



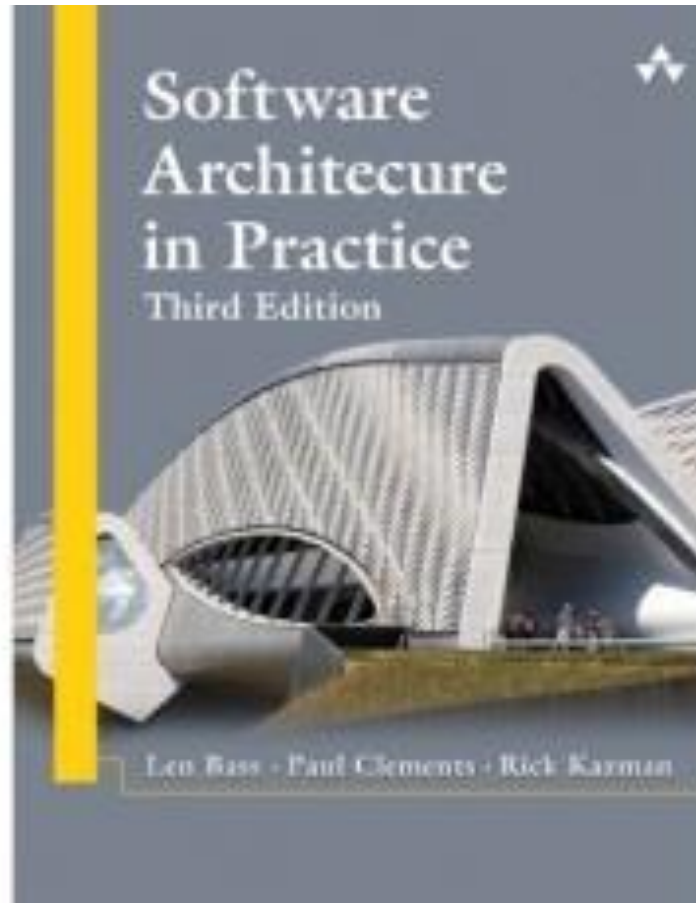
SE 4352

Software Architecture and Design

Fall 2018

Module 7

Chapter 21





Architectural analysis

- Architectural analysis is neither easy nor cheap
- The benefits typically far outweigh the drawbacks
- Early information about the system's key characteristics is indispensable
- Multiple analysis techniques often should be used in concert
- “How much analysis?”
 - This is the key facet of an architect's job
 - Too many will expend resources unnecessarily
 - Too few will carry the risk of propagating defects into the final system
 - Wrong analyses will have both drawbacks



Why?

We need method in which the right questions are asked *early to*:

- ✓ Discover *risks* -- alternatives that might create future problems in some quality attribute
- ✓ Discover *sensitivity points* -- alternatives for which a slight change makes a significant difference in some quality attribute
- ✓ Discover *tradeoffs* -- decisions affecting more than one quality attribute



Three Forms of Evaluation

- Evaluation by the designer within the design process.
- Evaluation by peers within the design process.
- Analysis by outsiders once the architecture has been designed.

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.



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.

Peer Review Steps

Steps:

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.
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.
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.
4. *Potential problems are captured.* Real problems must either 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.

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.



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.



What's Architectural Tradeoff Analysis Method (ATAM)?

- Purpose: To assess the consequences of architectural decisions in light of quality attribute* requirements.
- Primarily a risk identification mechanism
- Not a predictor of quality achievement

*Quality attribute = “ilities”



The Architecture Tradeoff Analysis Method

- 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.

System Quality Attributes

- Performance
- Availability
- Usability
- Security

End User's view

- Maintainability
- Portability
- Reusability
- Testability

Developer's view

- Time To Market
- Cost and Benefits
- Projected life time
- Targeted Market
- Integration with Legacy System
- Roll back Schedule

Business
Community
view



Runtime System Qualities

Runtime System Qualities can be measured as the system executes.

