Reference Chapter 21
Software Architecture in Practice
Third Edition
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Module 5

Session 01 & 02

Architecture Evaluation through

Architecture Trade off Analysis Method

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Chapter Outline

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- Evaluation Factors
- The Architecture Tradeoff Analysis Method (ATAM)
- Lightweight Architecture Evaluation
- Summary

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Evaluation Factors

Three Forms of Evaluation

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Evaluation by the designer within the design process.

Evaluation by peers within the design process.

Analysis by outsiders once the architecture has been designed.

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Evaluation by the Designer

Every time the designer makes a key design decision or completes a design milestone, the chosen and competing alternatives should be evaluated.

Evaluation by the designer is the "test" part of the "generate-and-test" approach to architecture design.

How much analysis? This depends on the importance of the decision. Factors include:

- *The importance of the decision*. The more important the decision, the more care should be taken in making it and making sure it's right.
- *The number of potential alternatives.* The more alternatives, the more time could be spent in evaluating them. Try to eliminate alternatives quickly so that the number of viable potential alternatives is small.
- *Good enough as opposed to perfect.* Many times, two possible alternatives do not differ dramatically in their consequences. In such a case, it is more important to make a choice and move on with the design process than it is to be absolutely certain that the best choice is being made. Again, do not spend more time on a decision than it is worth.

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Peer Review

Architectural designs can be peer reviewed, just as code can.

A peer review can be carried out at any point of the design process where a candidate architecture, or at least a coherent reviewable part of one, exists.

Allocate at least several hours and possibly half a day.

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Peer Review Steps

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Step 1

- *The reviewers determine a number of quality attribute scenarios to drive the review.* These scenarios can be developed by the review team or by additional stakeholders.

Step 2

- *The architect presents the portion of the architecture to be evaluated.* The reviewers individually ensure that they understand the architecture. Questions at this point are specifically for understanding.

Step 3

- *For each scenario, the designer walks through the architecture and explains how the scenario is satisfied.* The reviewers ask questions to determine (a) that the scenario is, in fact, satisfied and (b) whether any of the other scenarios being considered will not be satisfied.

Step 4

- *Potential problems are captured.* Real problems must either must be fixed or a decision must be explicitly made by the designers and the project manager that they are willing to accept the problems and its probability of occurrence.

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Analysis by Outsiders

Outside evaluators can cast an objective eye on an architecture.

"Outside" is relative; this may mean

- outside the development project
- outside the business unit where the project resides but within the same company
- outside the company altogether.

Outsiders are chosen because they possess specialized knowledge or experience, or long experience successfully evaluating architectures.

Managers tend to be more inclined to listen to problems uncovered by an outside team.

An outside team tends to be used to evaluate complete architectures.

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Contextual Factors for Evaluation

What artifacts are available?

- To perform an architectural evaluation, there must be an artifact that describes the architecture.

Who sees the results?

- Some evaluations are performed with the full knowledge and participation of all of the stakeholders. Others are performed more privately.

Who performs the evaluation?

- Evaluations can be carried out by an individual or a team.

Which stakeholders will participate?

- The evaluation process should provide a method to elicit the goals and concerns that the important stakeholders have regarding the system. Identifying the individuals who are needed and assuring their participation in the evaluation is critical.

What are the business goals?

- The evaluation should answer whether the system will satisfy the business goals.

The Architecture Tradeoff Analysis Method

The Architecture Tradeoff Analysis Method

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The Architecture Tradeoff Analysis Method (ATAM) has been used for over a decade to evaluate software architectures in domains ranging from automotive to financial to defense.

The ATAM is designed so that evaluators need not be familiar with the architecture or its business goals, the system need not yet be constructed, and there may be a large number of stakeholders.

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Participants in the ATAM

The evaluation team.

- External to the project whose architecture is being evaluated.
- Three to five people; a single person may adopt several roles in an ATAM.
- They need to be recognized as competent, unbiased outsiders.

Project decision makers.

- These people are empowered to speak for the development project or have the authority to mandate changes to it.
- They usually include the project manager, and if there is an identifiable customer who is footing the bill for the development, he or she may be present (or represented) as well.
- The architect is always included – the architect must willingly participate.

Architecture stakeholders.

- Stakeholders have a vested interest in the architecture performing as advertised.
- Stakeholders include developers, testers, integrators, maintainers, performance engineers, users, builders of systems interacting with the one under consideration, and, possibly, others.
- Their job is to articulate the specific quality attribute goals that the architecture should meet.
- Expect to enlist 12 to 15 stakeholders for the evaluation of a large enterprise-critical architecture.

