METHODS FOR EVALUATING SOFTWARE ARCHITECTURE-A SURVEY
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Abstract
In software systems, the software architecture evaluation methods play major role to increase the software quality attributes like maintainability and reliability in a system. Evaluation is used to test whether the architecture has met the desired quality requirements. Depending on the quality attributes, there are many methods and techniques came forward for evaluation of software architecture. This paper covers the fundamentals of 13 software architecture evaluation methods and compares them. The overall advantages and disadvantages of the evaluation methods are discussed here. The observation resulted from this paper is useful for the better understanding and design of software architecture evaluation methods.

1. Introduction
Software architecture acts as a blueprint for the development process of a system. Building an effective architecture is a challenging task with increase in number of users and functionalities day by day. System qualities such as performance, security and modifiability can be achieved by the architecture vision. Software architecture can be a design document for maintaining quality of systems. It describes software components, their functions and their interactions with each other. Architecture is the foundation for every software system.

The software architecture goal is to identify the quality attributes, their characteristics and risks in the design. Architecture can be evaluated at every stage of the development process. Evaluating in early stages is the crucial task. The evaluation goal is to determine that the software architecture satisfies the quality requirements. It is necessary to ensure that the selected architecture meets the project needs. Architecture evaluation helps to document and analyze the project’s architecture. There are many approaches to evaluate the software architecture like, simulation-based, scenario-based, experienced-based and mathematical-based. An experience-based evaluation is done according to the
previous experience and knowledge source of the developers. Simulation-based evaluation is done according to software modules and their implementation at high level-design. Mathematical model gives the non-functional requirements like reliability, performance, security using mathematical-concepts. A scenario-based evaluation is done by creating scenario profiles for the evaluation of quality attributes. These evaluation of software architectures are implemented at various stages of software development process. There are early scenario based evaluation methods, they are SAAM-Scenario-based software architecture analysis method.

ATAM-Architecture-based Trade off Analysis Method
ALPSM-Architecture Level Prediction of Software Maintenance
ALMA-Architecture-Level Modifiability Analysis
SBAR-Scenario Based Architecture Reengineering
SALUTA-Scenario-based Architecture Level Usability Analysis
SAAMCS-SAAM for Complex Scenarios
ESAAMI-Extending SAAM by Integration in the Domain
ASAAM-Aspectual Software Architecture Analysis Method
SACAM-Software Architecture Comparison Analysis Method
DoSAM-Domain-Specific Software Architecture Comparison Model
CBAM-Cost Benefit Analysis Method
FAAM, Family – Architecture Analysis Method

We will be discussing few methods in brief.

This paper plays important role for deriving best software architecture evaluation methods by reviewing the existing methods. This paper provides technical and non-tech issues in software architecture evaluation methods and distinguishes among them by defining their applicability in various fields.

In this paper: Section 1 gives details about previous surveys. Section 2 describes software architecture evaluation methods. In Section 3 comparison is made among the scenario-based evaluation methods. In Section 4 open problems are discussed in the scenario-based evaluation methods. Section 5 includes conclusion.

2. Literature Review

It is difficult to implement the software design which makes the software architecture more complex before fixing the
requirements and resources software architecture must be evaluated, using various methodologies and functions software architecture is evaluated and created. The quality attributes are non-functional requirements like reusability, scalability, performance, security and integrity. These methods are:

Each and every method has various goals which are implemented at different levels in software development life-cycle process. This paper distinguishes the evaluation methods and also identifies the similarities among the methods.[8][9]. Research works are being processed regarding software architecture evaluation methods.[10] To choose the particular method without any confusion for the software developers and the managers a framework for Comparing Software Architecture Analysis Methods (FOCSAAM) is proposed. There are many other works proposed for evaluation methods, based on different factors in the context.

Software architecture is implemented and evaluated at each and every stage of software development life cycle. In the initial phase of software life cycle process, architecture is compared with the alternatives for the strengths and weakness. There are many approaches for the evaluation of the software architecture like scenario-based evaluation, mathematical-based evaluation and simulation based evaluation. Among these scenario based is the most used approach which simplifies the architectural analysis.

**A. Scenario-Based Architecture Analysis Method (SAAM)**

SAAM is the first scenario-based software architecture analysis method. The goal is to verify architectural principles and assumptions against documents which describe the properties of a system. Analysis helps to identify the risks that may be inherited in the architecture. [6]SAAM also gives us the opportunity to express many quality attributes or non-functional requirements like, maintainability, reliability etc.

This method includes six steps overall.

In the first initial step, is to develop scenarios. It gives information about the candidate architecture providing a basis for all the team members to understand in the similar way.