Functionality- “ability of the system to do the work for which it was intended”

Performance – “response time, utilization, and throughput behavior of the system. Not to be confused with human performance or system delivery time”

Security – “measure of system’s ability to resist unauthorized attempts at usage or behavior modification, while still providing service to legitimate users”

Availability (Reliability quality attributes falls under this category) – “measure of time that the system is up and running correctly; the length of time between failures and the length of time needed to resume operation after a failure”

Usability- “ease of use and of training the end users of the system. Sub qualities: learnability, efficiency, affect, helpfulness, control”

Interoperability – “ability of two or more systems to cooperate at runtime”



Non-Runtime System Qualities

Non-Runtime System Qualities cannot be measured as the system executes.

Modifiability – “ease with which a software system can accommodate changes to its software”

Portability – “ability of a system to run under different computing environments. The environment types can be either hardware or software, but is usually a combination of the two.”

Reusability – “degree to which existing applications can be reused in new applications”

Integrability – “ability to make the separately developed components of the system work correctly together”

Testability – “ease with which software can be made to demonstrate its faults”



Business Qualities

Non-Software System Qualities that influence other quality attributes.

Cost and Schedule – “cost of the system with respect to time to market, expected project lifetime, and utilization of legacy and COTS systems”

Marketability – “use of the system with respect to market competition”

Appropriateness for Organization – “availability of the human input, allocation of expertise, and alignment of team and software structure. Business process re-engineering”

ATAM Overview

- Proposed by Kazman as a technique for understanding the tradeoffs points or dependencies among the attributes, inherent to architecture evaluation.
 - ***The purpose of the ATAM is: to assess the consequences of architectural decision alternatives in light of quality attribute requirements [Kazman].***
- Provides a way to evaluate software architecture's fitness with respect to multiple competing quality attributes.
- Since these attributes interact, the method helps to reason about architectural decisions that affect quality attribute interactions.
- Follows a spiral model of design, postulating candidate architectures followed by analysis and risk mitigation, leading to refined architectures.



More on purpose of ATAM

- The purpose of an ATAM is NOT to provide precise analyses . . . the purpose IS to discover risks created by architectural decisions.
- We want to find *trends*: correlation between architectural decisions and predictions of system properties.
- Discovered risks can then be made the focus of mitigation activities: e.g. further design, further analysis, prototyping.



Benefits of ATAM

- Clarified quality attribute requirements
- Improved architecture documentation
- Documented basis for architectural decisions
- Identified risks early in the life-cycle
- Increased communication among stakeholders
- The most important benefit is *improved architectures*.

ATAM - Vocabulary

- **Scenario** – A scenario is a short statement describing an interaction of one of the stakeholders with the system
- **Stakeholder** – An individual, team, or organization (or classes thereof) with interests in, or concerns relative to, a system
- **Architectural view** – A representation of a whole system from the perspective of a related set of concerns
- **Functional requirements** - specify what software has to do
- **Non-functional requirements** - specify how well it should be done
- **Non-Risks** – good decisions, implicit in architecture
- **Risks** – potentially problematic architectural decisions
- **Sensitivity Points** – parameters in the architecture to which some measurable quality attribute is highly correlated
- **Tradeoffs** – affects more than one quality attribute and is a sensitivity point for more than one attribute

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.*

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 - 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.

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

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

- 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.

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



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.

Step 2: Present Business Drivers

- 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)



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.



Step 4: Identify Architectural Approaches

- 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.

