INTERNATIONAL STANDARD

ISO/IEC/IEEE 42030

First edition
2019-07

Software, systems and enterprise — Architecture evaluation framework

Logiciel, systèmes et entreprise — Cadre d'évaluation de l'architecture

Reference number
ISO/IEC/IEEE 42030:2019(E)

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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the rules given in the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 7, *Software and systems engineering*, in cooperation with the Systems and Software Engineering Standards Committee of the IEEE Computer Society, under the Partner Standards Development Organization cooperation agreement between ISO and IEEE.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

The complexity of human-made systems has grown to an unprecedented level. This complexity leads to new opportunities and greater challenges for organizations that conceive, develop, industrialize, produce, maintain, utilize, recycle and dismantle enterprises, systems and software, and for various stakeholders that are impacted by these things. To address these opportunities and challenges, organizations increasingly apply concepts, principles, procedures and tools to drive better architecture strategies, make better architecture-related decisions, create more useful and effective architectures and improve architecture maturity. Architecture-related activities are not only strategic in nature; they are tactical and operational as well. Furthermore, the use of architecture frameworks, architecture description languages and generalist modeling languages have become common practice in commercial, public service, government, civil and military domains.

The concept of architecture used in this document goes beyond the case where the architecture entity is a system. Architecture is increasingly being applied to things not normally thought of as systems, including entities with system-like structure and behavior such as enterprises, services, data, business functions, mission areas, product lines, families of systems, software items, etc. This allows for a more generalized usage of the concept of architecture when the evaluation elements specified in this document are applied.

Architecture evaluations are performed for many reasons, such as:

a) determining if an entity of interest has been or is being architected in such a way that it fulfils its intended purpose (or can be changed in a way that suits a new purpose);

b) evaluating the effectiveness and suitability of an architecture towards addressing stakeholder needs and expectations;

c) identifying risks for mitigation;

d) identifying opportunities for the improvement of an entity or its architecture;

e) clarifying the problem space and stakeholder needs; and

f) assessing progress towards meeting architecture objectives.

Architecture evaluations can be performed on any kind of architecture, including a reference architecture, an architecture for a family of systems or an architecture for a product line where there are multiple kinds of architecture entities for a single architecture.

This document provides a generic, conceptual guiding framework that can be used for the planning, execution and documentation of architecture evaluations. Execution is addressed by specification of evaluation elements that can be used during performance of an evaluation effort. Planning and documentation are addressed by specification of work products for the evaluation effort. An organization using this document can establish specific frameworks for the work products and the evaluation elements that can be used as the basis for multiple, recurring architecture evaluation efforts. An organization can also establish tools, methods, best practices, capabilities and resources based on the generic framework provided in this document. The generic framework makes it easier to compare evaluations and evaluation frameworks used in specific cases. Implementation of the proposed architecture framework will in time result in improvement of architecture maturity of the organization.

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Software, systems and enterprise — Architecture evaluation framework

1 Scope

This document specifies the means to organize and record architecture evaluations for enterprise, systems and software fields of application.

The aim of this document is to enable architecture evaluations that are used to:

a) validate that architectures address the concerns of stakeholders;

b) assess the quality of architectures with respect to their intended purpose;

c) assess the value of architectures to their stakeholders;

d) determine whether architecture entities address their intended purpose;

e) provide knowledge and information about architecture entities;

f) assess progress towards achieving architecture objectives;

g) clarify understanding of problem space and of stakeholder needs and expectations;

h) identify risks and opportunities associated with architectures; and

i) support decision making where architectures are involved.

NOTE This document addresses the evaluation of an architecture and not an evaluation of the architecture description's suitability. Matters concerning the evaluation of the architecture description fall within the scope of the architecture conceptualization and architecture elaboration processes as defined in ISO/IEC/IEEE 42020. However, it is sometimes the case that the architecture description is evaluated concurrently with the evaluation of the architecture itself.

The entity being evaluated can be of several kinds, as illustrated in the following examples: enterprise, organization, solution, system, subsystem, business, data (as a data element or data structure), application, information technology (as a collection), mission, product, service, software item, hardware item, etc. The kind of entity can also be a product line, family of systems, system of systems, etc. It also spans the variety of applications that utilize digital technology such as mobile, cloud, big data, robotics, Internet of Things (IoT), web, desktop, embedded systems, and so on.

The generic Architecture Evaluation (AE) framework specified in this document can be used in support of the Architecture Evaluation process defined in ISO/IEC/IEEE 42020. Specific frameworks can be derived from this generic framework, which can provide a mapping to the system life cycle processes in ISO/IEC/IEEE 15288 or to the software life cycle processes in ISO/IEC/IEEE 12207.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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ISO, IEC and IEEE maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

— IEEE Standards Dictionary Online: available at: http://ieeexplore.ieee.org/xpls/dictionary.jsp

NOTE Definitions for other terms typically can be found in ISO/IEC/IEEE 24765[1)].

3.1
architecture
fundamental concepts or properties of an entity in its *environment* (3.7) and governing principles for the realization and evolution of this entity and its related life cycle processes

Note 1 to entry: *Architecture entity* (3.3) is the term used in this document when referring to the entity being architected or the entity subject to architecture processes. The fundamental concepts or properties of the architecture entity are usually intended to be embodied in the entity's components, the relationships between components, and the relationships between the entity and its environment.

Note 2 to entry: The concept of architecture used in this document applies broadly to the entity being architected or evaluated. This allows for a more generalized usage when the elements in this document are applied.

Note 3 to entry: The entity to be architected can be of several kinds, as illustrated in the following examples: enterprise, organization, solution, system, subsystem, business, data (as a data element or data structure), application, information technology (as a collection), mission, product, service, software item, hardware item, product line, family of systems, system of systems, etc. It also spans the variety of applications that utilize digital technology such as mobile, cloud, big data, robotics, Internet of Things (IoT), web, desktop, embedded systems, and so on.

Note 4 to entry: Representation of the concepts or properties of an entity and governing principles is captured in architecture models.

Note 5 to entry: Architectures can address a wide range of *concerns* (3.6) expressed, for example, through architecture views and models, as illustrated in the following examples associated with particular kinds of architectures such as: security architecture, functional architecture, physical architecture, resilience architecture, etc.

[SOURCE: ISO/IEC/IEEE 42020:2019, 3.3]

3.2
architecture description
work product used to express an *architecture* (3.1)

Note 1 to entry: This document does not require the existence or use of an architecture description when performing an *architecture evaluation* (3.4). Some *value* (3.10) assessment methods do not demand existence of documented architecture models or views. Examples are customer focus group, expert panels and quality workshops where sufficient knowledge of the architecture is in the people participating in use of these methods. The same is true for architectural analysis in that not all methods applied here necessarily need an explicit description of the architecture.

[SOURCE: ISO/IEC/IEEE 42010:2011, 3.3, modified — The abbreviated term "AD" has been removed; Note 1 to entry has been added.]

1) *System and software engineering — Vocabulary*, available at www.computer.org/sevocab.

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3.3
architecture entity
thing being characterized by an *architecture* (3.1)

EXAMPLE The following are kinds of architecture entities that can be dealt with by the architecture processes: enterprise, organization, solution, system (including software systems), subsystem, business, data (as a data element or data structure), application, information technology (as a collection), mission, product, service, software item, hardware item, product line, family of systems, system of systems, collection of systems, collection of applications, etc.

