

Karen Smiley, ABB Corporate Research / Industrial Software Systems, SEPG North America 2010, March 22-25, 2010

## Using Requirements Metrics to Guide Project Management and Assess Process Improvements

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### 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.

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## 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.



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## 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

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## Using Requirements Metrics – Overview Requirements in Development Lifecycle

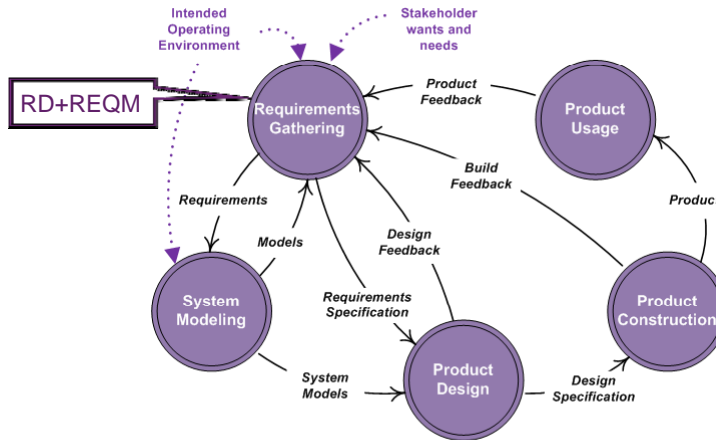


Diagram from "Mastering the Requirements Process", Robertson, 2<sup>nd</sup> Edition, 2006, p. 3

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## Using Requirements Metrics – Overview Requirements Effort During Lifecycle

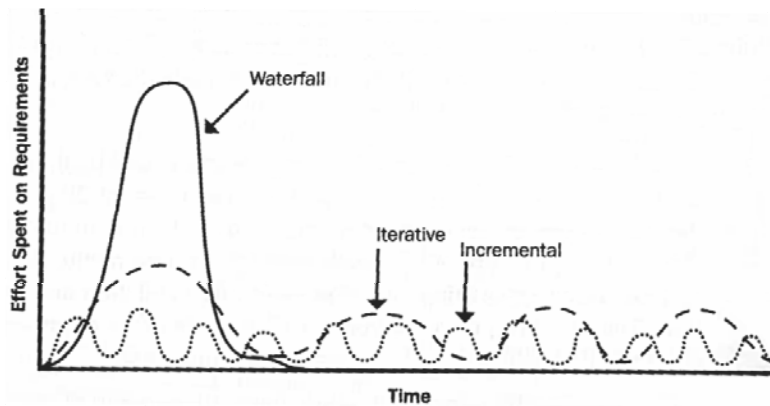
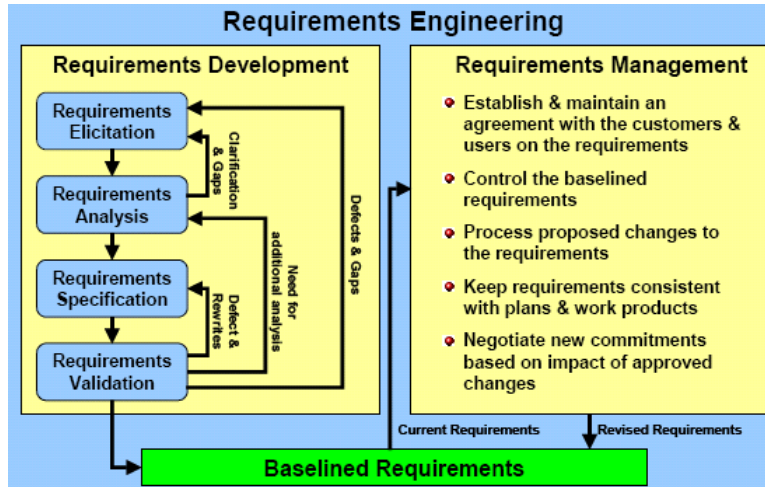


Figure from Wiegers 2003, Fig. 17-2; see [References](#) for full citation.

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# Using Requirements Metrics – Overview Requirements Processes and Practices

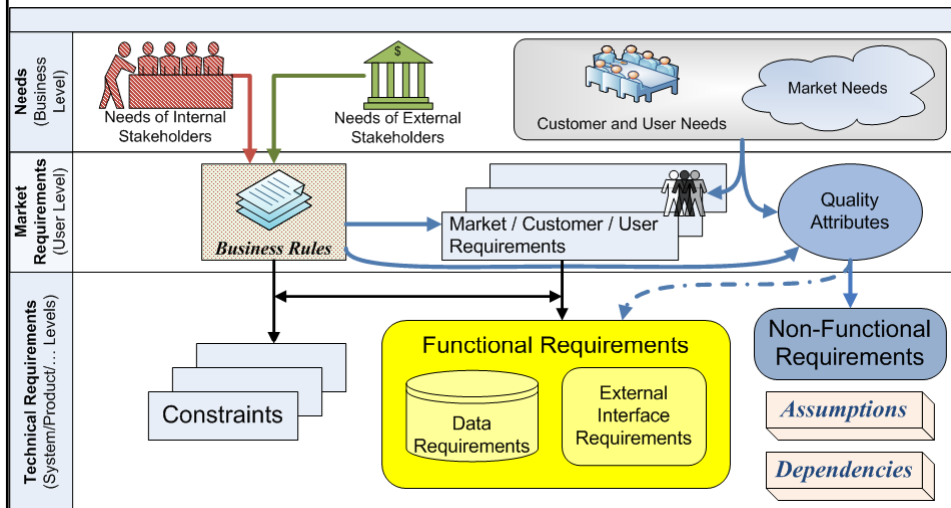


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Figure from Westfall 2005, based on Wiegers 2003; see References for full citation.



