**
- Monthly starting at Gate 0 until Gate 5 and at each Gate, then periodically (e.g., quarterly) for the reasonable supported life of the software release depending on the business need

### Using Requirements Metrics

#### RE Metrics Guide: Summary – Excerpt

<table>
<thead>
<tr>
<th>Group</th>
<th>#</th>
<th>Title</th>
<th>Level</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity</td>
<td>RE-M1</td>
<td>Total number of requirements</td>
<td>B</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>RE-M2</td>
<td>Number of functional requirements</td>
<td>B</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>RE-M3</td>
<td>Number of non-functional requirements</td>
<td>B</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>RE-M4</td>
<td>Number of constraints</td>
<td>B</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>RE-M5</td>
<td>Number of requirements change requests</td>
<td>B</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>RE-M6</td>
<td>Percentage of unprioritized requirements</td>
<td>A</td>
<td>H</td>
</tr>
<tr>
<td></td>
<td>RE-M7</td>
<td>Percentage of requirements without a source</td>
<td>B</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>RE-M8</td>
<td>Percentage of ambiguous requirements</td>
<td>B</td>
<td>M</td>
</tr>
<tr>
<td>Volatility</td>
<td>RE-M9</td>
<td>Ratio of requirements defects vs. number of requirements at GS</td>
<td>A</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>RE-M10</td>
<td>Ratio of requirements change requests received vs. total number of requirements</td>
<td>B</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>RE-M11</td>
<td>Ratio of requirements change requests accepted vs. total number of requirements</td>
<td>B</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>RE-M12</td>
<td>Percentage of requirements that are changed in the entire software development process (including new and deleted requirements)</td>
<td>B</td>
<td>L</td>
</tr>
<tr>
<td>Process</td>
<td>RE-M13</td>
<td>Percentage of projects that have clear assigned responsibility for each type of requirement</td>
<td>B</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>RE-M14</td>
<td>Average time interval between the receipt of a requirement change request and completion of a decision is made regarding this request</td>
<td>A</td>
<td>L</td>
</tr>
</tbody>
</table>
Using Requirements Metrics
RE Metrics Guide: Initial Use – Artifact Quality Study

Retrospective analysis to collect 14 base measures for 10 quality characteristics, using 13 specifications
• from 11 projects in three business areas
• across two levels of decomposition (MRS, PRS)
with varying requirements representation formats.

M# | Title
---|---
M16 | Percentage of unprioritized requirements
M17 | Percentage of requirements without a source
M18 | Percentage of ambiguous requirements

Average analysis time for 1152 requirements: 3.06 minutes

Three critical lessons emerged from this study.

1. **Domain expertise needed**
   Some requirement quality metrics may require domain knowledge to assess/measure (higher collection effort)

2. **Project/document selection critical**
   Comparing ‘apples and oranges’:
   • Market Requirements vs. Product Requirements
   • ‘Functional’, ‘non-functional’, both?
   • Individual requirement statements vs. sets of requirements
   Target values may vary for each, and by lifecycle phase

3. **Comprehensive view needed**
   • Quantity metrics needed to normalize other metrics
   • Practice metrics needed to understand how to address issues with quality of requirements artifacts
   • ‘Book’ definitions of requirement quality characteristics inadequate → spin-off research survey and task

Illustration adapted from Westfall/Wiegers 2003, Fig. 1-1; see References

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Using Requirements Metrics
Lessons Learned: Defining Requirements Quality

Identified, then harmonized, requirements quality metric definitions from a comprehensive state-of-the-art survey:

- **Names**
  - Address duplication (e.g. **Verifiability** and **Testability**)
  - Establish uniform ‘positive phrasing’ and ‘part of speech’

- **Definitions**
  - Resolve overlapping/conflicting meanings from multiple sources
  - Create three artifact ‘tiers’ for requirements qualities
  - Assign each characteristic to one or more relevant tiers

- **Calculations**
  - Consistent ‘higher-is-better’ scoring and interpretation
  - Numerically valid ratio-scale formulae yielding $[0,1]$ values, wherever suitable

- **Aggregation**
  - Proposed composite Requirements Quality Index for each tier

See References slide for details on the harmonized metric definitions and quality indices (ISSRE).