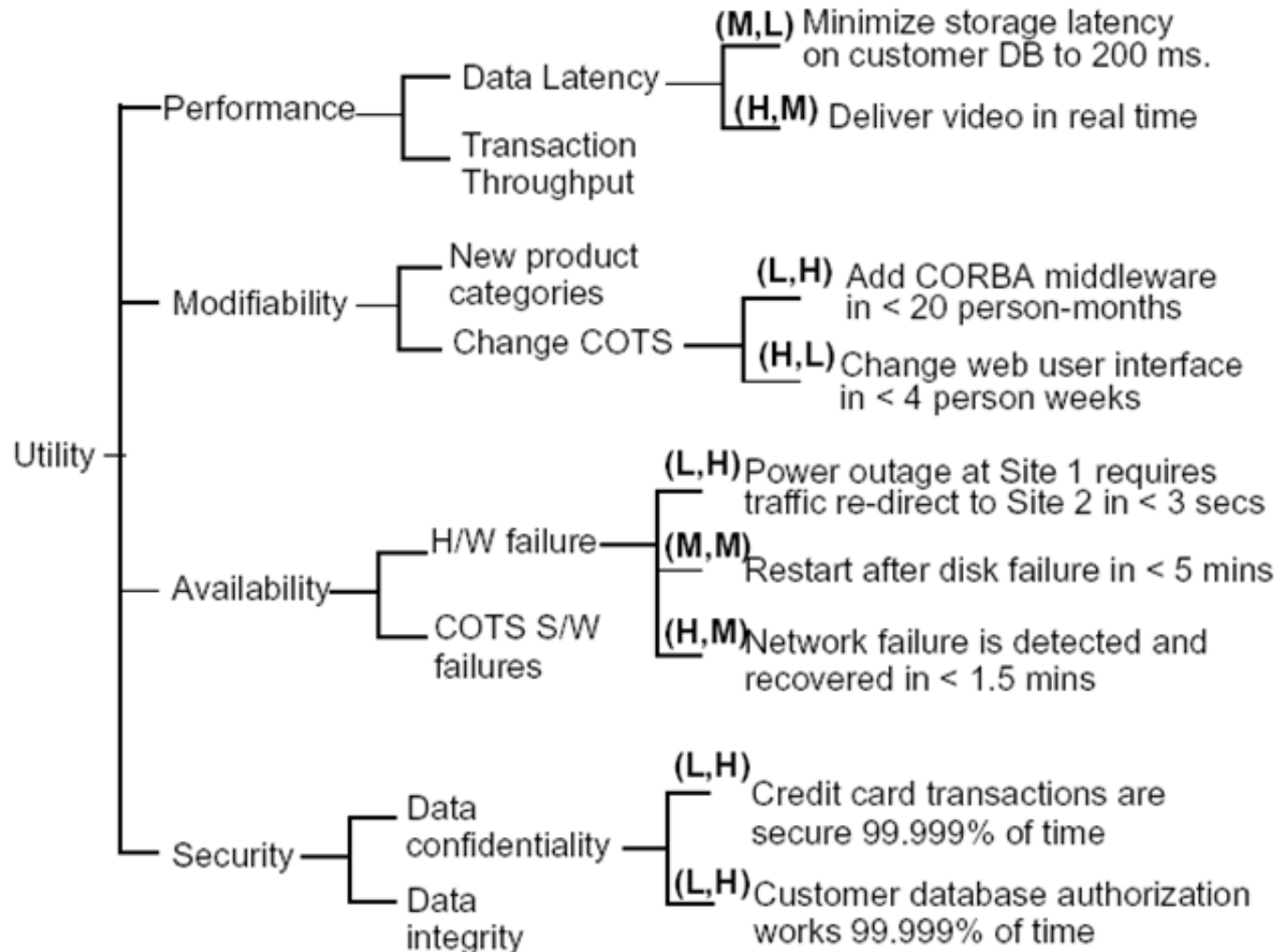


Step 5: Generate Utility Tree

- 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 5: Utility Tree

*(Business Value, Architectural Impact)



Step 5- Scenarios

- **Scenarios are used to**
 - Represent *stakeholders'* interests
 - Understand quality attribute requirements
- **Scenarios should cover a range of**
 - Anticipated uses of (use case scenarios),
 - Anticipated changes to (growth scenarios), or
 - Unanticipated stresses (exploratory scenarios) to the system.
- **A good scenario makes clear what the stimulus is that causes it and what responses are of interest.**

Step 5 – Scenario examples

- **Use case scenario**

- Remote user requests a database report via the Web during peak period and receives it within 5 seconds.

- **Growth scenario**

- *Add a new data server to reduce latency in scenario 1 to 2.5 seconds within 1 person-week.*

- **Exploratory scenario**

- Half of the servers go down during normal operation without affecting overall system availability.

- **Scenarios should be as specific as possible.**

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.

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.