Then, the description of architecture is done by creating more scenarios for better understanding of the activities and changes in the system. Classifying and prioritizing scenarios, they are divided into two: direct and indirect. Direct scenarios can be executed without any changes but Indirect scenarios require changes to execute it. For the evaluation of candidate architecture we need to weigh each scenario, where individual evaluation is done. We can measure the modularity of the architecture through interacting components. Overall evaluation is performed to compare multiple
architectures.

This method is widely used and adopted in the following cases such as embedded audio system, user interface development environment, internet information systems, WRCS (a revision control system), global information system and keyword in context (KWIC)

B. Architecture Trade-off Analysis Method (ATAM)

The architecture trade-off analysis method (ATAM) uses many quality attributes or non-functional requirements like reliability, maintenance and security. This method is used for maintaining the trade-offs for the quality attributes.[7]

The objective of ATAM is to design the software architecture so that it satisfies the requirements efficiently. ATAM is an extended version of SAAM.

This method consists of four phases:

1. Presentation
2. Investigation and analysis.
3. Testing
4. Reporting.

The overall process in these four phases can be described in nine steps.

The initial three steps include exchanging data by presentations.

The key quality attributes are assessed by the next 3 steps which are related to architectural approaches. The testing phase in the next 2 steps compares previous phase results to the current stakeholder needs.

At last, based on the information gathered, the team including evaluators present this process to the stakeholders.

ATAM is a well-defined method which is widely being used from the past few years.

C. Architecture-Level Modifiability Analysis (ALMA)

ALMA is a scenario-based method which is used in the software architecture for modification of the quality attributes.

The general goals are to predict the modification costs, identify system inflexibility and comparing with alternative architectures. The modification is done by using the following practices like maintenance cost prediction and risk assessment. Architecture-Level Modifiability Analysis (ALMA) is created by the combination of two methods by Lassing et al., and Bangtsson et al.[1] These above methods are almost similar in structure as they are derived from scenarios. Their goal makes them different from one another.
In several studies validation of ALMA is given. Evaluation in ALMA includes five steps,
1. Setting the analysis goal,
2. Describing software architectures,
3. Eliciting scenarios,
4. Evaluating change scenarios,
5. Interpreting the results.

As there will be modifying scenarios this method is using impact analysis for architecture evaluation. In order to describe the results in quantitative a framework is adopted.

ALMA is used in different situations like
a. haemo dialysis system (a medical treatment device),
b. mobile positioning center assessment (a telecommunications service provider system),
c. ComBAD Framework assessment (a domain specific architecture for administrative systems)

D. SAAM for Complex Scenarios (SAAMCS)

SAAMS inherits properties from SAAM as it is derived and extended from it. SAAMCS is proposed to expose boundary conditions of system architecture with respect to flexibility. The objective of SAAM is to get information about risk at the time of system modification. This method can handle complex scenarios which can be hard to implement. There are 3 factors that influence complexity of scenarios, level of the scenario impact on architecture, need for co-ordination, presence of version conflicts. In the last document of software architectural design, SAAMCS is used.[2] The stakeholders involve in this method similar to SAAM. In case of implementation scenarios, SAAMCS plays important role in initiation. A measurement instrument is used to identify the complicated scenarios. This method is checked and verified in business system involving case studies. There is no tool available for the method automation.

E. Scenario-Based Architecture Re-engineering (SBAR)

The Scenario-Based Architecture Re-engineering (SBAR) is put forward by Bongtsson and Bosch. The architecture need to be redesigned for performance improvement and reliability quality attributes.[1] The objective of this method involves architectural transformation and quality analysis which iterate among them. It is similar to ATAM by supporting many quality attributes but it uses various features for evaluation purpose.
This method has 4 architectural evaluation tech:

1. scenario-based,
2. mathematical modeling,
3. simulation,
4. experience-based.

In scenario-based method, SBAR has different scenarios for each quality attribute and performance mapping with architecture is done.

SBAR is used and implemented in the following cases:

a. fire-alarm system,
b. measurement system
c. dialysis system

**F. Architecture Level Prediction of Software Maintenance (ALPSM)**

The Architecture Level Prediction of Software Maintenance (ALPSM) is mainly involved in ilities like maintainability.

In other words ALPSM is also developed for the comparison of several architecture alternatives. It is the extension of ALMA specifically involves to indicate about the risk problem.[9]

The required inputs for the above method are:

1. Architecture design,
2. Historical maintenance data.
3. Requirement specification
4. Software engineer expertization

The expected outputs for the above method are:

1. Estimated maintenance efforts
2. Maintenance profile.

The ALPSM benefits are:

1. For the practical usage in the design of the architecture.
2. Better understanding of the requirements

Haemo (Dialysis system) has been validated by this method.
G. Extending SAAM by Integration in the Domain (ESAAMI)

ESAAMI has the same features as SAAM but SAAM does not give the wide knowledge about reusability. SAAM does not give permission to change scenario for reuse. ESAAMI provide the knowledge which has been integrated from the existing scenario and therefore it is centralized domain process as well as the development process followed by reuse. ESSAMI comes up with the idea called “protosenario” [1][9]. The products which are reusable has been deployed during the execution of the steps. The feature like stakeholder involvement is also the same as in SAAM method. Further improvements are under progress.