Note 1 to entry: When referring to the architecture itself of these architecture entities, it is common practice to place the name of the kind of entity in front of the word architecture. For example, the phrase system architecture is used when the thing being dealt with during the architecting effort is a system. Likewise, for the other kinds of entities that are being dealt with during the architecting effort.

[SOURCE: ISO/IEC/IEEE 42020:2019, 3.6, modified — The words "considered, described, discussed, studied, or otherwise addressed during the architecting effort" have been replaced with "characterized by an architecture".]

3.4
architecture evaluation
AE
judgment about one or more *architectures* (3.1) with respect to the specified evaluation objectives

EXAMPLE 1 Various kinds of judgments could be made during an architecture evaluation, such as validating that architectures address the *concerns* (3.6) of *stakeholders* (3.9), assessing the quality of architectures with respect to their intended purpose, assessing the *value* (3.10) of architectures or architecture entities to their stakeholders, determining whether architecture entities address their intended purpose, providing knowledge and information about architecture entities and identifying risks and opportunities associated with architectures.

EXAMPLE 2 Examples of architecture evaluations are provided in Annex C.

Note 1 to entry: A decision regarding disposition of the architecture is usually outside the scope of an AE effort, although it could be done in conjunction with the AE effort. The AE results are often reported to a decision maker who makes the actual determination of disposition based on those results and sometimes also on other *factors* (3.8) not considered by the AE effort. Sometimes this determination is called an "evaluation" but for the purpose of this document, the evaluation is limited to just the judgment with respect to relevant evaluation objectives.

3.5
architecture evaluation framework
conventions, principles and practices for evaluating *architectures* (3.1) in a consistent and repeatable manner

EXAMPLE Examples of AE frameworks are provided in Annex D for the following cases: Architecture Tradeoff Analysis Method (ATAM), the Method Framework and QUASAR method and Analysis of Alternatives (AoA).

Note 1 to entry: This framework can be generic in nature or specific to a domain of application, a collection of *concerns* (3.6) to be examined or a methodology. This document defines a generic AE framework and a specific AE framework can be derived from the generic framework.

Note 2 to entry: An AE framework can enable AE efforts to be performed in a more consistent and repeatable manner.

Note 3 to entry: The evaluation framework can consist of different sub-architecture frameworks for an entity with many layers or levels. These could be defined and consolidated as part of the comprehensive architecture framework package.

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3.6
concern
matter of interest or importance to a *stakeholder* (3.9)

EXAMPLE Affordability, agility, availability, dependability, flexibility, maintainability, reliability, resilience, usability and viability are examples of concerns. Survivability, depletion, degradation, loss, obsolescence are examples of concerns. The PESTEL mnemonic is a reminder of other possible areas of concern: political, economic, social, technological, environmental, and legal. A longer list of examples is provided in 4.2.

Note 1 to entry: The concept of concern is similar to "quality attributes" as used in the ATAM. See Annex D for an overview of the ATAM approach. In ATAM, quality attributes are typically decomposed into concerns.

Note 2 to entry: The concept of concern is similar to the concept of quality. See A.4 for an overview of the quality concept.

[SOURCE: ISO/IEC/IEEE 42020:2019, 3.8, modified — In EXAMPLE, reference to 4.2 has been added; Notes 1 and 2 to entry have been added.]

3.7
environment
context determining the setting and circumstances of influences upon an *architecture entity* (3.3) or upon which the architecture entity can have an influence

Note 1 to entry: There can be things beyond the environment that have an indirect impact on the architecture entity. It could be important to account for these indirect effects by incorporating these causative agents in the environment even though they are not usually considered to be within the immediate context. *Value* (3.10) chain analysis is an example of where this is done.

3.8
factor
circumstance, fact or influence that contributes to a result or outcome

Note 1 to entry: A factor is something that contributes causally to a result. Factors identification can sometimes be driven by knowledge of desired effects.

3.9
stakeholder
role, position, individual or organization having a right, share, claim or other interest in an *architecture entity* (3.3) or its *architecture* (3.1) that reflects their needs and expectations

[SOURCE: ISO/IEC/IEEE 42020:2019, 3.20]

3.10
value
regard that something is held to deserve; the importance, worth, or usefulness of something to somebody

Note 1 to entry: *Architecture evaluation* (3.4) is focused primarily on the value of an *architecture* (3.1) with respect to *stakeholder* (3.9) *concerns* (3.6) or architecture objectives for that thing. However, sometimes the purpose of the evaluation effort is, by inference, to determine the impact of the architecture on the value of the *architecture entity* (3.3) when the entity is developed or evolved to align with the architecture concepts and properties.

Note 2 to entry: The determination of architecture value can take various aspects into account, such as worth, significance, importance, usefulness, benefit, and quality. These words have similar but not identical meaning. Worth is usually what one is willing to pay for something. Significance is about being worthy of attention. Importance is about the state or fact of being of great significance or value. Usefulness is about serving some purpose, or about being advantageous, helpful or of good effect. Benefit is about an advantage or profit gained from something. Quality is about the degree of excellence of something. Throughout this document, the term value is used to mean one or more of these other concepts, as appropriate.

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Note 3 to entry: Even though a new architecture could be found to be of greater value with respect to the current situation, this needs to be balanced against the costs and risks of adopting the new architecture. So, it is not necessarily the case that when examining architecture alternatives, the one with the maximum value is proposed as the preferred choice since the extra cost or risk of this architecture might not be worth the extra burden. This is sometimes referred to as the benefit-cost ratio or some other term with similar meaning.

Note 4 to entry: Value is determined primarily in the Value Assessment Tier of the evaluation framework illustrated in Figure 1. Requirements on value assessment are specified in 6.2.

4 Conceptual foundation

4.1 General

This clause introduces key concepts used in this document with respect to architecture evaluation. The terms and the concepts presented in this clause are used in Clauses 6 through 8 to express requirements. The conceptual model of architecture evaluation is presented in parts throughout this clause.

The generic AE framework work products and elements, illustrated in Figure 1 and specified in this document, can be used in support of the Architecture Evaluation process defined in ISO/IEC/IEEE 42020. Specific frameworks can be derived from this generic framework.