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

Lightweight Architectural Evaluation

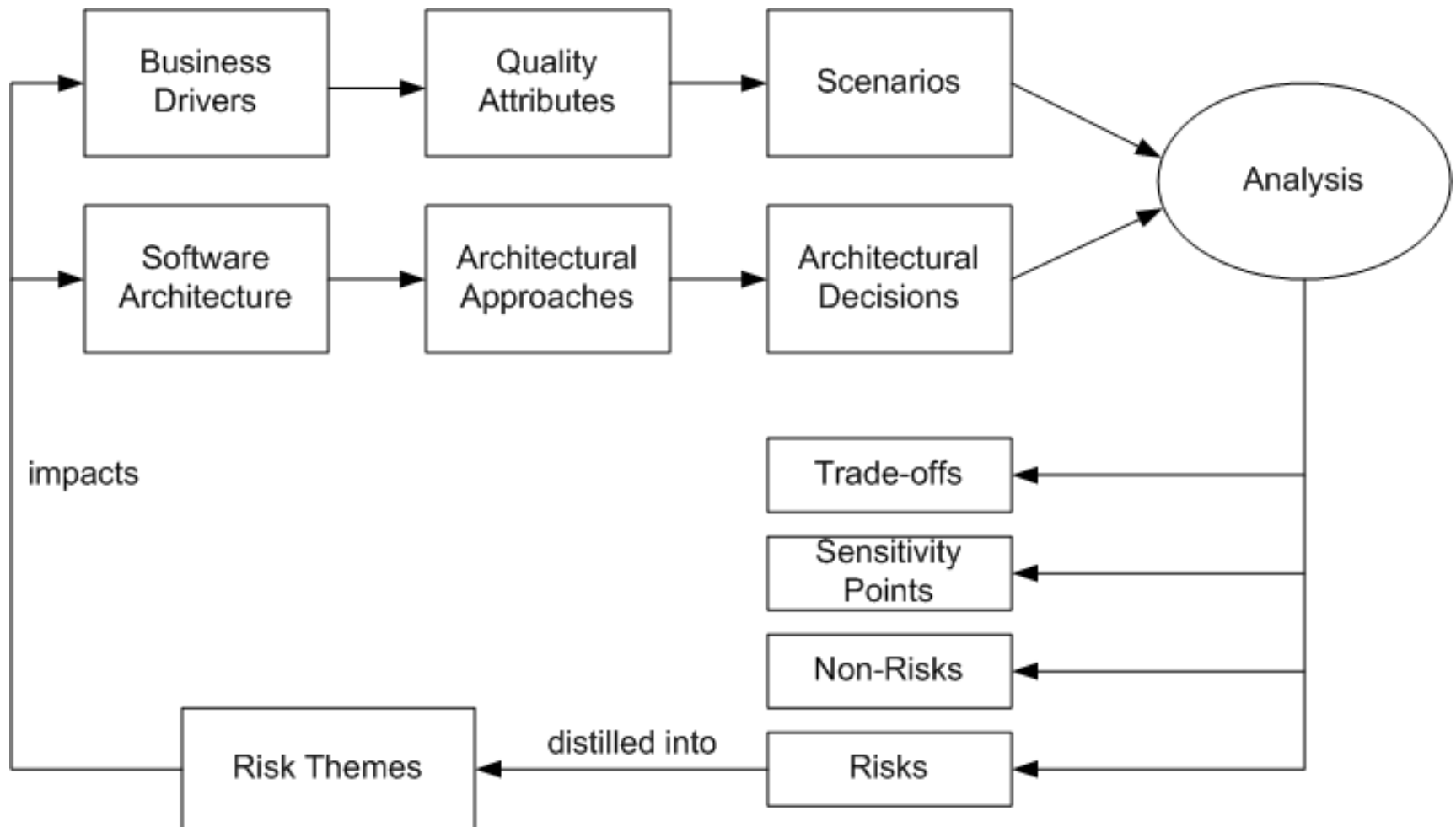
- An ATAM is a substantial undertaking.
 - It requires some 20 to 30 person-days of effort from an evaluation team, plus even more for the architect and stakeholders.
 - Investing this amount of time makes sense on a large and costly project, where the risks of making a major mistake in the architecture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



Typical Agenda: 4-6 Hours

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.

ATAM Process



InClass Group Project

- Teams of 4 to 5
- Using the utility tree that you wrote for the Automated teller machine, capture any two risks, sensitivity points and/or tradeoff points for ATAM method.
- Write down team answer
- Turn in for display to all students



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 nonrisks 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.

