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SEI Architecture Analysis Techniques and When to Use Them
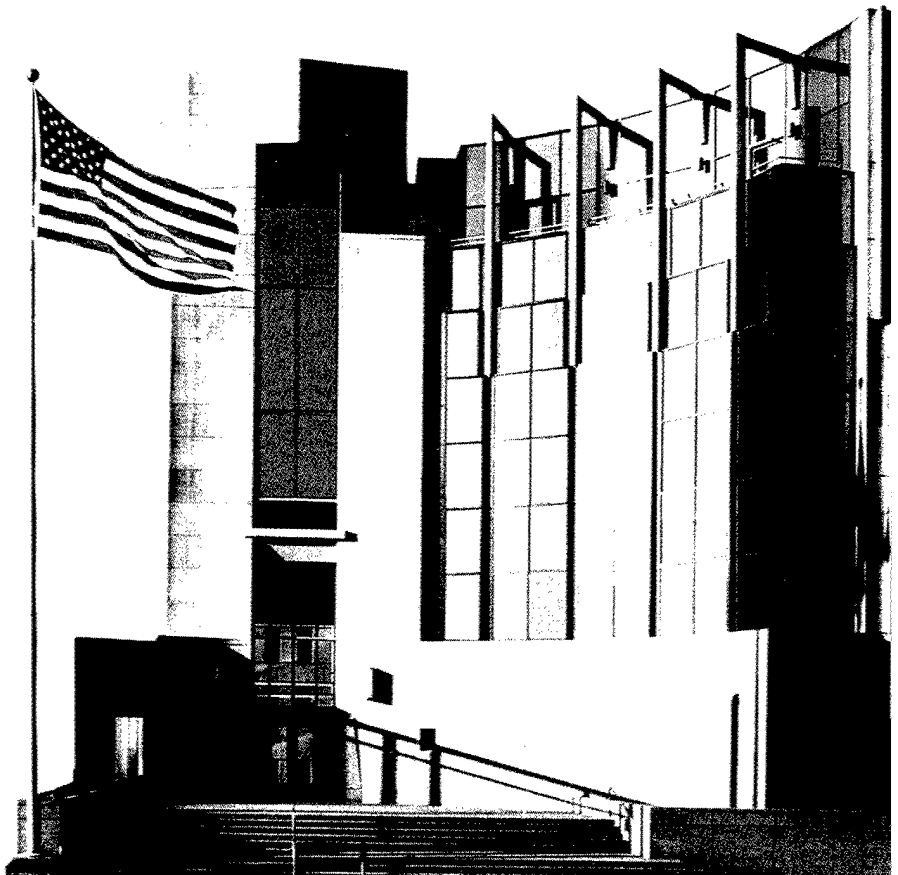
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SEI Architecture Analysis Techniques and When to Use Them

Mario R. Barbacci

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Abstract

The Software Engineering Institute (SEI[SM]) has developed two methods for analyzing system and software architectures—the Quality Attribute Workshop (QAW) and the Architecture Tradeoff Analysis Method[SM] (ATAM[SM]). These techniques, which are described in detail in various SEI technical reports and on the SEI Web site, can be used in combination to obtain early and continuous benefits. Designed to complement the ATAM, the QAW provides a method for analyzing a conceptual architecture or a system architecture against a number of critical quality attributes—such as availability, performance, security, interoperability, and modifiability—*before* the software architecture is fully developed. Once the software architecture is developed, the ATAM can be used to reveal how well the architecture satisfies particular quality attribute requirements and the risks, sensitivities, and tradeoffs involved in satisfying the requirements.

The purpose of this technical note is to describe, using a hypothetical example, the alignment, combination, and uses of the two methods.

1   Introduction

Quality Attribute Workshops (QAWs) provide a method for analyzing a system's architecture against a number of critical quality attributes—such as availability, performance, security, interoperability, and modifiability—that are derived from mission or business goals [Barbacci 02]. The QAW does not assume the existence of a software architecture. It was developed to complement the Architecture Tradeoff Analysis Method[SM] (ATAM[SM])[1] in response to customer requests for a method that identifies important quality attributes and clarifies system requirements *before* there is a software architecture to which the ATAM could be applied[2] [Kazman 00]. The QAW can be applied to a conceptual (or "notional") architecture or a system architecture. The QAW and the ATAM, which are described in detail in various Software Engineering Institute (SEI[SM])[3] technical reports, in the book *Evaluating Software Architectures: Methods and Case Studies* [Clements 01], and on the SEI Web site [SEI 02], can be used in combination to obtain early and continuous benefits. It should be noted that the SEI has developed related evaluation techniques, namely the Software Architecture Analysis Method (SAAM, a predecessor of the ATAM), Active Reviews for Intermediate Designs (ARID), and the Cost Benefit Analysis Method (CBAM), which are not covered in this technical note.

In an ATAM evaluation, an external team facilitates meetings between stakeholders during which scenarios representing the quality attributes of the system are developed, prioritized, and analyzed against the architectural approaches chosen for the system. Typical stakeholders include developers, users, maintainers, and buyers. The results of the analysis are expressed as risks, sensitivity points, and tradeoffs. To conduct an ATAM evaluation, an articulation of the business drivers and an initial draft of the software architecture are required. A typical ATAM evaluation would involve 2 two-to-three day meetings between the evaluation team and the stakeholders over the course of a few weeks.

