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Framework for Engineering Design Systems Architectures Evaluation and Selection: Case Study

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Abstract

Engineering companies face the challenge of developing complex Engineering Design Systems. These systems involve huge financial, people, and time investments within an environment that is characterised by continuously changing technologies and processes. Systems architecture provides the strategies and modelling approaches to ensure that adequate resources are spent in developing the possible To Be states for a target system. Architecture selection and evaluation involves evaluating different architectural alternatives with respect to multiple criteria, hence an Architecture Evaluation Framework which evaluates and down selects the appropriate architectures solutions is crucial to assess how these systems will deliver value over their lifetime, and where to channel the financial and human investments to maximize benefit delivered to the business' bottom line.

In this paper, an evaluation and selection architecture framework is proposed, which targets to maximise the alignment of Engineering Design Systems with business goals based on a quality centric architecture evaluation approach. The framework utilised software Quality Attributes as well as SWOT (Strength, Weakness, Opportunity, Threat) and PEST (Political, Economic, Social, Technological) analyses to capture different viewpoints related to technical, political and business context. The framework proposed employing AHP (Analytical Hierarchy Process) to quantitatively elicit relationships between Quality Attributes trade-offs and architectural characteristics. The framework was applied to a real case study considering five Engineering Design Systems alternative architectures, where workshops with subject matter experts and stakeholders were held to reach an informative decision, that maximise architectural quality, whilst maintaining business alignment.

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Keywords: Engineering design system architecutre, architecture evaluation, quality attributes, analytic hierarchy process (AHP), SWOT and PEST

1. Introduction

Engineering companies face the challenge of developing complex engineering design systems. These systems involve huge financial, people, and time investments within an environment that is characterised by continuously changing technologies and processes. Systems architecting provides the strategies and modelling approaches to ensure that adequate resources are spent in developing the possible To BE states for a target system. Architecture evaluation involves evaluating different architecture alternatives with respect to multiple criteria, hence a rigorous Architecture Evaluation Framework to evaluate architectural alternatives is crucial to assess how these systems will deliver value over their lifetime, and where to channel the financial and human investments to maximize the benefit to the businesses bottom line.

This paper gives an overview of the theoretical background of evaluation processes and Quality Attributes trade-offs and highlights the importance of appreciating business context of engineering systems when evaluating alternative solutions.

An evaluation and selection architecture framework is proposed, based on a quality centric architecture evaluation approach. Analytical Hierarchy Process (AHP) is utilised to quantitatively elicit relationship between Quality Attributes trade-offs and architecture characteristics. The Quality Attributes utilised are adopted from ISO/IEC 25010:2011 standard. The framework also employs SWOT and PEST

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analyses to capture different viewpoints related to political, societal and business contexts.

The framework was applied to a real case study considering five alternative architectures. Data collected has been analysed by a commercial AHP tool. The results, together with workshops discussion, have assisted stakeholders to reach an informative decision.

Nomenclature

AHP	Analytical Hierarchy Process
API	Application Programming Interface
DSL	Domain Specific Language
MCDM	Multi-Criteria Decision Making
MDE	Model Driven Engineering
PEST	Political, Economic, Social, Technological
QA	Quality Attributes
SQuaRE	Software Quality Requirements and Evaluation
SWOT	Strength, Weakness, Opportunity, Threat

2. Literature review and theoretical background

Engineering products and systems are becoming increasingly complex, not only driven by global competition and price pressure, but also with fast moving customers' requirements [1]. High level of complexity and customers' changes cause systems to grow over time in order to increase capabilities, hence leading to having evolved Engineering Design Systems and Sub-Systems that are not designed to support scalability. Instead, they were designed to meet specific and timely needs [2].

Systems architecting provides the strategies and modelling approaches to ensure that adequate resources is spent in developing the possible 'could be' states, and evaluating and selecting the best alternative given a set of desired properties and criteria for the future system [3]. As Design Systems become larger and more complex, their architectures assume ever greater importance in managing their growing integrity and coherence. Thus, when architectural integrity is compromised, the probability for serious operational problems increases dramatically. Interactions among layers and subsystems become increasingly more difficult to understand. The ability to assess unwanted side effects before implementing changes becomes more laborious. Modifications will be more intricate and tedious. Consequently, the verification of functional and structural quality becomes less thorough when speed delivery is the priority. Thus, architectural integrity enables safe rapid development cycles whilst maintain quality and safety [4].

2.1. .System Architecture Quality Attributes

Functional requirements show the ability of the system to deliver the services which it was designed for. However, how well the system caters for modifications like scalability, maintainability or portability is best assessed through capturing Quality Attributes (non-functional requirements), which are properties of a system that are used to indicate how well the system satisfies the needs of its stakeholders for future change [5].

Several Quality Models that provide hierarchical order of Quality Attributes have been published in the last decades [6]. One of the earliest models was established by Boehm et al. to define software quality through a given set of attributes and metrics [7]. Later models were defined through international standards such as ISO/IEC 9126-1:2001 [Software engineering Product quality], which was later revised by ISO/IEC 25010:2011 [Systems and software engineering, Systems and software Quality Requirements and Evaluation (SQuaRE)] [8].

ISO/IEC 25010:2011 standard classifies software quality within taxonomy of characteristics and sub-characteristics. The characteristics considered are; functionality, reliability, usability, efficiency, maintainability, and portability. Each of these characteristics is subdivided into Quality Attributes (Fig. 1) that can be measured and verified [4].

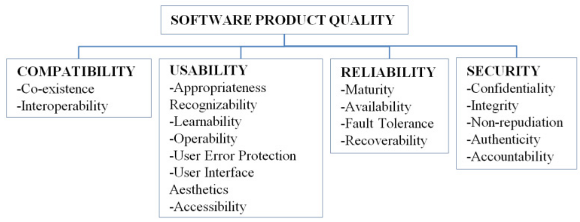

Fig. 1. Subset of ISO/IEC 25010:2011 Quality Model [8]

2.2. Systems Architecture Quality Attributes Trade-offs

A quality-based architecture is one designed to satisfy a single or multiple Quality Attributes. In most cases, it is impossible to maximize all of them, hence the architect must consider a trade-off to ensure high priority functions are not being compromised [9].

Systematic research suggests that there is an immaturity in the field of software quality trade-off, hence no approach or set of approaches have emerged as candidates to dominate the research space, however empirical evidences suggest that Analytical Hierarchy Process (AHP) is one of the most widely applied approach as Multi-Criteria Decision Making (MCDM) tool [10].

AHP is comprised of four main steps [11]:

1) Define the problem
2) Structure the decision hierarchy
3) Construct a set of pairwise comparison matrices
4) Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below.

AHP provides a consistency ratio (CR) factor, which is used to determine whether participants have answered consistently, i.e. in agreement with themselves, hence gives mathematically rigor for prioritisations [12].

Moreover, identifying critical decisions and performing sensitivity analysis can expose potential issues and lead to an architecture better prepared for future change [13].

As it is neither feasible nor desirable to fully automate the decision making process, semi-formal techniques such as SWOT (Strengths, Weaknesses, Opportunities, and Threats)