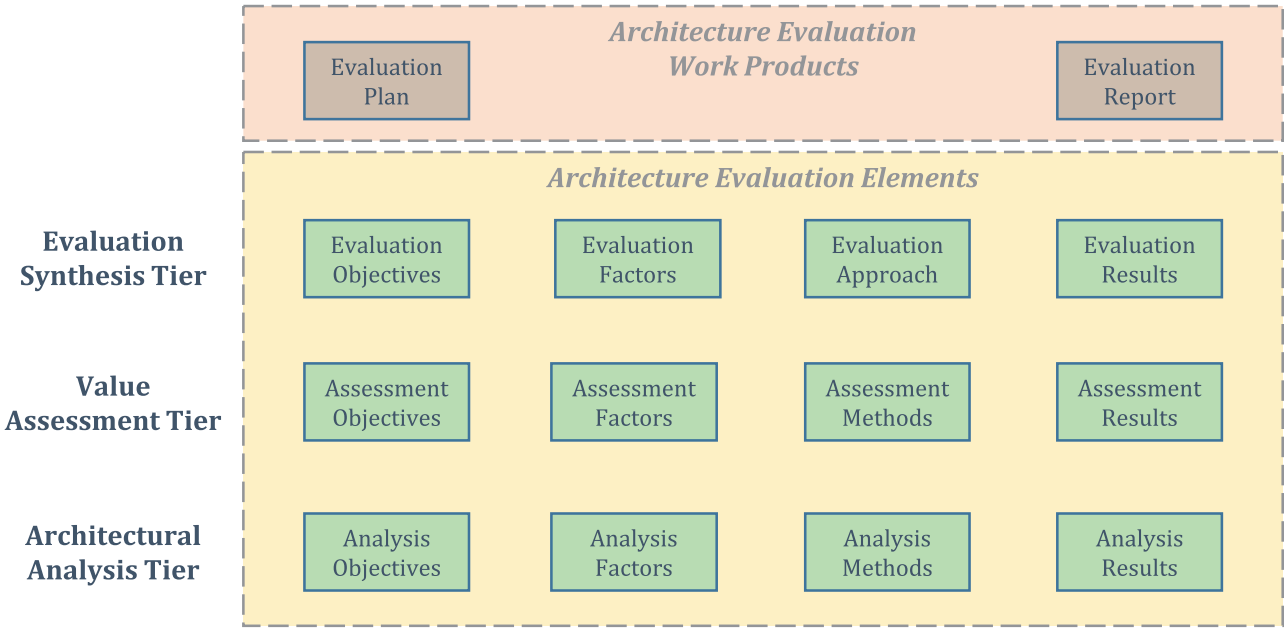


Figure 1 — Generic architecture evaluation framework

These specific frameworks may range from those targeting industry segments, such as automotive or refinery operations, to those targeting common business processes, such as portfolio management and program planning, and to those targeting common business architectures, such as banking, retail, insurance, telecom, travel and hospitality, etc. Specific frameworks allow the user to capture and reuse concepts common to many enterprises and thereby increase the efficiency with which architectures can be evaluated.

Architecture evaluation makes a judgment with respect to how well architecture objectives have been or will be achieved. It can provide answers to an identified set of questions to, for example, provide inputs to strategic decision making (such as whether it would be cheaper in the long run to modify an existing architecture to close value gaps), or to produce a new architecture that better addresses current and future stakeholder needs. An architecture evaluation can also provide inputs to decisions made at the operational and tactical levels. For example, the evaluation may provide useful information regarding capability limitations of the entity in question.

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The subclauses below describe the elements used in each tier of the generic framework and describe the different kinds of specific frameworks that utilize these elements.

4.2 Architecture evaluation context

Figure 2 depicts the context of architecture evaluation in terms of key concepts and the relations between them.

NOTE 1 The graphical notation used in this document is a simplified version of entity-relationship modeling.

NOTE 2 Only the key associations are shown in the diagrams.

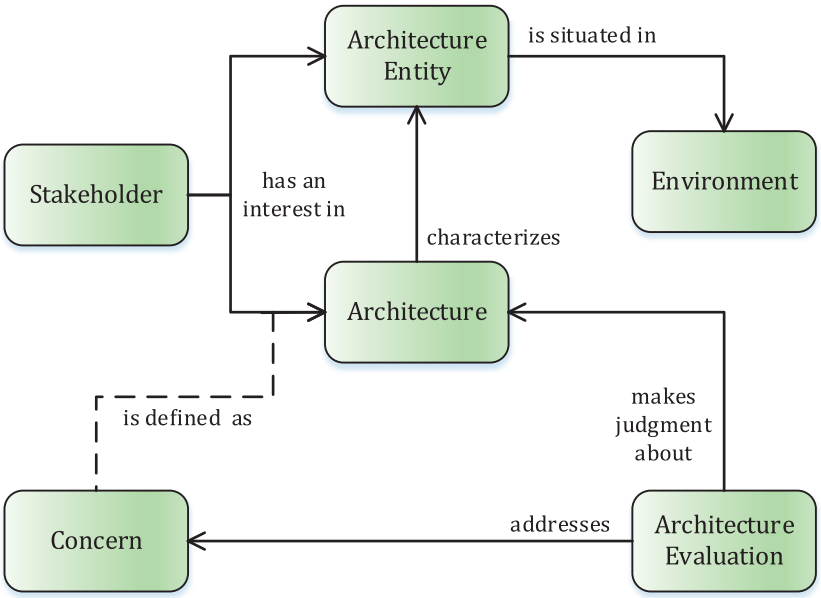


Figure 2 — Context of architecture evaluation

The AE effort can be performed at many stages of entity development, including during conceptual design through to during the operation and maintenance. The evaluation may need to be updated to reflect changes as the entity design progresses through its lifecycle.

An AE effort is often performed to determine the potential or actual value of the associated architecture entity. However, the primary focus of the AE effort is on the value of the architecture itself even though the ultimate aim could be a determination of the value of the architecture entity, or the impact on the environment, or the impact on the business that uses the architecture entity, etc. But the value of the architecture entity or other benefits might be determined by some other effort, such as system analysis, requirements analysis, business needs analysis, portfolio management, program assessment and evaluation, environmental impact assessment, etc.

Architecture evaluation makes a judgment regarding the extent to which architecture objectives have been or will be achieved. Because of this, it is dealing with the degree to which the architecture provides things such as needs satisfaction, feasibility, understandability, usability desired qualities.

The environment within which the architecture entity is situated could provide strategic context for determining the ways in which the architecture evaluation is conducted. The environment could also be a key factor in understanding the nature of stakeholder concerns. States and modes of operation of the architecture entity are often from the usage perspective of entities in the environment.

Stakeholders have interests in the architecture or associated architecture entities. These interests (called concerns) are usually the primary focus of architecture evaluation. This judgment provided by the AE effort represents the extent to which stakeholder concerns have been or will be satisfied by decisions that affect the associated architecture entities or their environments. This judgment can also

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represent the extent to which the architecture fulfills its intended purpose. Ways to measure this will be identified or specified during the AE effort along with the means by which these measures will be ascertained.

NOTE 3 Determination of the extent to which concerns are satisfied could entail either measurement of the degree to which something is done or a determination of whether something is true or not. Pass/fail criteria could need to be established prior to performing the evaluation. These criteria could be defined in the AE plan or could be established by the organization as a matter of policy or directive.

EXAMPLE 1 Stakeholders include people and organizations such as: users, operators, acquirers, owners, suppliers, developers, builders and maintainers. It also includes authorities engaged in certifying the architecture entity for a variety of purposes such as its readiness for use, conformance to legal provisions and compliance with regulations and policies with respect to safety, security, privacy, environmental impact, etc., as well as evaluators such as funding agencies, integration authorities, governance boards, management boards, client representatives and regulatory authorities. Stakeholders can go beyond individuals and organizations to also include things like governmental bodies, supply chains, value chains, institutions, and social groups, and.

EXAMPLE 2 Concerns include such things as: affordability, agility, alignment with business goals and strategies, autonomy, availability, behavior, business impact, capability, complexity, compliance to regulation, concurrency, control, cost, customer experience, data accessibility, deadlock, disposability, environment impact, error and exception handling, extensibility, evolvability, feasibility, flexibility, functionality, graceful degradation, information assurance, interoperability, inter-process communication, known limitations, maintainability, misuse, mission impact, modifiability, modularity, openness, performance, portability, privacy, quality of service, recoverability, reliability, resilience, resource utilization, schedule, security, shortcomings, state transitions through lifecycle, scalability, software and systems assurance (ISO/IEC 15026-1), structure, subsystem integration, architecture entity features, architecture entity properties, architecture entity purposes, usability, usage, viability, etc.