# Using Requirements Metrics – Overview Requirements Levels and Artifacts



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



## Using Requirements Metrics ABB Overview



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- 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



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## Using Requirements Metrics ABB Business Perspective: What To Measure?

### **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!*

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## 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?

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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**

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## Using Requirements Metrics Goal-Question-Metric (GQM) Overview

See References slide at the end for more information on GQM.

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:

<b>Goal</b>	<b>Purpose Issue Object (process) Viewpoint</b>	Improve the timeliness of change request processing from the project manager's viewpoint
<b>Question</b>		What is the current change request processing speed?
<b>Metrics</b>		<ul style="list-style-type: none"> <li>• Average delta time from submission of a new change request to its disposition</li> <li>• Standard deviation</li> <li>• % cases outside of the upper control limit</li> </ul>
<b>Question</b>		Is the performance of the processing improving?
<b>Metrics</b>		Delta time in hours from submission of a new change request to its disposition, tracked over time

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

Business perspective is relevant to Practices as well.

Artifacts are also important to Research.

<b>Goal:</b>	<b>Purpose Issue Object Viewpoint</b>	Baseline the current RE practices of ABB business units from <b>RESEARCH</b> perspective
<b>Question</b>		How often is there a person who has ownership for requirements?
<b>Metric</b>		% of projects that have the role of requirements engineer clearly assigned for each kind of requirements
<b>Question</b>		How well are requirements reviewed and validated before implementation starts?
<b>Metrics</b>		<ul style="list-style-type: none"> <li>• % of requirements that are reviewed and validated</li> <li>• Defect density in requirements reviews</li> <li>• Requirements-related defects found during implementation</li> </ul>
<b>Question</b>		<i>How well-defined are user stories when a sprint is planned and started?</i>
<b>Metrics</b>		<ul style="list-style-type: none"> <li>• % of user stories which are unambiguous</li> <li>• Degree of participation of Product Owner in Sprint Planning</li> </ul>

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## Using Requirements Metrics Goal, Questions, Metrics – RE Artifacts (Excerpt)

Research perspective is relevant to Artifacts as well.

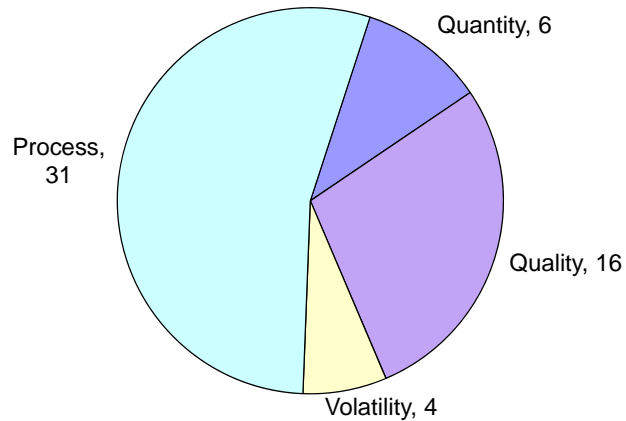
Practices are also important to the Business.

<b>Goal : Purpose Issue Object Viewpoint</b>	Evaluate the quality of requirements artifacts (documents + data in repository) from <b>BUSINESS</b> perspective (project manager)
<b>Question</b>	How good are the requirements?
<b>Metrics</b>	<ul style="list-style-type: none"> <li>• product requirements-related defect density, by phase</li> <li>• percentage of requirements that are not prioritized</li> <li>• percentage of requirements that do not have a source</li> <li>• percentage of requirements that are ambiguous</li> <li>• ...</li> </ul>
<b>Question</b>	How well are the individual non-functional requirements defined?
<b>Metrics</b>	<ul style="list-style-type: none"> <li>• percentage of NFRs that are complete (including having quantifiable and verifiable measures)</li> </ul>
<b>Question</b>	Are the non-functional requirements complete enough to warrant starting architectural analysis?
<b>Metric</b>	<ul style="list-style-type: none"> <li>• percentage of the relevant quality concerns of the system which are covered by the defined NFRs</li> <li>• ... ?</li> </ul>

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## Using Requirements Metrics GQM Brainstorming Session Results



57 proposed metrics in four categories

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## 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*)

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## 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.