H. Software Architecture Comparison Method (SACAM)

Software Architecture Comparison Method (SACAM) gives the option basis for the architecture selection using the comparison formula of several candidate architectures. Depending on the business goals of an organization numerous set of criteria’s has been used by this method. [1] Different contractors give the details

For the exploration of architecture design especially in product line architectures. Several architectures compared with SACAM by the following steps:

1. Preparation: Establish the business goals and the design architecture documents should be tested.
2. Criteria collation: For the comparison of candidate architectures numerous criteria has been selected.
3. Determination of extraction directives: From each and every candidate architecture views and ideas should be extracted.
4. View and indicator extraction: Documents should be extracted and search for existing styles and patterns.
5. Scoring: Gives the score about how well the software architecture method should be utilised in quality attribute.
6. Summary: Generate the reports with specialized recommendations.

I. SALUTA-Scenario-based Architecture Level Usability Analysis

SALUTA comes up with the special framework for accessing the quality attribute usability. Before the execution of software architecture evaluation methods the quality attribute usability had been accessed in this method SALUTA [2].

The information gets from the architecture are as follows:

1. Usability patterns
2. Usability properties

SALUTA is grouped into four divisions such as
1. Learnability
2. Reliability
3. Efficiency
4. Satisfaction.

**J. ASAAM-Aspectual Software Architecture Analysis Method**

To identify, specify and evaluate the aspects of software architecture design level ASAAM method is proposed. Depending on the SAAM method ASAAM increases the values and remove SAAM by joining the aspects of architecture in the analysis phase. ASAAM works in two phases:

1. It identifies aspects
2. It classify different types of components based on how they handle aspects

ASAAM depend on five artifacts:

1. Architecture
2. Problem description
3. Scenario
4. Aspect
5. Component.

**K. DoSAM-Domain Specific Software Architecture Comparison Model.**

In DoSAM, comparison of fitness between the candidate architectures has been applied for the selection of rationale in architecture process. Domain Architecture Comparison Framework (DACF) consists of five components which are created by DoSAM [2].

3. Relevant Quality attributes.
4. Quality attributes metrics.
5. Quality computation weights.

Components and connections are determined with each other.
L.CBAM-Cost Benefit Analysis Method

When software system is planned costs is added as the quality attribute which is considered as trade-offs. Costs, benefits and risks are important when making the design decisions of software architecture [3][4].

The following are the CBAM inputs:

1. The business goals.
2. The architectural decisions and possible trade-offs.
3. The quality attributes economical constraints and expectation level.

There are various steps in this evaluation process.

M.FAAM-Family-Architecture Assessment Model

FAAM is mainly focused two quality aspects such as Interoperability and extensibility [3][5]. The aim is to access information-system family architectures.

4.COMPARISON OF SCENARIO-BASED EVALUATION METHODS

We have been discussed several architecture evaluation methods. SAAM is the basis of all methods [8][1].

Comparison of several architecture evaluation methods has been made with the help of architecture elements such as

1. Method’s goal,
2. Evaluation approaches,
3. Quality attributes,
4. Applicable project stage,
5. Method’s activities,
6. Stakeholder’s involvement,
7. Method’s application,
8. Tool support

The description of the above mentioned architecture elements as follows:

**Method’s goal(s):**

Software architectures are recognized by using the evaluation methods for the fulfillment of the quality requirements.

SAAM and the methods depend on SAAM such as ESAAMI and SAAMCS are used to identify the risk potentials of the architectures. Among several quality attributes, analysis of trade-offs and sensitivity has been done by ATAM. Illities
such as maintainability has been noticed by ALMA and ALPSM. Method activities have been carried by SBAR. SACAM had done comparison between the architectures as well as the various domains.

**Evaluation approaches:**

The techniques of architecture evaluation are grouped into:

1. Measuring
2. Questioning techniques

The method such as SAAM and SAAMC S are completely scenario based methods. The techniques such as questioning and measuring have been done by the method called ATAM. Scenarios such as realization of goals and maps are done by ALMA. Maintainability estimation has been carried out by ALPSM while designing the architecture. Numerous approaches are applied for the architecture evaluation by SBAR. Fitness is realized by comparing the candidate architectures with one another by SACAM.

**Quality attributes:**

Several methods use several utilities for the various architectures. Few use single or unique quality attribute whereas some other methods use huge or many quality attribute such as performance, security, maintainability and availability. In the initial stage SAAM was first used for change or modifications purpose but now for the evaluation purpose it is applied as the generic method. Hybrid approach is applied by ATAM for recognizing the architectures simultaneously with many utilities. ESAAMI and ALMA are applied for the changes in the architectures. Utilities such as flexibility is carried out by SAAMCS. Several quality attributes are involved in SBAR method.