The QAW involves similar activities earlier in the life cycle of a project. In the QAW, an external team facilitates meetings between stakeholders, during which scenarios representing quality attribute requirements are generated, prioritized, and refined (refining involves adding details about the personnel and assets required, the sequence of activities, and questions about

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1   Architecture Tradeoff Analysis Method and ATAM are service marks of Carnegie Mellon University.

2   The ATAM was developed to evaluate a software architecture and has been technically validated for this purpose. Others have applied the ATAM to other types of architecture, but the SEI currently makes no claims about the ATAM's capabilities beyond the evaluation of a software architecture.

3   SEI is a service mark of Carnegie Mellon University.

the requirements). After the scenario generation meeting(s), the refined scenarios are con-
verted into architectural test cases that the architecture team analyzes against the system archi-
tecture. The architectural test case development and analysis often takes place over an
extended period of time (perhaps months) before the architecture team presents the results of
the analysis to the stakeholders.

The remainder of this technical note describes the QAW and the ATAM and uses a hypotheti-
cal example (based on a common United States government acquisition strategy) to illustrate
when various QAW and ATAM activities are applicable.

2 QAW Process

The QAW process shown in Figure 1 can be organized into four distinct groups of activities: (1) scenario generation, prioritization, and refinement, (2) architectural test case development, (3) analysis of test cases against the system architecture, and (4) presentation of the results.

The first and last activities of the process occur in facilitated, short meetings that last one or two days. The two middle activities take place offline and can continue over an extended period of time. Depending on the application context, the specific roles and responsibilities of the participants in the various activities can be customized [Barbacci 02].

The process is iterative in that the architectural test case analyses might lead to modifications of the architecture that, in turn, might prompt additional test case analyses that result in a continuous cycle of analyses and architectural modifications.[4]

This document describes the QAW method in generic terms. The actual application of the method can be tailored to the needs of a specific organization [Barbacci 02].

2.1 Scenario Generation

The first activity in the QAW process is to generate, prioritize, and refine scenarios. In this process, a *scenario* is a statement about some anticipated or potential use or behavior of the system; it captures stakeholders' concerns about how the system will do its job. The scenarios are generated during a facilitated brainstorming meeting of system stakeholders [Barbacci 02].

A typical agenda for this meeting is shown in Table 1. The meeting starts with a facilitation team's presentation of an overview of the QAW process, including QAW activities (the ovals in Figure 1) and their expected outcomes. A customer representative then describes the system's mission or business drivers, including the business context for the system, architectural drivers (quality attributes that "shape" the architecture), and critical requirements (quality attributes that are most central to the system's success). The presentation of the business drivers is followed by an overview of the system architecture. The overview addresses technical constraints (such as an operating system, hardware, or middleware prescribed for use), other

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4   Figure 1 does not include planning activities such as planning the scenario generation meeting because these activities might require a number of interchanges.
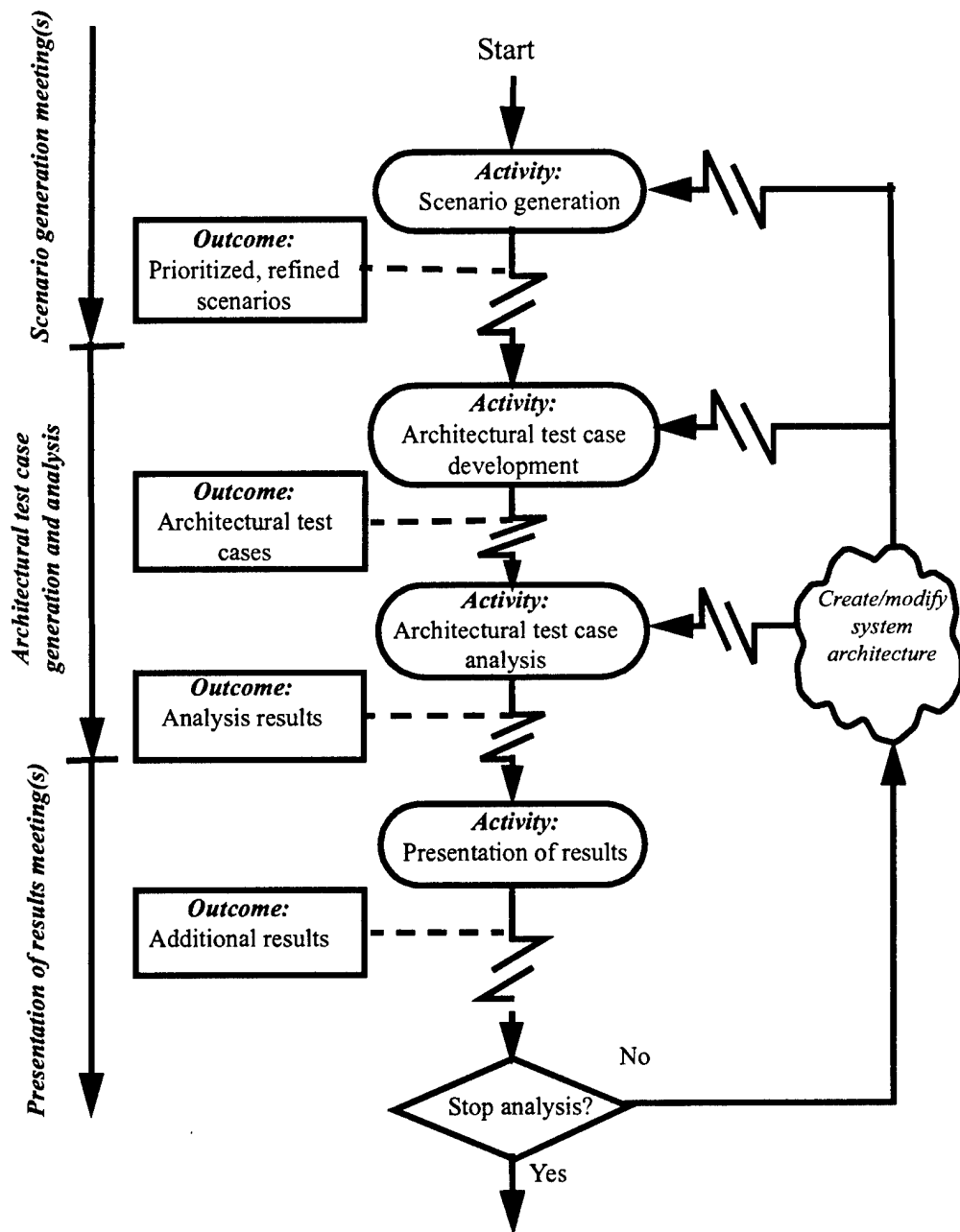
Figure 1:   QAW Process