EXAMPLE 3 The PESTEL mnemonic is a reminder of other possible areas of concern: political, economic, social, technological, environmental, and legal. Survivability, depletion, degradation, loss and obsolescence are other examples of areas of concern. Other mnemonics that could be useful include STEEPLED that adds ethics and demographic factors, SPELIT that adds intercultural factors, STEER that adds regulatory factors and STEP that adds ecological factors.

EXAMPLE 4 Examples of value include such things as: physiological well-being, safety from harm, feelings, aesthetics, price, savings, sense of belonging, self-esteem and self-actualization.

Architecture principles, although not shown in the diagram, will shape the architecture and can perform a key role in the architecture evaluation. An understanding of these principles can help guide proper evaluation of an architecture. These principles will influence selection of AE factors used throughout the evaluation effort and help in the identification of relevant concerns. Architectural features and functions need to be consistent with the architecture principles. See Reference [17] and [18].

4.3 Architecture evaluation tiers

4.3.1 Evaluation synthesis

Synthesis involves the combination of results from multiple value assessments to determine to what extent the evaluation objectives will be achieved. Stakeholders who have concerns about the subject of the evaluation could have specific goals that should be addressed in the evaluation. (These concerns could be about the architecture, the architecture entity or both.) These goals should be considered when establishing the factors and objectives to be used in the evaluation. These goals might not correspond to the original goals for the architecture when it was initially conceived.

NOTE 1 The experts involved in the evaluation are also stakeholders and can bring important evaluation objectives that are not a known concern for traditional stakeholders (such as acquirer, user, service provider), but are concerns that the profession defines to be important (and where the evaluators could be the best placed stakeholders to represent the profession).

Architecture trade-offs are identified and characterized during architecture development. However, they can be revisited during the evaluation synthesis. Trade-offs among stakeholder concerns and feasibility limitations will be identified. Typical trade-offs to consider are the following: cost vs

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performance, cost vs schedule, weight vs speed, accuracy vs timeliness, acquisition cost vs operating cost, ease of use vs security, flexibility vs predictability, agility vs robustness, risk vs reward, etc. Trade-offs could be with respect to the various factors within a single architecture or across alternative architectures under examination.

An AE effort examines one or more architectures with respect to potential stakeholder concerns about the associated architecture entities. Figure 3 depicts AE elements that can be used in an evaluation synthesis effort in terms of the key concepts and the relations between them. Most of these concepts are also used in related standards described in Annex B.

NOTE 2 Value is determined primarily in the Value Assessment Tier of the evaluation framework illustrated in Figure 1. Requirements on value assessment are specified in 6.2.

The evaluation synthesis effort is the result of applying the concepts in the document during the evaluation of one or more architectures to determine their value to stakeholders or the extent to which the architecture objectives are satisfied.

NOTE 3 The evaluation synthesis effort is usually a non-trivial exercise that requires a pre-defined mapping of attributes and issues (gaps in desired outcomes) across the lineage of interactions between stakeholders and assets (and the services they rely upon to get their jobs done) and with respect to dependencies on the designs, development efforts and operations (used to deliver those assets and services), and finally with respect to the architectural artifacts relied upon by the designers, developers, users and operators.

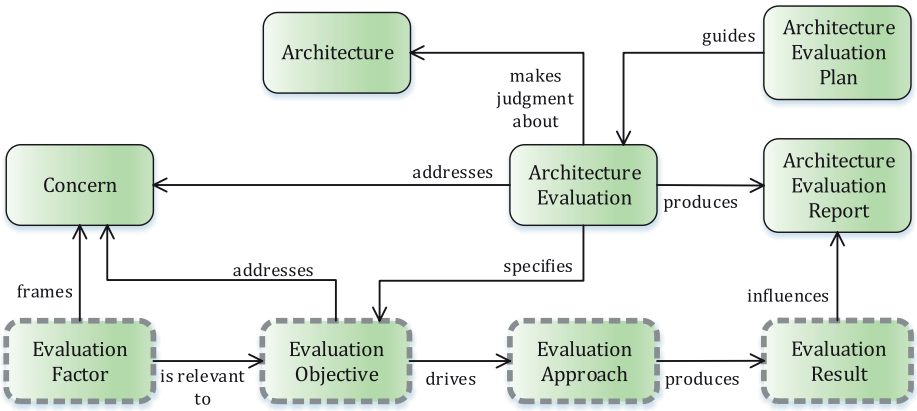


Figure 3 — Key concepts with respect to evaluation synthesis effort

AE objectives are derived from one or more of the relevant concerns. One or more AE approaches are used to address the AE objectives. AE objectives assigned to an AE approach help to determine what concerns are relevant to that approach and what approaches are relevant to each concern. More than one approach could be used within a single evaluation effort to improve the ability to address different aspects of the architecture leading to more accurate, cost-effective and timely evaluations.

EXAMPLE 1 Examples of AE approaches are: review panel, prototype demonstration, system experiment, modeling and simulation, model walkthrough, technical analysis, compliance audit, concept review and user symposium.

EXAMPLE 2 Examples of AE objectives are:

— Will the business solution meet primary business needs?

— Is the system affordable?

— Will the service be dependable?

— Will the product have sufficient market penetration?

— What is the return on investment?

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NOTE 4 The AE approach does not necessarily have to be highly structured or formal in nature, which is why this is not called a "method." A method, on the other hand, is a particular form of procedure for accomplishing something, especially a systematic or established one.

NOTE 5 Evaluation of artifacts used to guide the design, development and delivery of assets and/or services can provide useful insights when assessing the value of architecture(s).

Evaluation factors are established based on relevant stakeholder concerns. The evaluation factors will contribute to addressing one or more of the evaluation objectives. The evaluation approach determines how necessary information will be gathered and processed, and how evaluation criteria will be applied on the processed information to generate evaluation results for use in the AE report.

The evaluation approach will use value assessment results as one of the criteria for making judgment(s) about the architecture. Other criteria for making these judgments could include such things as technical feasibility, operational suitability, backward/forward compatibility, technology maturity, budget constraints, time limits, window of opportunity, intellectual property advantages, etc.

NOTE 6 Evaluation factors could be derived from the desired outcomes that stakeholders are trying to obtain from the services and assets they rely upon.

EXAMPLE 3 Examples of AE factors are cost, schedule, performance and risk.

The AE plan guides management and execution of the AE effort by specifying, among other things, the evaluation objectives. It documents the purpose and scope of the evaluation and the circumstances under which the AE effort will be conducted. It documents the expected schedule and resources to deliver the evaluation results. The AE plan describes the evaluation approaches that will be driven by the evaluation objectives. The AE plan, if appropriate, can also specify the methods to be used for value assessment and architectural analysis.

The AE plan identifies necessary information sources, such as:

— those that are useful for creating an understanding of the architecture as a basis for generating evaluation results and drawing valid conclusions;

— those that are useful for creating an understanding of architecture entities as a basis for making relevant judgments about the architecture; and

— non-architecture-related sources, such as business plans, cost data, project schedules, software code and operating manuals.

NOTE 7 The activities in the Architecture Evaluation process specified in ISO/IEC/IEEE 42020 can be used as a guide when planning an AE effort. The planning activity specified in that AE process provides recommended tasks for planning an AE effort.

The overall conclusions of the AE effort are provided in AE reports along with any supporting data and information.

NOTE 8 More than one report could be needed to address different audiences or possibly be provided as interim reports along the way. For example, the sponsor could receive a highly detailed report while the decision maker could receive a high-level summary with only the factors most relevant to the decision at hand. There could be a sensitive or classified version of the report for people with the appropriate clearances and another version that only contains unclassified or less sensitive information.

