Achieving Quality Requirements with Reused Software Components:

Challenges to Successful Reuse

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Donald Firesmith

Software Engineering Institute
Carnegie Mellon University
Pittsburgh, PA 15213
dgf@sei.cmu.edu

Topics

- Introduction
- Reusing Software
- Quality Models and Requirements
- Risks and Risk Mitigation
- Conclusion

Introduction 1

- When reusing components, many well known problems exist regarding achieving functional requirements.
- Reusing components is an *architectural* decision as well as a management decision.
- Architectures are more about achieving quality requirements than achieving functional requirements.
- If specified at all, quality requirements tend to be specified as very high level goals rather than as feasible requirements. For example:
  - "The system shall be secure."

Introduction 2

- *Actual* quality requirements (as opposed to goals) are often less negotiable than functional requirements.
- Quality requirements are much harder to verify.
- Quality requirement achievability and tradeoffs is one of top 10 risks with software-intensive systems of systems. (Boehm et al. 2004)
- How can you learn what quality requirements were originally used to build a reusable component?
- What should architects know and do?

Reusing Software

- Scope of Reuse
- Types of Reusable Software
- Characteristics of Reusable Software

Scope of Reuse

- Our subject is the development of software-intensive systems that incorporate some reused component containing or consisting of software.
- We are *not* talking about developing software for reuse in such systems
(i.e., this is not a 'design for reuse' discussion).
- The scope is all reusable software, not just COTS software.

Types of Reusable Software

- Non-developmental Item (NDI) components with SW come in many forms:
  - COTS (Commercial Off-The-Shelf)
  - GOTS (Government Off-The-Shelf)
  - GFI (Government Furnished Information)
  - GFE (Government Furnished Equipment)
  - OSS (Open Source Software)
  - Shareware
  - Legacy (for Ad Hoc Reuse)
  - Legacy (for Product Line)
- They have mostly similar characteristics.
- Differences more quantitative than qualitative

Characteristics of Reusable SW 1

- *Not* developed for use in applications / systems with your exact requirements. For example, they were built to different (or unknown):
  - **Functional requirements** (operational profiles, feature sets / use cases / use case paths)
  - **Quality requirements** (capacity, extensibility, maintainability, interoperability, performance, safety, security, testability, usability)
  - **Data requirements** (types / ranges / attributes)
  - **Interface requirements** (syntax, semantics, protocols, state models, exception handling)
  - **Constraints** (architecture compatibility, regulations, business rules, life cycle costs)

Characteristics of Reusable SW 2

- Intended to be used as a blackbox
- Hard, expensive, and risky to modify and maintain
- The following may not be available, adequate, or up-to-date:
  - Requirements Specifications
  - Architectural Documents
  - Design Documentation
  - Analyses
  - Source code
  - Test code and test results
- Lack of documentation is especially common with COTS SW.

Characteristics of Reusable SW 3

- Maintained, updated, and released by others according to a schedule over which you have no control
- Typically requires licensing, which may involve major issues
- Often needs a wrapper or an adaptor:
  - Must make trade-off decision that developing glue code is worth the cost and effort of using the component