Time	Activity
8:30 a.m.	Start
	Welcome and introductions
	QAW overview
	Business drivers
	System architecture
10:00 a.m.	Scenario generation and prioritization
Noon	Lunch break
1:00 p.m.	Scenario refinement
3:00 p.m.	Wrap-up
	Review scenarios
	Action items
4:00 p.m.	End

Table 1:   Agenda for QAW Scenario Generation

systems with which the system will interact, and planned architectural approaches to address quality attribute requirements.[5] These three presentations set the context for the activities that follow.

Stakeholders are encouraged to generate as many scenarios as possible to represent a wide range of concerns. However, only a small number of scenarios can be refined during a one-day meeting. Thus, stakeholders must prioritize the scenarios generated previously by using a voting process; they must then refine the top three or four scenarios to provide a better understanding of them in terms of context and detail. Prior to voting, the stakeholders can merge scenarios that they consider to be closely related. The template shown in Table 2 illustrates the types of details that usually emerge from the refinement.

The result of this meeting is a prioritized list of scenarios and refined descriptions of the top three or four (merged) scenarios on that list.

5   Depending on the situation (e.g., a planned competitive acquisition vs. an internal corporate development), the system developers may or may not be participants in this meeting. If developers are excluded, the architecture presentation would be made by a customer representative and would describe desired rather than planned approaches.

Section	Content
Reference Scenario(s)	The scenario that is being refined is listed here. If it is a merged scenario, the combined scenarios are listed here in their original form.
Organizations	Organizations involved in or affected by the scenario(s)
Actors/Participants	Individuals involved in or affected by the scenario(s)
Quality Attributes	Quality attributes involved in or affected by the scenario(s)
Context	A description of additional details such as the environment in which the scenario takes place, and the sequence, frequency, and duration of events
Questions	Specific questions that the stakeholders would like to ask the architect and the designers of the system. Typically one or more questions are included for each quality attribute identified above, for example • How will the system prevent unauthorized users from accessing the system? • How will the system store one year of information online? • How will the system respond to user requests within 10 seconds during peak time?

Table 2:   Template for QAW Scenario Refinement

2.2   Architectural Test Case Development

The objective of developing architectural test cases is to transform each refined scenario from a statement and list of organizations, participants, quality attributes, and questions into a well-documented architectural test case. Test cases may add assumptions and clarifications to the context, add or rephrase questions, group questions by topic, and so forth. The individual or team responsible for developing test cases depends on the situation. Barbacci and associates describe how the QAW method has been applied and who carried out the task (such as the sponsor/acquirer or development team) [Barbacci 02].

An architectural test case has a context section that outlines the important aspects of the case, an issues and questions section that states the stakeholders' concerns, and a graphical illustration that summarizes these issues and questions. Figure 2 provides a visual summary of the most important quality attributes and the specific issues and questions that pertain to the attributes.

Quality Attribute	Specific Quality Attribute Issue	Question

... frequency of messages?

... time to send a message...

... latency of messages?

... priority of messages?

performance

... time to perform a critical function...

... question 1

... question 2

... question 3

... time to restart a service...

... question 1

... question 2

... question 3

attribute 1

... issue 1

... question1

... question 2

... question 3

... issue 2

... question 1

... question 2

... question 3

attribute 2

Figure 2: Example Illustration of Refined Scenario Issues and Questions

2.3 Architectural Test Case Analysis

Typical steps for conducting the architectural test case analysis include the following:

1. Review the capabilities of the assets in the test case context and determine how the system will react to the situation.

2. Make and document any assumptions necessary to proceed with the analysis.

3. Determine which architectural views (e.g., operational, system, technical, process, behavioral, structural) can best describe how the system will address the issues and their associated questions.