4.3.2 Value assessment

Value assessment is a determination regarding the amount and kind of value a stakeholder can expect from the architecture. Value can be defined as either a qualitative description or a quantitative extent of this expectation from the use, possession or operation of the architecture entity.

EXAMPLE 1 In some cases, the mere possession of an architecture entity can provide value to a stakeholder. For example, holding gold in the vault can provide security to the owner. A nation possessing a strong defensive capability can provide security to the citizens, hoping they never have to use such a capability.

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Value assessment may identify gaps as well as opportunities for improving stakeholder value. Information from architectural analysis contributes to value assessment.

An AE approach specifies one or more value assessment objectives to be used in the value assessment effort. The use of particular value assessment methods for an AE effort can be influenced by the nature of the AE objectives, the available information sources, prior evaluations of this kind, available evaluation methods and tools, anticipated value assessment results and relevant architecture methodologies.

EXAMPLE 2 Examples of Assessment methods are: multi-attribute utility analysis (MAUA), mission impact assessment, business case analysis, socio-economic analysis, strategy-to-task analysis, user focus group, analysis of alternatives, environmental impact assessment, etc.

EXAMPLE 3 Examples of assessment objectives are:

— Will the business solution provide adequate productivity improvement?

— Is the system usable by available personnel?

— Will the service provide information in a timely manner?

— Will the product provide accurate and timely data?

Figure 4 depicts the elements that can be used in a value assessment effort in terms of the key concepts and the relations between them. Value assessment objectives are intended to satisfy the AE objectives and frame the relevant stakeholder concerns. Value assessment factors will frame the relevant AE factors.

EXAMPLE 4 Examples of value assessment factors are: development cost, operational cost, development time, training time, ease of use, maintainability, resilience, dependability.

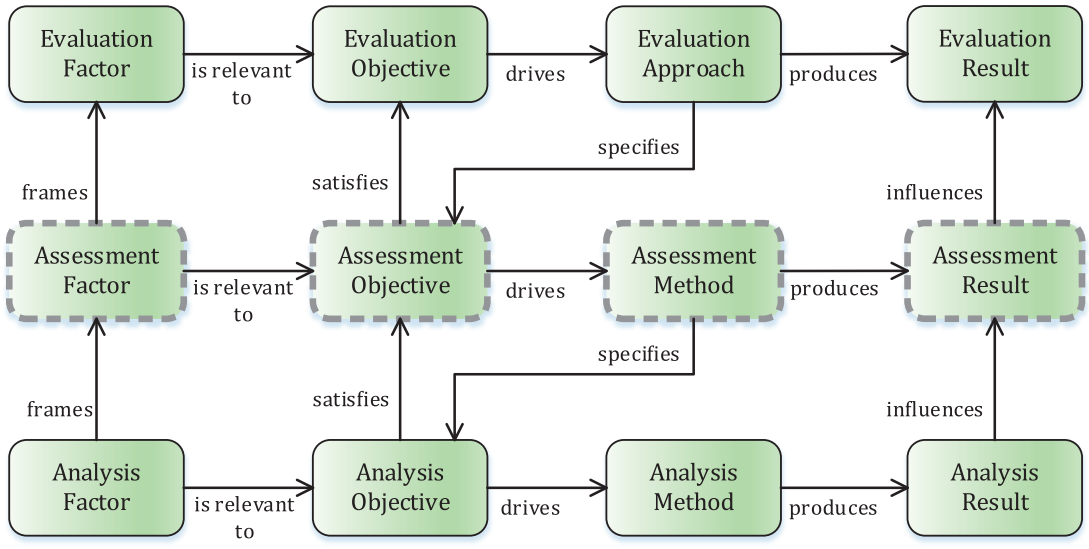


Figure 4 — Key concepts with respect to value assessment effort

The assessment method may prescribe how necessary information will be gathered and processed, and how value assessment criteria will be applied on the processed information to generate value assessment results for use by an AE approach. The assessment method can be decomposed into specific activities, tasks, roles and artifacts pertinent to that method.

NOTE 1 Where available, one or more applicable value models can be referenced to assist in formulating the value assessment criteria. Value models are information structures that organize metrics for a set of value assessment factors such that they can serve as tools for assessing and managing value. These models are built over time based on best practices and lessons learned for a variety of value assessment factors. Value models can be developed by an industry, established within an organization or derived from the architecture requirements specification. See for example the Structured Metrics Meta-Model[67].

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The assessment method will specify, if needed, objectives for one or more analysis methods to be employed and how the architectural analysis results will be used in the value assessment.

NOTE 2 If the information needed to perform a value assessment is already available from other sources (such as industry reports, design documentation, architecture descriptions, operational data, previous analyses, experiments, or demonstrations, etc.) then there can be no need to perform an architectural analysis.

4.3.3 Architectural analysis

Architectural analysis examines the key attributes of an architecture, e.g. its characteristics along particular dimensions such as security, cost, performance, and so on, or the relevant attributes of the architecture entity, as well as actual or potential impacts on stakeholders or on the environment. It also examines architecture vision, principles, concepts and properties, etc. that are relevant to achieving the architectural analysis objectives. Analysis may also look at other aspects of the architecture such as forms, patterns, structures, behaviors, functions, flows, and so on, as well as examining the assumptions that were made about technologies, operations, policies, constraints, etc.

NOTE 1 Architectural analysis is optional since the information needed to generate value assessment results could already be available from other sources, hence removing the need to do analysis. The AE plan will indicate if and to what extent that architectural analysis is needed for a particular AE effort.

An assessment method will employ, if needed, one or more analysis methods. The employment of particular analysis methods for a particular AE effort can be influenced by the nature of the assessment objectives, the available information sources, prior analyses of this kind, available analysis methods and tools, anticipated analysis results and relevant architecture methodologies.

EXAMPLE 1 Examples of Analysis methods are: functional analysis; object oriented analysis, performance analysis, behavioral analysis, cost and schedule analysis, risk and opportunity analysis, failure modes, effects and criticality analysis (FMECA), focus group surveys and Delphi method. (All of these methods can be used for architectural analysis, as well as for architecture development.)

EXAMPLE 2 Examples of analysis objectives are:

— Will the business solution have a positive return on investment exceeding the hurdle rate?

— Is the system producible in large enough quantities to meet the target price?

— Will the service provide enough bandwidth to meet expected user demand?

— Will the product deliver data fast enough to meet its requirements?

— Will the equipment be reliable enough to provide the expected level of availability?

Figure 5 depicts the elements that can be used in an architectural analysis effort in terms of the key concepts and the relations between them. Analysis objectives are intended to satisfy the assessment objectives and frame the relevant stakeholder concerns. Analysis factors will frame the relevant assessment factors.

EXAMPLE 3 Examples of analysis factors are: operational latency, accuracy, resolution, mean time between failure, uptime.