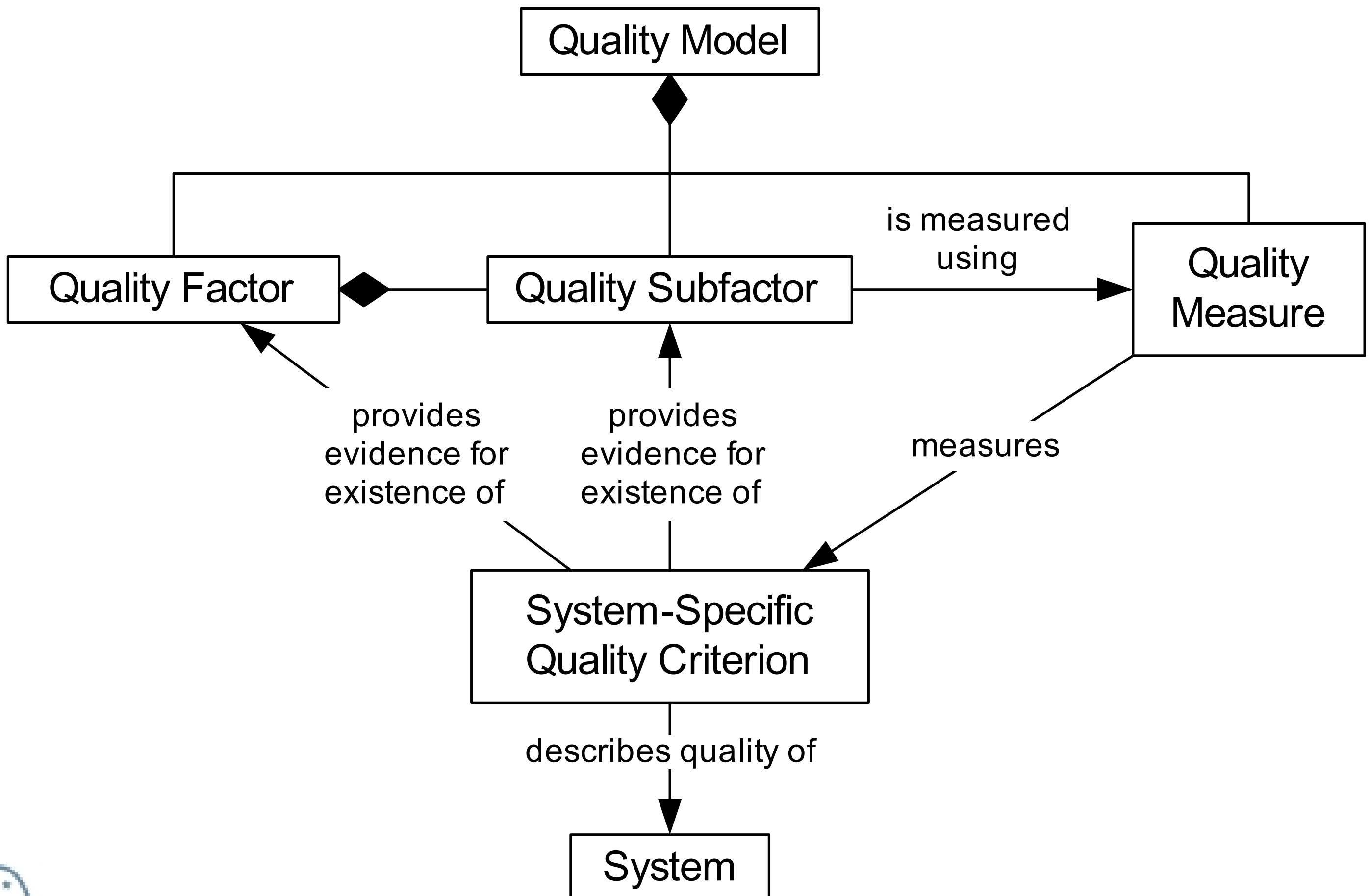
Component Quality Requirements

- Often overlooked
- Typically poorly engineered:
  - Not specified at all
  - Not specified properly (incomplete, ambiguous, incorrect, infeasible)
    - Specified as ambiguous, high-level quality goals rather than as verifiable quality requirements
- Must be analyzed and specified in terms of corresponding quality attributes
- Requires quality model to do properly