4. Perform the analysis for the selected architectural test cases.

5. If necessary, refine the architecture to help answer the questions.

6. Document the answers as specifically as possible.

The analysis for a specific architectural test case would clarify or confirm specific quality attribute requirements and might identify concerns that would drive the development of the software architecture. Some of the test cases could later be used as "seed scenarios" in an ATAM evaluation (e.g., to check if a concern identified during the test case analysis was addressed by the software architecture). The results of analyzing a test case should be documented with specific architectural decisions, quality attribute requirements, and rationales.

2.4 Presentation of Results

The presentation is a one- or two-day facilitated meeting attended by the architecture team and other stakeholders. As the final activity in the QAW process, it provides an opportunity for the architecture team to present the results of their analysis and demonstrate that the proposed architecture is able to handle the architectural test cases correctly.

Prior to the meeting, participants are provided with a short document describing the QAW process, business drivers, and architectural plans that were presented during the scenario generation meeting. In addition, the document includes the original scenarios, the architectural test cases, and an example of a test case analysis. Ideally, the participants would be the same stakeholders who took part in the scenario generation meeting. However, since the presentation of results might take place a few months after the first meeting, there will likely be some participants who were not involved in the early meeting. The short document serves as a reminder to those participants who were involved in the scenario generation meeting and as an introduction to the QAW process for new participants.

The conclusions, recommendations, and action items resulting from the presentation must be captured in a short report to be distributed to the participants. The results might lead to modifications of the architecture, which, in turn, might lead to further analysis of test cases or even new test cases. These iterations are shown in Figure 1.

3 ATAM Process

Since the ATAM is a few years more mature than the QAW, the ATAM process is more precisely defined and has been more rigorously validated. The ATAM process, shown in Figure 3, is organized into two main phases, each consisting of several steps. The steps in each phase usually take place during a one- to two-day facilitated meeting, while the two phases are usually a few weeks apart.[6]

Phase 1 involves a small group of predominantly technically-oriented stakeholders. This phase is architecture-centric, focused on eliciting detailed architectural information and conducting a top-down analysis. Phase 2 involves a larger group of stakeholders. This phase is stakeholder-centric and focuses on eliciting points of view from diverse stakeholders and on verifying the results of Phase 1.

The ATAM involves nine steps:

1. Present the ATAM

2. Present business drivers

3. Present architecture

4. Identify architectural approaches

5. Generate quality attribute utility tree

6. Analyze architectural approaches

7. Brainstorm and prioritize scenarios

8. Analyze architectural approaches

9. Present results

The first three steps are similar to the QAW presentations made before scenario generation and the QAW presentation of results meetings in that they inform the participants about the process, the techniques used, and the expected outcomes.

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[6]   The complete ATAM process includes a set of planning steps in a Phase 0. These steps include negotiations and planning tasks that might take a number of interchanges because they involve scheduling meetings, selecting facilities and participants, and reviewing documents. Phase 0 can extend over a long time and involves multiple interactions with the customers.