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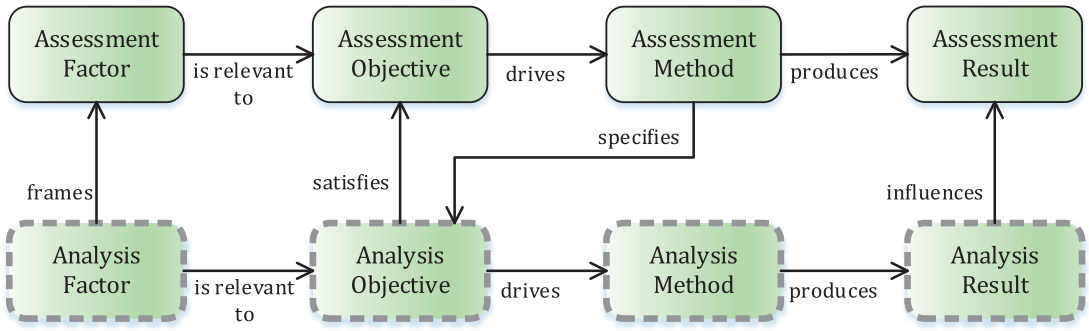


Figure 5 — Key concepts with respect to an architectural analysis effort

The analysis method may prescribe how necessary information will be gathered and processed, and how analysis criteria will be applied on the processed information to generate analysis results for use by an assessment method. The analysis method can be decomposed into specific activities, tasks, roles and artifacts pertinent to that method.

Analysis factors are identified based on the relevant architectural features, functions, quality characteristics, conceptual properties, and so on, related to the analysis objectives.

EXAMPLE 4 Examples of Analysis factors are: functionality, performance, number of interfaces, types of message elements transmitted and received, size, weight, power, cyber security, threat vulnerability, resilience, latency and response time.

NOTE 2 A measures model can be used as a foundation for evaluating and assessing the quality of an architecture. The measures model can provide insights on how to achieve alignment back to functional, operational and performance measures for the organization. This can provide justification for investing in good architecture practices (part of the business case). See for example the Structured Metrics Meta-Model provided by OMG[67]. See Annex A for information about quality characteristics and value.

4.4 Architecture evaluation conceptual model

The overall conceptual model used in this document for architecture evaluation is illustrated in Figure 6.

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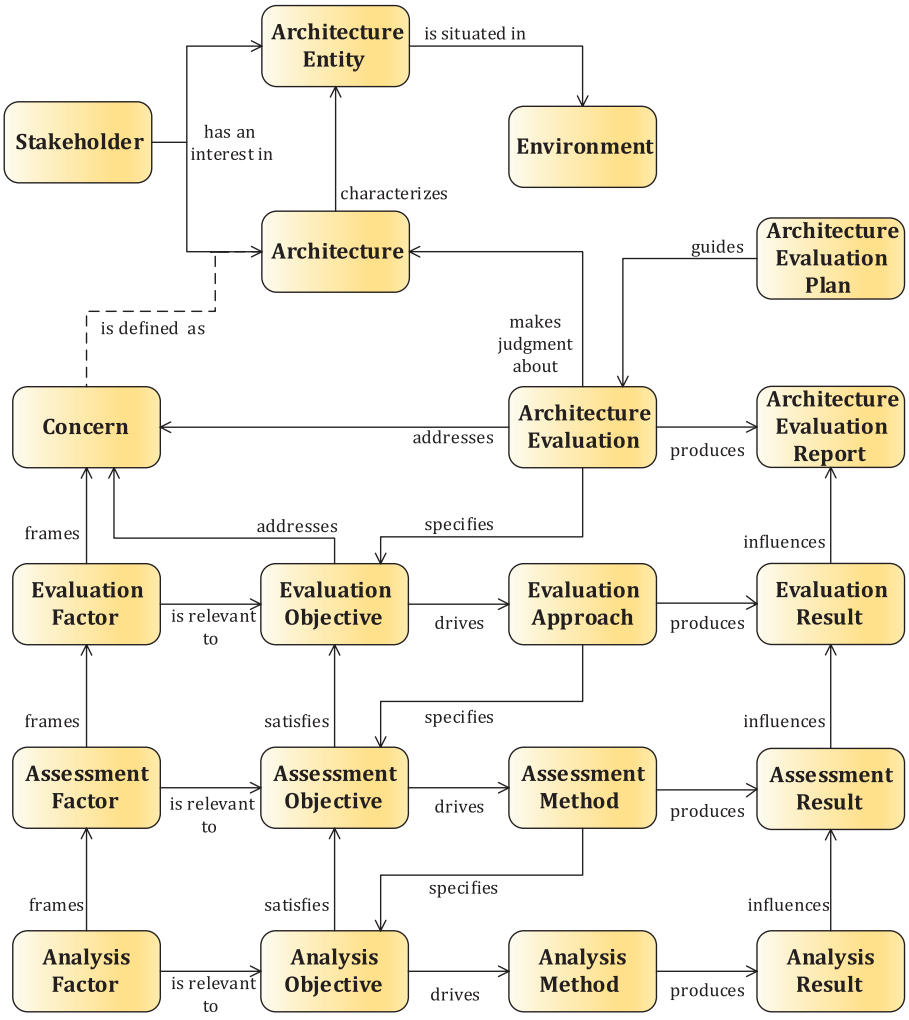


Figure 6 — Conceptual model for architecture evaluation

4.5 Comparison between assessment and analysis

Assessment is used to determine the extent to which an architecture provides value to stakeholders, where value is associated with addressing stakeholder concerns or meeting architecture objectives. Value is also associated with the extent to which the architecture is aligned to its intended purpose. A number of examples are provided in Table 1 to show the distinctions between assessment and analysis.

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Table 1 — Assessment vs analysis comparison

Characteristics	Value assessment	Architectural analysis
Goal orientation	Ends Objectives (often multi-level)	Means Objectives (often multi-level)
Results	Passes "judgment"	Matters of Fact
Breadth	Single, Unified Activity	Multiple, Separate Activities
Basis of work	Synthesis of analysis results	Technical and other analyses
Scope	Utility, Value, Worth, Priorities, Ranking, Trade-offs	Ways & Means
Focus	Effectiveness, Efficiencies, Equities	Performance determination, Limits identification (bounds)
Typical figures of merit	Measure of Effectiveness (MOE's), Return on Investment (ROI), Breakeven Point, Key Success Factors (KSF's)	Measures of Performance (MOP's), Key Performance Parameters (KPP's), Technical Performance Measures (TPM's), Quality Metrics
Key items of interest	Competing Concerns, performing trade-offs, achieving balance & robustness	Individual Concerns, determining system properties & characteristics
Primary questions of interest	So what? Who cares? What impacts? Why? Why not?	What, where, when, how, how much, how often?

4.6 Architecture evaluation factors

A factor is a circumstance, fact or influence that contributes to a result or outcome. It is something that contributes causally to a result. Identification of factors can sometimes be driven by knowledge of desired effects. Factors should be consistent with the architectural principles that shaped the architecture; and these principles should influence selection of factors to use in the evaluation.

The factors used in an architecture evaluation are central in helping to organize the evaluation effort and to achieve more transparent and understandable results.

EXAMPLE Vitruvius, the Roman architect, is known for asserting in his book *De architectura*[38] that a structure must exhibit the three qualities of *firmitas, utilitas, venustas* – that is, it must be solid, useful, beautiful. These are sometimes called the Vitruvian virtues or the Vitruvian Triad. This is a good example of factors that can be used in an architecture evaluation.

NOTE Examples of factors decomposition are provided in Annex A. Examples of value and quality factors are provided in Annex A.

4.7 Customized architecture evaluation frameworks

A generic AE framework is specified in this document that can be used in support of the Architecture Evaluation process defined in ISO/IEC/IEEE 42020. Specific frameworks can be derived from this generic framework. This clause describes the basic concepts regarding instantiation of specific AE frameworks while Clause 7 specifies provisions for instantiated specific AE frameworks.