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ATAM Evaluation Team Roles

Role

Responsibilities

Team leader

- Sets up the evaluation; coordinates with client, making sure client's needs are met; establishes evaluation contract; forms evaluation team; sees that final report is produced and delivered (although the writing may be delegated)

Evaluation leader

- Runs evaluation; facilitates elicitation of scenarios; administers scenario selection/prioritization process; facilitates evaluation of scenarios against architecture; facilitates on-site analysis

Scenario scribe

- Writes scenarios on flipchart or whiteboard during scenario elicitation; captures agreed-on wording of each scenario, halting discussion until exact wording is captured

Proceedings scribe

- Captures proceedings in electronic form on laptop or workstation: raw scenarios, issue(s) that motivate each scenario (often lost in the wording of the scenario itself), and resolution of each scenario when applied to architecture(s); also generates a printed list of adopted scenarios for handout to all participants

Questioner

- Raises issues of architectural interest, usually related to the quality attributes in which he or she has expertise

Outputs of the ATAM

1. A concise presentation of the architecture. The architecture is presented in one hour

2. Articulation of the business goals. Frequently, the business goals presented in the ATAM are being seen by some of the assembled participants for the first time and these are captured in the outputs.

3. Prioritized quality attribute requirements expressed as quality attribute scenarios. These quality attribute scenarios take the form described in Chapter 4.

4. A set of risks and nonrisks.
   - A risk is defined as an architectural decision that may lead to undesirable consequences in light of quality attribute requirements.
   - A nonrisk is an architectural decision that, upon analysis, is deemed safe.
   - The identified risks form the basis for an architectural risk mitigation plan.

Outputs of the ATAM

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5.
- A set of risk themes. When the analysis is complete, the evaluation team examines the full set of discovered risks to look for overarching themes that identify systemic weaknesses in the architecture or even in the architecture process and team. If left untreated, these risk themes will threaten the project's business goals.

6.
- Mapping of architectural decisions to quality requirements. For each quality attribute scenario examined during an ATAM, those architectural decisions that help to achieve it are determined and captured.

7.
- A set of identified sensitivity and tradeoff points. These are architectural decisions that have a marked effect on one or more quality attributes.

Intangible Outputs

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There are also *intangible* results of an ATAM-based evaluation. These include

- a sense of community on the part of the stakeholders
- open communication channels between the architect and the stakeholders
- a better overall understanding on the part of all participants of the architecture and its strengths and weaknesses.

While these results are hard to measure,

- they are no less important than the others and often are the longest-lasting.

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Phases of the ATAM

Phase	Activity	Participants	Typical duration
0	Partnership and preparation: Logistics, planning, stakeholder recruitment, team formation	Evaluation team leadership and key project decision-makers	Proceeds informally as required, perhaps over a few weeks
1	Evaluation: Steps 1-6	Evaluation team and project decision-makers	1-2 days followed by a hiatus of 2-3 weeks
2	Evaluation: Steps 7-9	Evaluation team, project decision makers, stakeholders	2 days
3	Follow-up: Report generation and delivery, process improvement	Evaluation team and evaluation client	1 week

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Step 1: Present the ATAM

The evaluation leader presents the ATAM to the assembled project representatives.

This time is used to explain the process that everyone will be following, to answer questions, and to set the context and expectations for the remainder of the activities.

Using a standard presentation, the leader describes the ATAM steps in brief and the outputs of the evaluation.

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Step 2: Present Business Drivers

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Everyone involved in the evaluation needs to understand the context for the system and the primary business drivers motivating its development.

In this step, a project decision maker (ideally the project manager or the system's customer) presents a system overview from a business perspective.

The presentation should describe the following:

- The system's most important functions
- Any relevant technical, managerial, economic, or political constraints
- The business goals and context as they relate to the project
- The major stakeholders
- The architectural drivers (that is, the architecturally significant requirements)

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Step 3: Present the Architecture

The lead architect (or architecture team) makes a presentation describing the architecture.

The architect covers technical constraints such as operating system, hardware, or middleware prescribed for use, and other systems with which the system must interact.

The architect describes the architectural approaches (or patterns, or tactics, if the architect is fluent in that vocabulary) used to meet the requirements.

The architect's presentation should convey the essence of the architecture and not stray into ancillary areas or delve too deeply into the details of just a few aspects.

The architect should present the views that he or she found most important during the creation of the architecture and the views that help to reason about the most important quality attribute concerns of the system.

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Step 4: Identify Architectural Approaches

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The ATAM focuses on analyzing an architecture by understanding its architectural approaches, especially patterns and tactics.