Start

Steps 1-3: ATAM presentations

Outcome: Business drivers and architectural styles

Step 4: Architectural approaches

Outcome: Identified architectural approaches

Step 5: Utility tree generation

Outcome: Quality attributes and prioritized scenarios

Step 6: Scenario analyses

Outcome: Risks, sensitivities, and tradeoffs

Recapitulation of Phase 1 Steps 1-6

Outcome: Understanding of Phase 1 results

Step 7: Scenario generation

Outcome: Prioritized scenarios

Step 8: Scenario analyses

Outcome: Risks, sensitivities, and tradeoffs

Step 9: Presentation of results

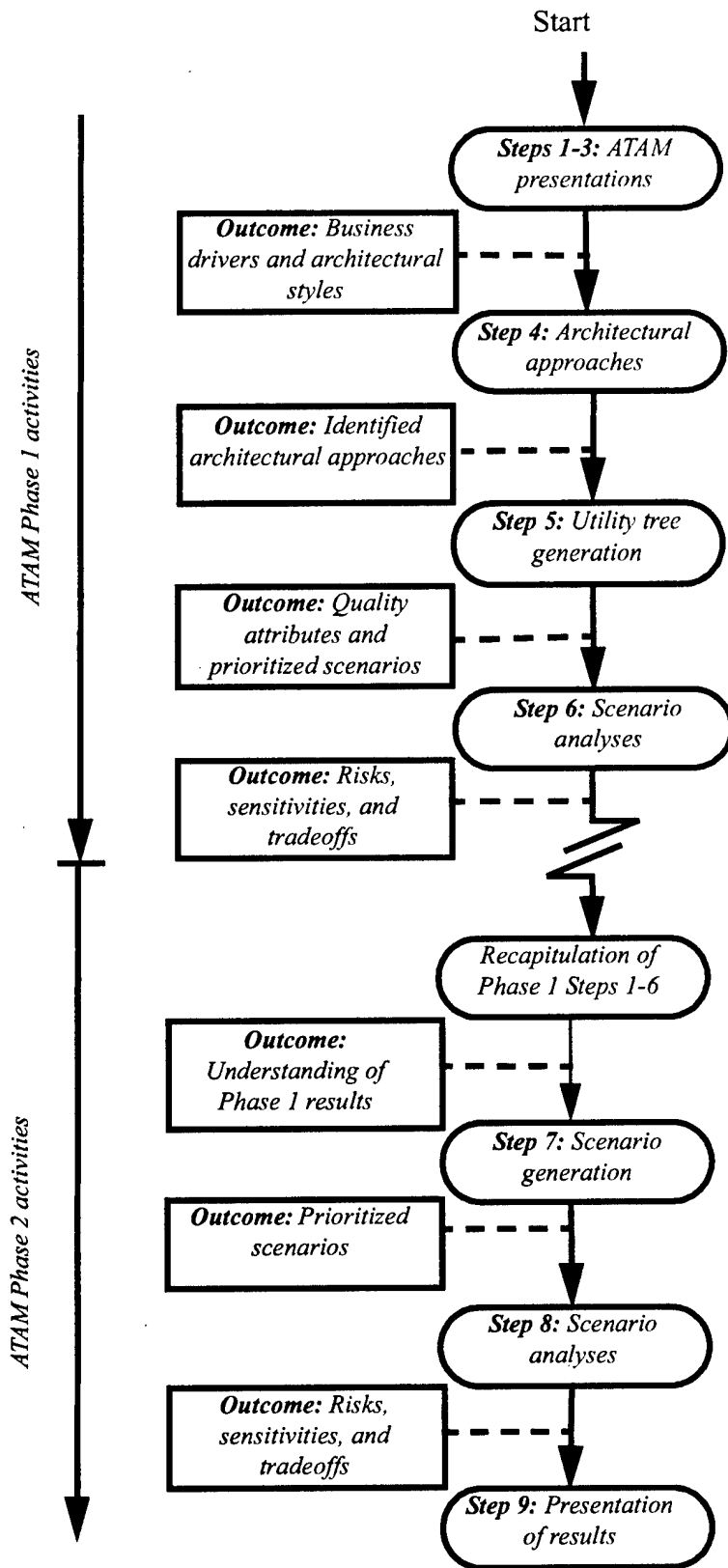ATAM Phase 1 activities

ATAM Phase 2 activities

Figure 3: ATAM Process

3.1 Phase 1

In Step 1, the evaluation team presents an overview of the ATAM, including steps, techniques, and expected outputs (such as architectural approaches, a utility tree, scenarios, risks, sensitivity points, and tradeoffs).

In Step 2, a customer representative describes the system's business drivers, including the business context for the system, high-level functional requirements, high-level quality attribute requirements, architectural drivers (quality attributes that "shape" the architecture), and critical requirements (quality attributes that are central to the system's success).

In Step 3, the architect presents an overview of the architecture, including technical constraints (such as an operating system, hardware, or middleware prescribed for use), other systems with which the system must interact, and architectural approaches used to address quality attribute requirements.

In Step 4, the evaluators begin to identify places in the architecture that are key to realizing quality attribute goals; they also identify predominant architectural approaches (some examples include client-server, 3-tier, watchdog, publish-subscribe, and redundant hardware).

In Step 5, the participants identify, prioritize, and refine the most important quality attribute goals by building a utility tree. A *utility tree* is a top-down vehicle for characterizing the "driving" attribute-specific requirements. The most important quality goals are the high-level nodes —typically performance, modifiability, security, and availability. Scenarios are the leaves of the utility tree, as illustrated in Figure 4.

Scenarios are used to represent stakeholders' interests and should cover a range of anticipated uses of the system (use case scenarios), anticipated changes to the system (growth scenarios), or unanticipated stresses to the system (exploratory scenarios). A good scenario clearly indicates which stimulus causes it and what responses are important. During scenario prioritization, scenarios are categorized by two parameters, importance and difficulty, using a scale of Low (L)-Medium (M)-High (H).