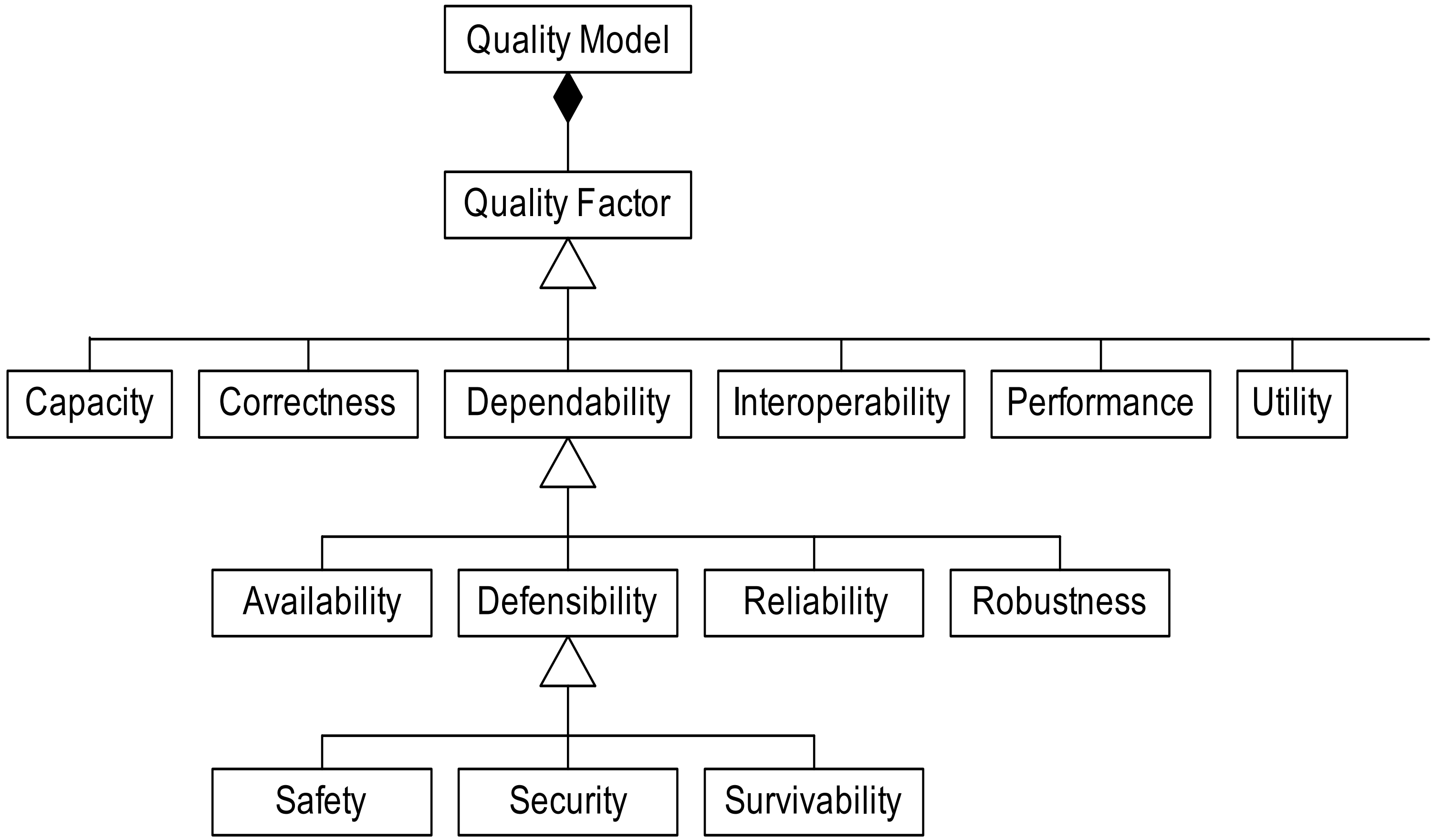
Quality Models 1

- **Quality Model** – a hierarchical model (i.e., a layered collection of related abstractions or simplifications) for formalizing the concept of the quality of a system in terms of its:
  - **Quality Factors** – high-level characteristics or attributes of a system that capture major aspects of its quality (e.g., interoperability, performance, reliability, safety, and usability)
  - **Quality Subfactors** – major components of a quality factor or another quality subfactor that capture a subordinate aspect of the quality of a system (e.g., throughput, response time, jitter)
  - **Quality Criteria** - specific descriptions of a system that provide evidence either for or against the existence of a specific quality factor or subfactor
  - **Quality Measures** – gauges that quantify a quality criterion and thus make it measurable, objective, and unambiguous (e.g., transactions per second)