The generic framework as illustrated by Figure 1 provides the elements and work products which could be instantiated or derived in specific frameworks. These specific frameworks may range from those targeting industry segments, like automotive or refinery operations, to those targeting common business processes, like portfolio management and program planning, and to those targeting common business architectures, like banking, retail, insurance, telecom, travel and hospitality, and so on. These frameworks allow the user to capture and reuse concepts common to many enterprises and thereby to increase the efficiency with which architectures can be evaluated.

Instantiation of specific frameworks will need adaptation to the requirements of the specific situation where an AE effort will be performed. The specific framework is usually defined or developed with respect to the processes, methods and tools used in the local context.

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A specific AE framework provides a structure for reuse and evolution according to the evaluation needs. It may specify standardized practices for doing architecture evaluations. It can be used for:

— addressing specific evaluation objectives;

— evaluating certain kinds of concerns of stakeholders;

— addressing specific value assessment objectives; or

— addressing specific architectural analysis objectives.

A specific AE framework can instantiate or derive one or more tiers of the generic AE framework. In particular, it instantiates or derives one of the following:

— evaluation approach(es);

— assessment method(s); or

— analysis method(s).

NOTE The ATAM is an example of a specific AE framework that includes an evaluation approach based on the use of quality attribute workshops, and that specifies value assessment and analysis methods to be used. A summary description of ATAM is provided in Annex D.

A specific AE framework may include:

— corresponding objectives and factors;

— expected roles and responsibilities of evaluators;

— expected roles and responsibilities of stakeholders;

— conditions of applicability and guidance on proper utilization; and

— standardized format for evaluation results.

Communicating stakeholder perspectives requires clear semantics and terminology. The framework can include vocabulary, conventions, principles, practices, and applicable standards and regulatory requirements for evaluating architectures that can be generic in nature or specific to a domain of application, a collection of concerns to be examined or a particular methodology. The methods aggregated into a framework can share a common vocabulary, address similar concerns or be used together for other theoretical or practical considerations.

An AE approach can be developed afresh each time an evaluation is needed, or the constructs of the generic AE framework in this document can be used as the starting point and tailored for its particular use - either by way of specialization for a particular domain or with respect to concerns that are most relevant to the AE objectives.

4.8 Tailoring

Tailoring may entail the addition, changing or removal of AE elements from the generic AE framework specified in this document. It may be performed for many reasons including the scale of the AE effort, the purpose of the evaluation, the intended uses of the AE results and the evaluation methodologies that will be employed. For example, if the purpose of the AE effort is to evaluate an architecture from an extant system or system design (i.e. to employ reverse architecting) then certain elements, such as architectural analysis, may not need to be performed.

In all cases where such tailoring of AE elements is employed, the rationale behind the tailoring shall be recorded. Recording the rationale will assist stakeholders in determining the value arising from the AE effort and the confidence they should attribute to its outcomes.

Tailoring may diminish the perceived value of a claim of conformance to this document. This is because it is difficult for other organizations to understand the extent to which tailoring may have applied

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desirable provisions. An organization asserting a single-party claim of conformance to this document may find it advantageous to claim full conformance to a smaller set of AE elements rather than tailored conformance to a larger set of AE elements.

The AE elements described in this document are not intended to preclude or discourage the use of additional AE elements that organizations find useful. In particular, governance and directives of the organization will be applied for tailoring of the AE elements.

5 Conformance

5.1 General

The requirements in this document are contained in Clauses 6 to 8. Situations in which claims of conformance with the provisions of this document can be made include those in 5.2 and 5.3.

NOTE An organization can have its own set of requirements or directives with respect to following the provisions of this document. For example, compliance can be limited to a set of architecture evaluation elements (objectives, approaches, factors and/or results) or work products (plan and/or report). This allows the architecture evaluation effort to be aligned and consistent with other efforts within the organizations of either those requesting evaluation to be done or those doing the evaluation.

EXAMPLE Specification of conformance for architecture evaluation objectives and results can be a way to establish contracts for the architecture evaluation efforts with freedom for the organization in charge of the architecture evaluation execution.

5.2 Creating AE artifacts

Claims of conformance with the provisions of this document can be made in the following situations:

— When conformance is claimed for a customized architecture evaluation framework, the claim shall demonstrate that the architecture evaluation framework meets the requirements specified in Clause 7.

— When conformance is claimed for an architecture evaluation plan, the claim shall demonstrate that the requirements specified in 8.1 and 8.2 are met.

— When conformance is claimed for an architecture evaluation report, the claim shall demonstrate that the requirements specified in 8.1 and 8.3 are met.

5.3 Using generic AE framework to conduct AE efforts

Claims of conformance with the provisions of this document can be made in the following situations:

a) When conformance is claimed for an evaluation synthesis effort, the claim shall demonstrate that the evaluation approach used meets the requirements specified in 6.1.

NOTE 1 Evaluation synthesis is the effort conducted using the elements in the Evaluation Synthesis Tier of the generic AE framework specified in this document. It involves the combination of results from multiple value assessments to determine to what extent the evaluation objectives will be achieved. See 4.3.1 for more information on this concept.

b) When conformance is claimed for a value assessment effort, the claim shall demonstrate that the assessment method used meets the requirements specified in 6.2.

NOTE 2 Value assessment is the effort conducted using the elements in the Value Assessment Tier of the generic AE framework specified in this document. It is concerned with a determination of the regard that something is held to deserve, or the importance, worth or usefulness of something to somebody. See 4.3.2 for more information on this concept. A comparison between the concepts of assessment and analysis is provided in 4.5.

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c) When conformance is claimed for an architectural analysis effort, the claim shall demonstrate that the analysis method used meets the requirements specified in 6.3.

NOTE 3 Architectural analysis is the effort conducted using the elements in the Architectural Analysis Tier of the generic AE framework specified in this document. It is concerned with an examination of the key attributes of an architecture, e.g. its characteristics along particular dimensions such as security, cost, performance, and so on, or the relevant attributes of the architecture entity, as well as actual or potential impacts on stakeholders or on the environment. See 4.3.3 for more information on this concept. A comparison between the concepts of assessment and analysis is provided in 4.5.

d) When conformance is claimed for an architecture evaluation effort, the claim shall demonstrate that the requirements specified in Clauses 7 and 8 are met.

NOTE 4 Architectural evaluation is concerned with a judgment about one or more architectures with respect to the specified evaluation objectives. See 4.2 for more information on this concept.

5.4 Verbal forms for the expression of provisions

Requirements of this document are marked by the use of the verb “shall”. Recommendations are marked by the use of the verb “should”. Permissions are marked by the use of the verb “may”. In the event of a conflict between normative figures and text, the text shall take precedence.

6 Architecture evaluation framework elements

6.1 Evaluation synthesis

6.1.1 General requirements

NOTE 1 Figure 3 depicts AE elements that can be used in an evaluation synthesis effort in terms of the key concepts and the relations between them. Most of these concepts are also used in related standards described in Annex B.

An architecture evaluation includes the following elements as specified in the subsequent subclauses:

a) one or more AE objectives;

b) one or more AE approaches;

c) one or more AE factors; and

d) one or more AE results.

The AE effort shall:

— identify one or more AE approaches to address the AE objectives;

— address the relevant AE factors;

— produce the appropriate AE results;

— determine the extent to which the AE objectives are met;

— address relevant concerns;

— address relevant business drivers and mission drivers;

— determine the value of the architecture; and

— produce one or more AE reports.

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The AE effort shall examine the AE results to determine the extent to which the AE objectives have been met. The AE effort may need to integrate and examine the AE results coming from multiple AE approaches used in the evaluation.