In Step 6, the evaluation team probes architectural approaches to identify risks, sensitivity points, and tradeoffs for specific quality attributes. A *risk* is a potentially problematic architectural decision. A *sensitivity point* is a property of one or more components (and/or component relationships) that is critical for achieving a particular quality attribute response. A *tradeoff* is a property that affects and is a sensitivity point for more than one attribute.
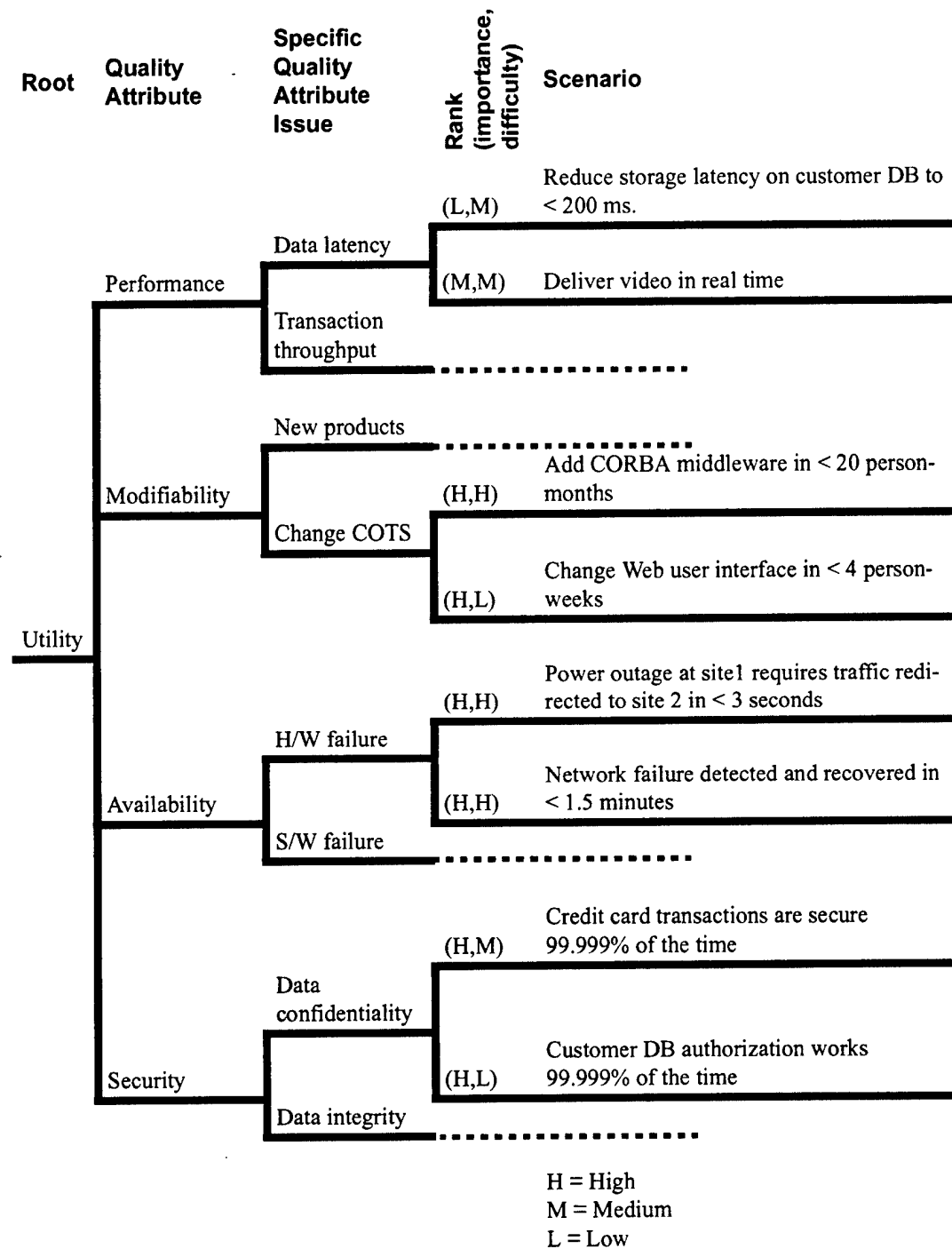
Root | Quality Attribute | Specific Quality Attribute Issue | Rank (importance, difficulty) | Scenario

Utility

Performance
- Data latency
  - (L,M) Reduce storage latency on customer DB to < 200 ms.
  - (M,M) Deliver video in real time
- Transaction throughput
  - ....

Modifiability
- New products
  - ....
  - (H,H) Add CORBA middleware in < 20 person-months
- Change COTS
  - (H,L) Change Web user interface in < 4 person-weeks

Availability
- H/W failure
  - (H,H) Power outage at site1 requires traffic redirected to site 2 in < 3 seconds
  - (H,H) Network failure detected and recovered in < 1.5 minutes
- S/W failure
  - ....

Security
- Data confidentiality
  - (H,M) Credit card transactions are secure 99.999% of the time
  - (H,L) Customer DB authorization works 99.999% of the time
- Data integrity
  - ....

H = High
M = Medium
L = Low

Figure 4: Example ATAM Utility Tree

3.2 Phase 2

At the beginning of the Phase 2 meeting, the evaluation team and some of the participants from the Phase 1 meeting briefly recapitulate the results of the Phase 1 meeting, including the quality attributes and scenarios in the utility tree.

In Step 7, the stakeholders generate and prioritize scenarios using a facilitated brainstorming process. These scenarios are not restricted to the quality attributes listed in the Phase 1 utility tree; rather, they are generated to represent the expanded set of stakeholders' interests. However, the scenarios in the utility tree should not be ignored; these scenarios could be used as example scenarios.

In Step 8, the stakeholders identify the architectural approaches affected by the scenarios generated in Step 7. Step 8 continues the analysis started in Step 6 of Phase 1 using the new scenarios and identifying additional risks, sensitivity points, and tradeoffs.

Finally, in Step 9, the evaluation team presents the ATAM outputs to the stakeholders as confirmation of the architectural approaches, utility tree, scenarios, risks, sensitivity points, and tradeoffs identified during the exercise.

4 An Example Application of Both Methods

There are often contexts in which both the QAW and the ATAM can be used on the same system. Figure 5 illustrates a common United States government acquisition strategy. Starting with an initial request for proposals (RFP), an acquisition organization evaluates proposals from multiple contractors and awards contracts to a small number of contractors to conduct a Competitive Fly-Off. At the end of the Competitive Fly-Off, the contractors submit updated technical proposals, including additional details, and the acquirer makes a Final Down Select.
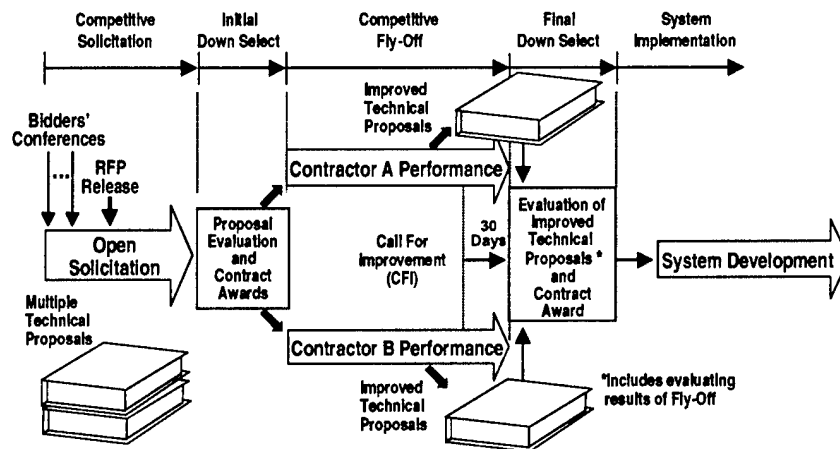

Figure 5:   A Common Acquisition Strategy [Bergey 02]

We will use this example to illustrate how QAW and ATAM activities can be combined. In this case, both methods are used during the acquisition process.