Quality Model 2

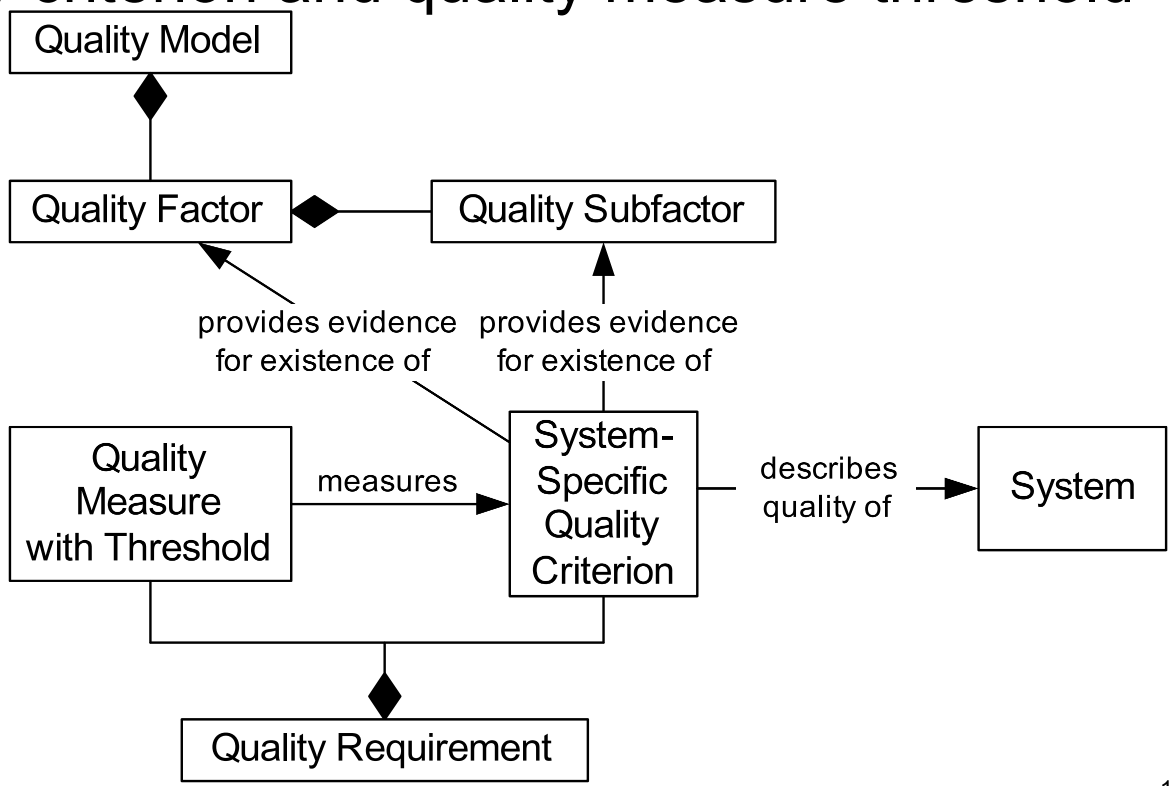


Quality Factors



Quality Requirements

Quality requirement – a mandated combination of quality criterion and quality measure threshold or range



Some Important Quality Factors

- All quality factors may have requirements that reusable components must meet.
- Today, we will briefly consider the following:
    - Availability
    - Capacity
    - Performance
    - Reliability
    - Robustness
    - Safety
    - Security
    - Testability

Availability

- **Availability** – the proportion of the time that an application or component functions properly (and thus is available for performing useful work)
    - *Measured*/*Specified* as the average percent of time that *one or more functions*/*features*/*use cases*/*use case paths* [must] properly operate without scheduled or unscheduled downtime under given normal conditions.
- Becomes exponentially more difficult and expensive as required availability increases (99% vs. 99.999%)
- Many possible [inconsistent] architectural mechanisms
- Requires many long-running tests to verify
- SW dependencies makes estimation of overall availability from component availabilities difficult, even if known

Capacity

- **Capacity** - the maximum number of things that an application or component can successfully handle at a single point in time
  - *Measured/Specified* in terms of number of users, number of simultaneous transactions, number of records stored, etc.
- Cannot be indefinitely large
- Solutions require both hardware and software architectural decisions that may be inconsistent with those of the reusable components
- Reasonably straight-forward to test if required capacity is achieved, but not actual system capacity

Performance 1

- **Performance** – the execution time of a function of an application or component. Subfactors include:
  - **Determinism** – the extent to which events and behaviors are deterministic and can be precisely and accurately predicted and scheduled
  - **Jitter** – the variability of the time interval between an application or component's periodic actions
  - **Latency** – the time that an application or component takes to execute specific tasks (e.g., system operations and use case paths) from end to end
  - **Response Time** – the time that an application or component takes to *initially* respond to a client request for a service or to be allowed access to a resource
  - **Throughput** – the number of times that an application or component is able to complete an operation or provide a service in a specified unit of time

Performance 2

- Measured and specified in many different ways
- Not all functions need high performance
- Although certain performance subfactors are vital for safety and security certification and for real time scheduling analysis, these performance subfactors are rarely considered by product suppliers and other developers
- Architectural mechanisms include real-time OS, cyclic executive, no automatic garbage collection, repeated hardware, etc.
- Requires significant analysis and testing to verify