The AE effort may determine the value of architecture entities associated with the architecture under evaluation.

The AE effort may specify the value assessment objectives that will satisfy the specified AE objectives.

The AE effort may specify how to integrate AE results into the architecture description, when there is one.

NOTE 2 While it is desirable to have a documented architecture description for use in the architecture evaluation, producing a description is sometimes not feasible with resources available, or it could be unnecessary if the architecture is based on widely accepted solutions in the domain. This document does not mandate the use of an explicit architecture description, but this document does encourage documentation of evidence collected in support of the architecture evaluation, including any understanding of the architecture obtained through various mechanisms, either generated during the evaluation or used in the evaluation.

Evaluation approaches, assessment methods and analysis methods may identify factors not previously associated with a stakeholder concern or architecture feature which are nonetheless determined to be a critical factor with respect to having the architecture entity be fit-for-purpose. When identified, the relevant reports should specify the newly identified factors with recommendations for the elaboration of value assessment factors, architecture evaluation factors, concern definition and stakeholder identification sufficient to address the newly identified criticality.

6.1.2 Architecture evaluation objectives

Each AE objective shall:

a) address one or more stakeholder concerns;

b) address relevant business drivers and mission drivers;

c) be expressed in terms of AE factors; and

d) be expressed in terms of expected or desired values or value range for the AE factors, when applicable.

EXAMPLE Examples of AE objectives are:

— Will the business solution meet primary business needs?

— Is the system affordable?

— Will the service be dependable?

— Will the product have sufficient market penetration?

Each AE objective shall be a statement describing the extent to which the AE effort will address one or more of the relevant stakeholder concerns, such that they can form the basis for deriving value assessment objectives.

The AE objectives should be compatible with the established purpose and scope for the AE effort.

The AE objectives may be expressed as questions to facilitate understanding of their intent.

NOTE The reason for expressing the questions in such a manner and with sufficient elaboration is to ensure better understanding of the objectives by the assessors and stakeholders..

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6.1.3 Architecture evaluation approaches

Each AE approach shall provide the means to:

a) identify AE objectives to be addressed;

b) specify AE factors to be used and AE criteria to be applied;

c) specify one or more value assessment objectives, aligning them to the AE objectives;

d) specify one or more assessment methods to address the value assessment objectives;

e) specify the value assessment factors to be used, aligning them to relevant stakeholder concerns;

f) specify value assessment criteria to be applied;

g) specify the type and form of value assessment results to be examined when executing the AE approach;

h) specify how and when the identified assessment methods will be employed;

i) specify the mechanisms through which the AE criteria will be applied on AE factors; and

j) generate the AE results.

Each AE approach should provide the means to:

k) examine the value assessment results to determine the extent to which the stakeholder concerns have been addressed;

l) examine the value assessment results to determine the extent to which the value assessment objectives have been met;

m) identify and characterize trade-offs between competing stakeholder concerns; and

n) formulate findings and recommendations to be included in the AE results.

An AE approach may be specified as an AE framework for reuse in multiple architecture evaluations. The AE framework specification should be in accordance with Clause 7.

EXAMPLE The ATAM is an example of a published AE framework. ATAM is described in Annex D.

6.1.4 Architecture evaluation factors

Each AE factor used in the AE approach shall:

a) be representative of one or more stakeholder concerns;

b) be in a normalized form suitable for comparison or integration with other factors;

c) contribute to one or more AE objectives; and

d) be usable by the AE approach to generate the AE results.

EXAMPLE Examples of AE factors are: cost, schedule, performance, risk.

Each AE factor should be specific and measurable.

Each AE factor should enable the AE effort to produce accurate, reliable and timely results.

NOTE The recommendations above are based on the general rule that good metrics are SMART – Specific, Measurable, Accurate, Reliable and Timely.

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6.1.5 Architecture evaluation results

Each AE result shall be traceable to inputs used, the AE criteria applied to derive it and the AE approach that applied the criteria.

Each AE result should:

a) be the outcome of an impartial and objective examination done as part of using the AE approach;

b) document assumptions, risks and caveats to be taken into account while using the result; and

c) include a statement of estimated uncertainty of the stated result.

Discrepancies between AE results from different AE approaches used should be explained.

6.2 Value assessment

6.2.1 General requirements

NOTE 1 Figure 4 depicts the elements that can be used in a value assessment effort in terms of the key concepts and the relations between them. Value assessment objectives are intended to satisfy the AE objectives and frame the relevant stakeholder concerns. Value assessment factors will frame the relevant AE factors.

NOTE 2 Information on the nature of value and how it relates to the concept of quality is provided in Annex A.

Each value assessment includes the following elements as specified in the subsequent subclauses:

a) one or more value assessment objectives;

b) one or more value assessment methods;

c) one or more value assessment factors, and

d) one or more value assessment results.

The value assessment effort shall examine the value assessment results to determine the extent to which the value assessment objectives have been met. The value assessment effort may need to integrate and examine the architectural analysis results coming from multiple architectural analysis methods used in the evaluation. The value assessment effort may need to explain discrepancies between architectural analysis results from different architectural analysis methods used.

Each value assessment effort shall:

— specify value assessment objectives to address the relevant concerns;

— identify one or more value assessment methods to address the value assessment objectives;

— address the relevant value assessment factors;

— address relevant concerns;

— address relevant business drivers and mission drivers;

— determine the extent to which the value assessment objectives are met; and

— produce the appropriate value assessment results.

Each value assessment effort should be compatible with the established purpose and scope for the AE effort.

Value assessment should determine the lineage from architecture artifacts to design, construction, and ultimately the products and services used to deliver value to stakeholders (note that there are no direct relationships between architecture and stakeholders).

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Each value assessment effort may specify the architectural analysis objectives that will satisfy the specified value assessment objectives.

6.2.2 Value assessment objectives

Each value assessment objective shall be a statement describing the extent to which the value assessment effort will address one or more of the relevant stakeholder concerns, such that they can form the basis for deriving architectural analysis objectives.

The value assessment objectives may be expressed as questions to facilitate understanding of their intent.

Each value assessment objective shall be expressible in terms of the kind of value a stakeholder expects to receive. Each value assessment objective shall include a qualitative description or quantitative extent of this expectation from use or operation of the architecture entity, or in its possession.

EXAMPLE 1 A qualitative description could state something like "profit should increase" while a quantitative extent could state something like "profit should increase by 50 % in 3 years".

NOTE Information on the nature of value and how it relates to the concept of quality is provided in Annex A.

Each value assessment objective shall:

a) satisfy one or more AE objectives;

b) be expressed in terms of value assessment factors; and

c) be expressed in terms of expected or desired values or value range for the AE factors; and

d) enable identification of the information necessary to assess achievement of the value assessment objective.

EXAMPLE 2 Examples of value assessment objectives are:

— Will the business solution provide adequate productivity improvement?

— Does the system support level 5 trained personnel to control the factory process flow?

— Will the service provide information in a timely manner?

— Will the product provide accurate and timely data?

6.2.3 Value assessment methods

Each value assessment method shall provide the means to:

a) address assigned value assessment objectives;

b) specify the value assessment factors to be used;

c) specify value assessment criteria to be applied;

d) specify the mechanisms through which the value assessment criteria will be applied on value assessment factors;

e) formulate findings and recommendations to be included in the value assessment results; and

f) generate the value assessment results.

Each value assessment method should provide the means to:

— identify, if needed, one or more architectural analysis methods pertaining to the value assessment objectives it addresses;

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