4.1 Activities During the Competitive Solicitation Phase

Figure 6 shows how QAW activities can be incorporated during the Competitive Solicitation Phase.

1. One or more QAW scenario generation meetings are conducted with teams from the acquiring organization (e.g., representative groups of stakeholders with similar needs and responsibilities).

2. From these scenarios, the acquiring organization develops a collection of architectural test cases that represent concerns of the stakeholders.

3. Early in the Competitive Solicitation phase and prior to the release of the RFP, the acquirer conducts bidders' conferences to inform potential bidders about the need for conducting architectural analysis.

4. The acquirer drafts sections of the RFP to incorporate architectural analysis requirements and includes the architectural test cases as government-furnished items in the RFP proper.

5. As part of their proposals, bidders are expected to describe how they will conduct the architectural analysis [Bergey 02].
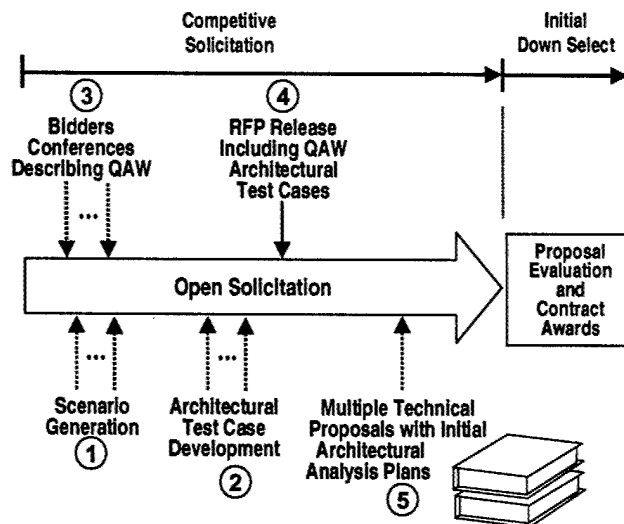

Figure 6: QAW Activities During the Competitive Solicitation Phase

4.2 Activities During the Competitive Fly-Off Phase

Figure 7 shows how QAW activities can be incorporated during the Competitive Fly-Off phase.

1. The contractors analyze their architectures against the architectural test cases and, if necessary, modify their planned architecture.

2. The contractors present the results of their analysis in both a *dry-run* (rehearsal) as well as a final presentation.

   A dry-run presentation should be conducted when the architecture team making the presentation is unsure about any of the following:

   • the level of detail required
   • the precision expected from its answers to the architectural test case questions
   • how to incorporate other analysis results (such as reliability, availability, and maintainability analysis or network-loading analysis)
   • what additional architectural documents might be needed

   The final presentation takes place after the contractors polish the results of the dry-run presentation.

3. After resolving any potential concerns resulting from the presentation of results, the contractors present their technical proposals to the acquiring organization.
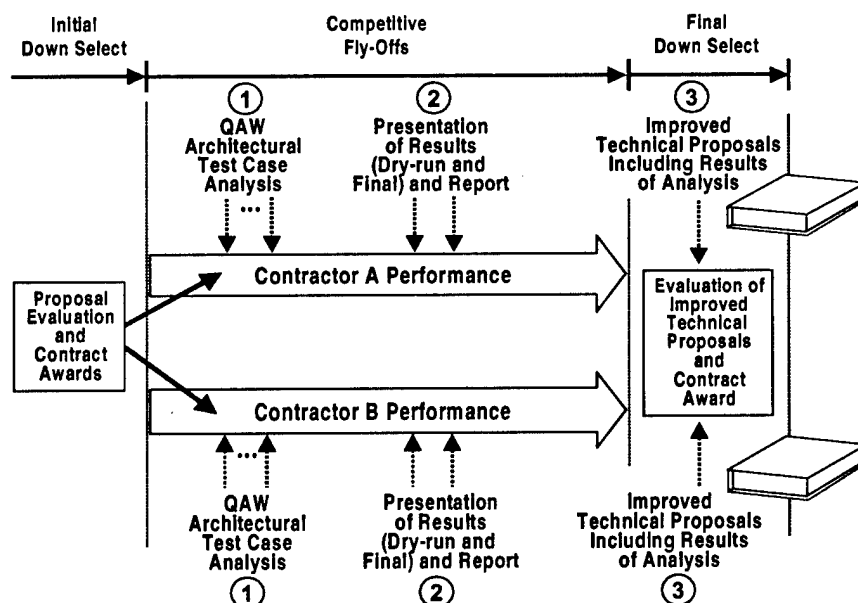

Figure 7:   QAW Activities During the Competitive Fly-Off Phase

4.3 Activities During the System Implementation Phase

Figure 8 shows how ATAM activities can be incorporated during the System Implementation phase.