Using Requirements Metrics
Measuring Three Tiers of Requirements Quality

Requirements quality characteristics are now classified and defined by their applicability to one or more tiers:

<table>
<thead>
<tr>
<th>Tier</th>
<th>Example Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual Requirements Statement</td>
<td>Design-Independent, Precise, Correct</td>
</tr>
<tr>
<td>Set of Requirements</td>
<td>Modifiable, Internally Consistent, Complete</td>
</tr>
<tr>
<td>Collection of Requirements Documents</td>
<td>Traceable, Externally Consistent, Cross-referenced</td>
</tr>
</tbody>
</table>

Each tier has a proposed Requirements Quality Index, based upon importance-weighted aggregation of the component measures in its tier.
Using Requirements Metrics
Next Steps at ABB (Work in Progress)

- **Measuring Business Processes and Artifacts**
  - Beginning to pilot RE metrics with business units for their operational purposes (not research purposes)
    - Different viewpoint for GQM?
    - Different priorities \(\rightarrow\) importance?
    - Different set of metrics?

- **Requirements Metrics with Scrum**
  - Piloting RE tool support with metrics for Scrum projects

- **Validation of New RE Metrics**
  - Evaluating usefulness of the proposed Requirements Quality Indices for each tier

- **More Research Data**
  - Expansion of data gathering scope for volatility, process, quantity, and quality metrics is underway
    - Multiple development projects across several businesses

Using Requirements Metrics: SEPG NA 2010 Update
Lesson Learned: Measuring Volatility

Compared to our expectations, volatility:
- is more important to the business unit, and
- has more possible ways to count ‘changes’, and
- is harder to count/measure accurately in practice
  \(\rightarrow\) but: accuracy may not be needed

Result:
- Move volatility up to ‘phase 1 of metrics’
- Incrementally refine the operational definition
  - Start with ‘the simplest thing that could possibly work’
  - Inspect and adapt:
    - Is it useful enough?
Using Requirements Metrics

Q&A / Contact Information

Presenter/Author:  Karen Smiley
Co-Authors:  Qingfeng He, Prateeti Mohapatra

ABB Corporate Research
Industrial Software Systems program
940 Main Campus Drive
Raleigh, NC 27606  USA

QUESTIONS WELCOME!

Email presenter at:<first name>.<last name> @ us.abb.com

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Using Requirements Metrics

References


Using Requirements Metrics: Backup Slide
Defining Importance and Effort

Collection Effort:

- **High**: Data is not readily available, and significant manual effort is required; or many people have to be involved in the data collection process (e.g., interviewed).
- **Medium**: Obtaining data requires moderate manual effort or involves a few people’s participation.
- **Low**: Data is readily available and can be obtained by simple counting, or through a questionnaire study, i.e. obtaining data requires little or no manual effort.

Importance:

- High / Medium / Low

- **Key question: importance to whom?**
  - CRC – for research purposes
  - BU – for operational purposes
## 2.1 Requirements Quality Characteristics and Metrics

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achievable</td>
<td>5</td>
</tr>
<tr>
<td>At Right Level of Abstraction/Detail</td>
<td>7</td>
</tr>
<tr>
<td>Annotated or Ranked by Version or Stability</td>
<td>9</td>
</tr>
<tr>
<td>Complete</td>
<td>13</td>
</tr>
<tr>
<td>Concise</td>
<td>14</td>
</tr>
<tr>
<td>Contingent</td>
<td>15</td>
</tr>
<tr>
<td>Consistent</td>
<td>17</td>
</tr>
<tr>
<td>Cross-referenced</td>
<td>18</td>
</tr>
<tr>
<td>Design-Independent/Implementation-neutral/Unnecessary Constraints</td>
<td>20</td>
</tr>
<tr>
<td>Executable</td>
<td>20</td>
</tr>
<tr>
<td>Minimal</td>
<td>21</td>
</tr>
<tr>
<td>Maintainable</td>
<td>22</td>
</tr>
<tr>
<td>Necessary</td>
<td>23</td>
</tr>
<tr>
<td>Non-Redundant</td>
<td>24</td>
</tr>
<tr>
<td>Organized</td>
<td>25</td>
</tr>
<tr>
<td>Precise</td>
<td>26</td>
</tr>
<tr>
<td>Prioritized (Annotated or Ranked by Importance)</td>
<td>27</td>
</tr>
<tr>
<td>Reusable</td>
<td>28</td>
</tr>
<tr>
<td>Testable</td>
<td>29</td>
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<tr>
<td>Understandable</td>
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<td>Validated</td>
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<td>Verifiable</td>
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