**Applicable project stage:**

Architectures are corrected by the start and end of the SDLC process. The methods of evaluation is also divided into start and end evaluation methods. In the final stage of evaluation methods SAAM and its related types has been identified. After the detailed description of the design phase as well as the iteration process ATAM is used. During the stage of reengineering and SBAR is used. During the design phase of architecture the quality attribute such as maintainability and its perfection is done by ALMA and ALPSM.

**Method’s activities:**

Multiple activities are carried out by various architectures. Various methods have various number, order and nature. Six activities were carried out by ESSAMI and SAAM. Some activities which are similar at higher level may slightly vary
when compared to lower level. Some activities are the collection of other activities. The method called ATAM has taken phase of four and nine activities. By using scenario profile, classification of scenarios is done by ALMA. For the measurement of complexity SAAMCS is used. If any modifications happened the respective system should adapt to the architecture as well as the new environment situation and this will be carried out by SBAR.

**Stakeholder’ involvement:**

Stakeholders play a wide role in the architecture evaluation process. The team of architecture evaluation has different types of stakeholders such as

1. system analyst,
2. marketing specialists
3. end users architecture team
4. system administrators
5. Software architects.

All wide range of stakeholders is taken care by SAAM and ESAAMI. Designers for architectures have been involved in execution of architectures by SBAR method. The methods such as ALPSM and SACAM have been applying only the architecture designers. Different activities stakeholders are applied by ALMA.

**Method’s application:**

Several engineering domains have applying the various evaluation methods. Large systems like battlefield control system; earth observation system is used by ATAM and ALMA. Established system called SAAM was evaluated in numerous cases such as

- Keyword in context (KWIC) systems
- Embedded audio systems
- Air traffic control,
- Internet information systems,
- Global information systems,
- WRCS (revision control system),
- User interface development environments

For business information systems SAAMCS is used.
SBAR applied on fire alarm system, measurement system, and dialysis systems

SACAM involves in product line migration.

**Tool Support:**

Design and evaluation of software architecture methods uses several tools. Tools are as follows:

- Architecture Evaluation Tool (AET),
- Arche Opterix
- Acme Simulator
- ArchE design assistant
- Desi

These tools are depending on scenarios. The tool called SAAMTOOL is specifically designed for the evaluation methods but fewer materials are available for this tool.

5. **Open Problems**

Scenario coverage is difficult to handle in the scenario based evaluation methods. Fewer evaluation methods which depend on the scenarios have giving the effective approach that supports the scenario elicitation. SAAMCS introduced the framework that gives the measurement instrument which gives a certain level in software architecture evaluation methods by showing the hidden assumption.

Quality function deployment is another step to deal the scenario based problem. According to the stakeholders needs it gives the countable number of matrices which resembles the importance of non-functional requirements. This method provides the solution for the scenario based problem.

Time consuming and resources are the two factors have been involved at the full scale architecture evaluation methods. Even for the small projects both the resources and man-power is needed.

For example:

ATAM requires 200-400 man-powers for the software architecture evaluation. The solution to the above problem is Domain specific software architecture (DSSA). Several problems have been solved using these methods.

**Advantages**

There is several architecture evaluation methods had been learned through this paper.

With respect to advantages, this paper helps to find the suitable architecture evaluation methods for the given scenario.
Each and every method is compared with one another and therefore every method has their own merits and demerits with respect to the scenario as well as the problem.

Each and every method is differs from one another with respect to the application as well as the results.

With the help of these methods many real-world problems has been solved.

The tools support can be extendable.

**Disadvantages**

Analyzing the problem in the implementation part is little bit difficult in the architectural design. These methods are similar to each other and so it made the slight confusion to analyze the suitable methods to solve the problem.

Stakeholders requirements such as both functional and non-functional need to be confirm before proceed to the next steps. Each and every steps need to be documented for the future use.

Fewer tools give less support to the system.

**Conclusion**

There are some set of criteria or facts for selecting the best evaluation methods in the development process. Architecture evaluation methods like SAAM (Scenario-based software architecture analysis method), ATAM (Architecture-based Trade-off Analysis Method) SBAR (Scenario Based Architecture Reengineering), ALMA (Architecture-Level Modifiability Analysis), ALPSM (Architecture Level Prediction of Software Maintenance) etc had been discussed in this paper.

Several architectural elements like stakeholder’s involvement, method’s goal, quality attribute, applicable project stage, method’s activities, method’s application, evaluation approaches and tool support are utilized in this paper. Different open problems had gone through this paper in the comparative analysis.

We need to have higher attention when using this in application analysis. Researches are highly focused on software architecture evaluation methods design effectively in the future.

**References**


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