1. The preceding QAW activities have already identified the important quality attribute concerns that can be used to draft the beginning of the utility tree (Step 5 in Phase 1 of the ATAM).

   The draft utility tree could be further augmented with "seed scenarios" derived from selected architectural test cases, to determine whether concerns identified during the test case analyses were addressed by the software architecture.

2. ATAM evaluations could be scheduled to fit the development plans, although the results of previous QAW architectural test case analyses might influence the schedule. For example, components or subsystems that were identified as sources of concern to the developers might be subject to ATAM evaluations earlier than other subsystems. These subsystems could also be subject to multiple ATAM evaluations during development.

3. Risks identified during the ATAM evaluations should be addressed during system development.

Depending on the circumstances and the results of the QAW architectural test case analyses, ATAM phases could be customized to allow, for example, one Phase-1 evaluation (involving mostly developers) and multiple Phase-2 evaluations (involving different groups of stakeholders, such as clients or users with different needs).
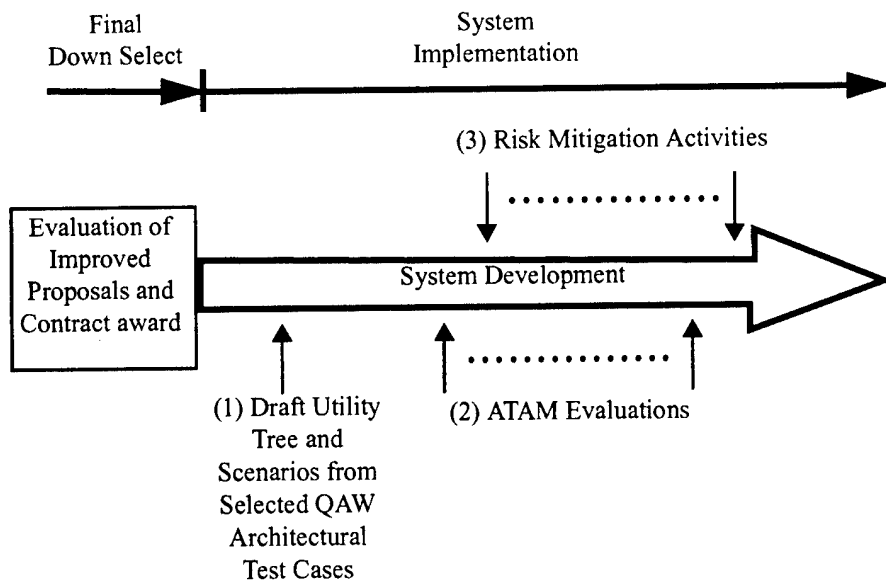
Figure 8: *ATAM Activities During the System Implementation Phase*

5   Summary Comparison

Table 3 provides a brief summary of the inputs, outputs, and participants involved in the various QAW activities and ATAM Phases.

	Inputs	Outputs	Participants	Duration
QAW Scenario Generation	QAW presentations (business drivers, conceptual or system architecture, quality attribute requirements)	prioritized, refined scenarios	system stakeholders (see presentation of results). Depending on the situation, they may or may not include system developers.	one- or two-day facilitated meetings
QAW Architectural Test Case Development	prioritized, refined scenarios	architectural test cases	Depending on the situation, the participants might be system developers or acquirers/sponsors.	. . . could take several days
QAW Architectural Test Case Analysis	architectural test cases	results of architectural test case analysis	system developers	. . . could take weeks or months
QAW Presentation of Results	results of architectural test case analysis	additional results and analysis report	presentation made by system developers to other system stakeholders (see scenario generation)	one- or two-day facilitated meetings
ATAM Phase 1	ATAM Presentations (business drivers and architectural approaches)	utility tree, risks, sensitivities, and tradeoffs	sponsors and developers (technically oriented stakeholders)	one- or two-day facilitated meetings
ATAM Phase 2	ATAM Presentations (business drivers and architectural approaches); results from Phase 1 (utility tree, risks, sensitivities, and tradeoffs)	results from Phase 1, additional scenarios, risks, sensitivities, and tradeoffs	sponsors, developers, and other stakeholders (such as customers, users, maintainers)	one- or two-day facilitated meetings

Table 3:   QAW and ATAM Inputs, Outputs, and Participants for Various Activities

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13. ABSTRACT (maximum 200 words)

The Software Engineering Institute (SEI[SM]) has developed two methods for analyzing system and software architectures—the Quality Attribute Workshop (QAW) and the Architecture Tradeoff Analysis Method[SM] (ATAM[SM]). These techniques, which are described in detail in various SEI technical reports and on the SEI Web site, can be used in combination to obtain early and continuous benefits. Designed to complement the ATAM, the QAW provides a method for analyzing a conceptual architecture or a system architecture against a number of critical quality attributes—such as availability, performance, security, interoperability, and modifiability—*before* the software architecture is fully developed. Once the software architecture is developed, the ATAM can be used to reveal how well the architecture satisfies particular quality attribute requirements and the risks, sensitivities, and tradeoffs involved in satisfying the requirements.

The purpose of this technical note is to describe, using a hypothetical example, the alignment, combination, and uses of the two methods.

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