Reliability

- **Reliability** – the degree to which an application or component continues to function properly without failure under *normal* conditions or circumstances
- *Measured*/*specified* as the:
  - Mean time between failures (MTBF) during a given time period under a given operational profile, whereby MTBF is defined as the average period of time that the application continues [shall continue] to function correctly without failure under stated conditions.
  - [Maximum permitted] number of failures per unit time
- Becomes exponentially more difficult and expensive as required reliability increases
- Many possible [inconsistent] architectural mechanisms
- Requires many long-running tests to verify

Robustness

- **Robustness** – the degree to which an application or component continues to function properly under *abnormal* conditions or circumstances during a given time period:
  - **Environmental tolerance** (e.g., vibration or power)
  - **Failure tolerance** (fail safety, fail softness – degraded mode)
  - **Fault tolerance** (presence of defects/bugs)
  - **Error tolerance** (erroneous input)
- Becomes exponentially more difficult and expensive as required robustness increases
- Many possible [inconsistent] architectural mechanisms (e.g., fault detection by heartbeat vs. ping/echo vs. exception)
- Requires many difficult and expensive tests to verify
- SW dependencies makes estimation of overall robustness from component robustness difficult, even if known

Safety 1

- **Safety** is the *degree*:
  - Of freedom from:
    - *Accidental* (unintentional) harm to valuable assets
    - Safety *incidents* (*accidents* and *near misses*) that can cause accidental harm
    - *Hazards* that may cause safety incidents
    - Safety *risks* (max. harm times probability)
  - To which the following exist:
    - *Prevention* of accidental harm
    - *Detection* of safety incidents
    - *Reaction* to safety incidents
    - *Adaptation* to avoid accidental harm in the future

Safety 2

- Safety is becoming more and more critical as more and more systems have safety ramifications.
- Reusable software (e.g., COTS) often does not address safety.
- Safety Integrity Levels (SILs) in the requirements require proportionate Safety Evidence Assurance Levels (SEALs) regarding the development of components to achieve certification:
  - Architecture as well as design, coding, and testing

Safety 3

- Reused components have:
  - Different or nonexistent safety *requirements*
  - Different, incompatible, or nonexistent *safeguards*
- Poor (inappropriate, incomplete, missing) requirements are the cause of roughly 40% of accidents.
- Therac-25 (6 deaths) and Ariane-5 ($500 million) examples of accidents due to reuse

Security 1

- **Security** is the *degree* :
  - Of freedom from:
    - *Malicious* harm to valuable assets from attackers
    - Security incidents (successful *attacks*, unsuccessful attacks, *probes*) that can cause malicious harm
    - *Threats* that may cause security incidents
    - Security *risks* (max. harm times probability)
  - To which the following exist:
    - *Prevention* of malicious harm
    - *Detection* of security incidents
    - *Reaction* to security incidents
    - *Adaptation* to avoid security problems in the future

Security 2

- Security is becoming more and more critical as more and more systems have security ramifications (e.g., private data, nonrepudiation needs, valuable assets)
- Reusable software (e.g., COTS) often does not adequately address security
- Security must be architected into systems, not added on afterwards
- Reused components have:
  - Different or nonexistent security requirements
  - Different, nonexistent, or incompatible security controls

Testability

- **Testability** – the degree to which an application or component facilitates the creation and execution of successful tests
- A function of:
  - Observability
  - Controllability
- Directly at odds with security
- Typically low with blackbox components not delivered with test cases and test harnesses
- Limited to blackbox component testing, system integration testing, system testing, and **quality requirements testing**

Summary of Risks

- Reusable component is built to different quality requirements than current system.
- Components often have incompatible architectural approaches to support achieving important quality requirements.
- Difficult and expensive to verify achievement of quality requirements by reusable components
- Difficult to obtain safety and security certifications for reused components and resulting systems
- Glue code is neither always adequate nor inexpensive.

Risk Mitigation 1

- Do not assume that reuse will necessarily be cheaper, faster, or better.
- Negotiate quality requirements with ranges as well as hard thresholds if practical.
- Demand credible evidence from supplier to support reusability analysis.
- Talk to users of the reusable components to learn from their experiences.

Risk Mitigation 2

- Do not overlook quality requirements / attributes when assessing the appropriateness of “reusable” components.
- Perform major reuse readiness assessment of the reusable components that includes verification of quality requirements:
  - Technical analysis
  - Prototyping
  - Testing
- Plan for the significant cost (schedule, effort, expense) of performing a real readiness assessment.

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Conclusion

If you are not concerned, you have probably not paid sufficient attention.