By now, the evaluation team will have a good idea of what patterns and tactics the architect used in designing the system.

- They will have studied the architecture documentation
- They will have heard the architect's presentation in step 3.
- The team should also be adept at spotting approaches not mentioned explicitly

The evaluation team simply catalogs the patterns and tactics that have been identified.

The list is publicly captured and will serve as the basis for later analysis.

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Step 5: Generate Utility Tree

The quality attribute goals are articulated in detail via a quality attribute utility tree.

Utility trees serve to make the requirements concrete by defining precisely the relevant quality attribute requirements that the architects were working to provide.

The important quality attribute goals for the architecture under consideration were named in step 2.

In this step, the evaluation team works with the project decision makers to identify, prioritize, and refine the system's most important quality attribute goals.

These are expressed as scenarios, which populate the leaves of the utility tree.

The scenarios are assigned a rank of importance (High, Medium, Low).

Step 6: Analyze Architectural Approaches

The evaluation team examines the highest-ranked scenarios one at a time; the architect is asked to explain how the architecture supports each one.

Evaluation team members—especially the questioners—probe for the architectural approaches that the architect used to carry out the scenario.

Along the way, the evaluation team documents the relevant architectural decisions and identifies and catalogs their risks, nonrisks, sensitivity points, and tradeoffs. Examples:

- Risk: The frequency of heartbeats affects the time in which the system can detect a failed component. Some assignments will result in unacceptable values of this response.
- Sensitivity point: The number of simultaneous database clients will affect the number of transactions that a database can process per second.
- Tradeoff: The heartbeat frequency determines the time for detecting a fault. Higher frequency leads to better availability but consumes more processing time and communication bandwidth (potentially reducing performance).

These, in turn, may catalyze a deeper analysis.

The analysis is not meant to be comprehensive. The key is to elicit sufficient architectural information to establish a link between the architectural decisions made and the quality attribute requirements that need to be satisfied.

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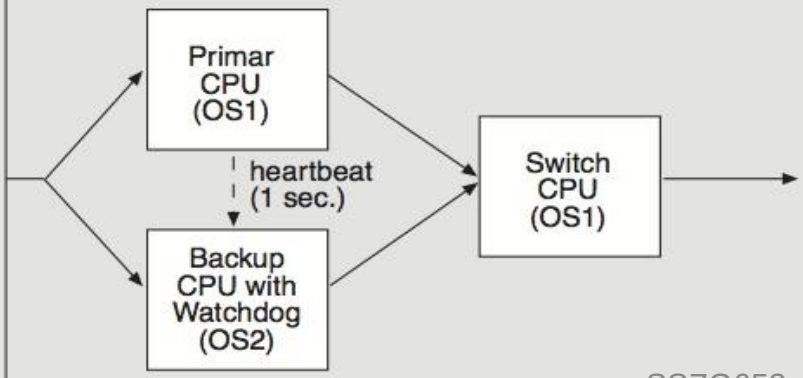
Example of an Analysis

Scenario #: A12	Scenario: Detect and recover from HW failure of main switch.
Attribute(s)	Availability
Environment	Normal operations
Stimulus	One of the CPUs fails
Response	0.999999 availability of switch

Architectural decisions	Sensitivity	Tradeoff	Risk	Nonrisk
Backup CPU(s)	S2		R8	
No backup data channel	S3	T3	R9	
Watchdog	S4			N12
Heartbeat	S5			N13
Failover routing	S6			N14

Reasoning	Ensures no common mode failure by using different hardware and operating system (see Risk 8) Worst-case rollover is accomplished in 4 seconds as computing state takes that long at worst Guaranteed to detect failure within 2 seconds based on rates of heartbeat and watchdog Watchdog is simple and has proved reliable Availability requirement might be at risk due to lack of backup data channel ... (see Risk 9)
Architecture diagram	

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Step 7: Brainstorm and Prioritize Scenarios

The stakeholders brainstorm scenarios that are operationally meaningful with respect to the stakeholders' individual roles.

- A maintainer will likely propose a modifiability scenario
- A user will probably come up with a scenario that expresses useful functionality or ease of operation
- A quality assurance person will propose a scenario about testing the system or being able to replicate the state of the system leading up to a fault.

The purpose of scenario brainstorming is to take the pulse of the larger stakeholder community: to understand what system success means for them.

Once the scenarios have been collected, they are prioritized by voting.

The list of prioritized scenarios is compared with those from the utility tree exercise.

- If they agree, it indicates good alignment between what the architect had in mind and what the stakeholders actually wanted.
- If additional driving scenarios are discovered—and they usually are—this may itself be a risk, if the discrepancy is large. This would indicate that there was some disagreement in the system's important goals between the stakeholders and the architect.