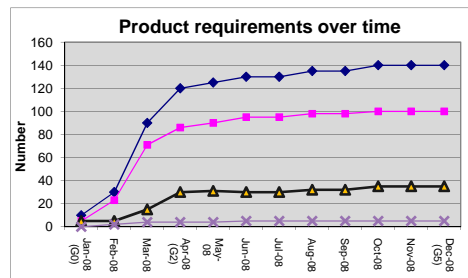
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## Using Requirements Metrics RE Metrics Guide: Detail – Example (partial)

### RE-M1 Total Number of Requirements By Type

<b>Level:</b> Beginning	<b>Target:</b> N/A
<b>Objective:</b> Other-quantify the requirements or normalize other metrics	<b>Cost:</b> Low
<b>Data Source(s):</b> Requirements Management System Market Requirements Specifications (MRS) document Product Requirements Specifications (PRS) document	
<b>Update Frequency:</b> 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	



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## Using Requirements Metrics RE Metrics Guide: Summary – Excerpt

Group	M#	Title	Lvl	Cost
Quantity Metrics (6 metrics)	RE-M1	Total number of requirements	B	L
	RE-M2	Number of functional requirements	B	L
	RE-M3	Number of non-functional requirements	B	L
	RE-M4	Number of constraints	B	L
	RE-M66	Number of requirements change requests received	B	L
	RE-M67	Number of defects due to requirements errors	A	H
Quality Metrics (9 metrics)	RE-M16	Percentage of unprioritized requirements	B	L
	RE-M17	Percentage of requirements without a source	B	L
	RE-M18	Percentage of ambiguous requirements	B	M
	...	...	...	...
RE-M27	Ratio of requirements defects vs. number of requirements	A	M	
Volatility Metrics (4 metrics)	RE-M28	Percentage of new requirements identified between G2-G5 vs. number of requirements at G5	B	L
	RE-M33	Ratio of number of requirements change requests received vs. total number of requirements	B	L
	RE-M34	Ratio of number of requirements change requests accepted vs. total number of requirements	B	L
	RE-M35	Percentage of requirements that are changed in the entire software development process (including new and deleted requirements)	B	L
Process Metrics (5 metrics)	...	...	...	...
	RE-M41	Percentage of projects that have clear assigned responsibility for each type of requirement	B	L
RE-M68	Average time interval between the receipt of a requirement change request and completion of a decision is made regarding this request	A	L	

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## 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.

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## Using Requirements Metrics Lessons Learned: Measuring RE Artifact Quality

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

### 1. Domain expertise needed

Some requirement quality metrics may require domain knowledge to assess/measure (*higher collection effort*)

### 2. Project/document selection critical

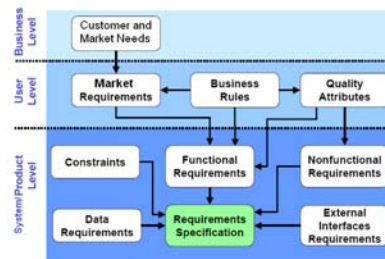
Comparing 'apples and oranges':

- 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*



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## Using Requirements Metrics

### Lessons Learned: Defining Requirements Quality

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

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 following slide for details on the three artifact tiers.

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## Using Requirements Metrics

### Measuring Three Tiers of Requirements Quality

See References for further details on the tiers, metrics, and the definitions of requirements quality indices (ISSRE).

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

Tier	Example Metrics
Individual Requirements Statement	Design-Independent, Precise, Correct
Set of Requirements	Modifiable, Internally Consistent, Complete
Collection of Requirements Documents	Traceable, Externally Consistent, Cross-referenced

Each tier has a proposed Requirements Quality Index, based upon importance-weighted aggregation of the component measures in its tier.

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## 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 → **importance?** *Volatility*
    - 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

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## 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
  - *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?

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## Using Requirements Metrics Q&A / Contact Information

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**QUESTIONS WELCOME!**

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## Using Requirements Metrics References

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## 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

## Using Requirements Metrics: Backup Slide Survey of Quality Characteristics

<b>2.1</b>	<b>Requirements Quality Characteristics and Metrics</b>	<b>5</b>
2.1.1	Achievable	5
2.1.2	At Right Level of Abstraction/Detail	7
2.1.3	Annotated or Ranked by Version or Stability	8
2.1.4	Complete	9
2.1.5	Complex	13
2.1.6	Concise	11
2.1.7	Conformant to Standards	15
2.1.8	Consistent	16
2.1.9	Correct	18
2.1.10	Cross-referenced	20
2.1.11	Design-independent/Implementation-free/No Unnecessary Constraints	21
2.1.12	Electronically Stored	23
2.1.13	Executable	24
2.1.14	Minimal	25
2.1.15	Modifiable	25
2.1.16	Necessary	27
2.1.17	Non Redundant	29
2.1.18	Organized	30
2.1.19	Precise	31
2.1.20	Prioritized (Annotated or Ranked by Importance)	32
2.1.21	Readable	34
2.1.22	Reusable	36
2.1.23	Traceable	37
2.1.24	Unambiguous	40
2.1.25	Understandable	43
2.1.26	Validatable	45
2.1.27	Verifiable/Testable	46

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