Step 8: Analyze Architectural Approaches

In this step the evaluation team performs the same activities as in step 6, using the highest-ranked, newly generated scenarios.

The evaluation team guides the architect in the process of carrying out the highest ranked new scenarios.

The architect explains how relevant architectural decisions contribute to realizing each one.

This step might cover the top 5-10 scenarios, as time permits.

Step 9: Present Results

The evaluation team confers privately to group risks into risk themes, based on some common underlying concern or systemic deficiency.

- For example, a group of risks about inadequate or out-of-date documentation might be grouped into a risk theme stating that documentation is given insufficient consideration.
- A group of risks about the system's inability to function in the face of various hardware and/or software failures might lead to a risk theme about insufficient attention to backup capability or providing high availability.

For each risk theme, the evaluation team identifies which of the business drivers listed in step 2 are affected.

- This elevates the risks that were uncovered to the attention of management, who cares about the business drivers.

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Step 9: Present Results

The collected information from the evaluation is summarized and presented to stakeholders.

The following outputs are presented:

- The architectural approaches documented
- The set of scenarios and their prioritization from the brainstorming
- The utility tree
- The risks discovered
- The nonrisks documented
- The sensitivity points and tradeoff points found
- Risk themes and the business drivers threatened by each one

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Lightweight Architectural Evaluation

Lightweight Architectural Evaluation

An ATAM is a substantial undertaking.

- It requires some 20 to 30 person-days of effort from an evaluation team, plus even more for the architect and stakeholders.
- Investing this amount of time makes sense on a large and costly project, where the risks of making a major mistake in the architecture are unacceptable.

We have developed a Lightweight Architecture Evaluation method, based on the ATAM, for smaller, less risky projects.

- May take place in a single day, or even a half-day meeting.
- May be carried out entirely by members internal to the organization.
- Of course this lower level of scrutiny and objectivity may not probe the architecture as deeply.

Because the participants are all internal to the organization and fewer in number than for the ATAM, giving everyone their say and achieving a shared understanding takes much less time.

The steps and phases of a Lightweight Architecture Evaluation can be carried out more quickly.

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Typical Agenda: 4-6 Hours

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Step	Time	Notes
1. Present the ATAM	0 hours	Participants already familiar with process.
2. Present business drivers	0.25 hours	The participants are expected to understand the system and its business goals and their priorities. A brief review ensures that these are fresh in everyone's mind and that there are no surprises.
3. Present architecture	0.5 hours	All participants are expected to be familiar with the system. A brief overview of the architecture, using at least module and C&C views, is presented. 1-2 scenarios are traced through these views.
4. Identify architectural approaches	0.25 hours	The architecture approaches for specific quality attribute concerns are identified by the architect. This may be done as a portion of step 3.
5. Generate QA utility tree	0.5- 1.5 hours	Scenarios might exist: part of previous evaluations, part of design, part of requirements elicitation. Put these in a tree. Or, a utility tree may already exist.
6. Analyze architectural approaches	2-3 hours	This step—mapping the highly ranked scenarios onto the architecture—consumes the bulk of the time and can be expanded or contracted as needed.
7. Brainstorm scenarios	0 hours	This step can be omitted as the assembled (internal) stakeholders are expected to contribute scenarios expressing their concerns in step 5.
8. Analyze architectural approaches	0 hours	This step is also omitted, since all analysis is done in step 6.
9. Present results	0.5 hours	At the end of an evaluation, the team reviews the existing and newly discovered risks, nonrisks, sensitivities, and tradeoffs and discusses whether any new risk themes have arisen.

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Summary

If a system is important enough for you to explicitly design its architecture, then that architecture should be evaluated.

The number of evaluations and the extent of each evaluation may vary from project to project.

- A designer should perform an evaluation during the process of making an important decision.
- Lightweight evaluations can be performed several times during a project as a peer review exercise.

The ATAM is a comprehensive method for evaluating software architectures. It works by having project decision makers and stakeholders articulate a precise list of quality attribute requirements (in the form of scenarios) and by illuminating the architectural decisions relevant to carrying out each high-priority scenario. The decisions can then be understood in terms of risks or non-risks to find any trouble spots in the architecture.

Lightweight Architecture Evaluation, based on the ATAM, provides an inexpensive, low-ceremony architecture evaluation that can be carried out in an afternoon.

Thank you……..

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Credits

- **Chapter Reference from Text T1: 21**
- Slides have been adapted from Authors Slides Software Architecture in Practice – Third Ed.
  - Len Bass
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