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Toward Addressing the Software Architecture Blind Spot of Information System Success Factors in the Public Health domain

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Research-in-progress

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Abstract

Context: In the public health domain, there is no shortage of failed Information Systems projects. In addition to overblown budgets and elapsed deadlines (ad nauseam), technical issues exist. These include poor usability, instability, system performance, and data inconsistency issues. The issues relate to Software Engineering, and specifically Software Architecture. The role of Software Architecture underpins these issues. However, the enquiries and analyses of these failed Information Systems projects have focused on the perspective of stakeholders (e.g., government ministers and health practitioners) and project managers. While stakeholders provide input into project requirements and goals, the project failure or success does not emanate from these roles exclusively. For example, system instability is not specifically a stakeholder issue but rather a Software Architecture concern.

Aim: To bring to bear and address public sector health Information System failure from the Software Architecture perspective.

Method: A literature survey was conducted to ascertain the perceived failure and success factors within the public health domain.

Results: We observed that the available literature on health Information Systems appears to lack success factors which have been noted in the Software Engineering and Software Architecture literature. Software Architecture appears to be an understudied area within the public health domain.

Contribution: To bring awareness to the public health domain that the Information System's success requires multi-faceted perspectives and actions. Specifically, perspectives and actions involving Software Architects and Software Engineers are required to successfully address the quality attributes of the proposed systems during development.

Keywords Public Health, Information Systems, Success Factors, Software Architecture, Software Engineering.

1 Introduction

The benefits of health information technology have been widely reported (Buntin et al. 2011). However, within the context of the public health domain, there have been notable challenges regarding the implementation of Information Systems (IS) and Information & Communication Technology (ICT). A key challenge is to ensure that the software meets the needs of both the end users and the practitioners. Lack of practitioner and end user satisfaction can manifest in resistance to adoption (Ebad 2020). Often this stems from issues related to system performance, reliability, functional suitability, and usability. Projects can be very costly (iTnews_au 2023), hence it is important to address issues early within the development of such systems. Therefore, in this paper we view the literature from the perspective of Software Engineering and Software Architecture (SA) (ISO 2022). To this end, we consider the aspects of the software development life cycle (Davis et al. 1988) including planning, requirements gathering, design, implementation, testing, deployment, and maintenance.

2 Background

In this section, we present a brief background of failure and successes within the public and public health domains.

2.1 Public Sector (General)

IS projects in the public sector have been shown to be susceptible to failures. The capability of external suppliers and individuals have been shown to be key factors (Douglas 2021; Worrall 2020). Per contra, the Agile project delivery method (Fernandez and Fernandez 2008) in conjunction with an ITC experienced sponsor (a government stakeholder) have been named as success factors (Worrall 2020).

2.2 Notable Failures in the Public Health Domain

In Australia, a costly Electronic Health Records (EHR) system (iTnews_au 2023) experienced low adoption due to privacy, and security concerns (BenSmee 2018). A Large-Scale EHR system was implemented in Denmark and Finland (Hertzum et al. 2022) where practitioners experienced frequent crashes, difficulty in use, and disruption of nurses' workflow. A high-profile public health IS failure in the western world was healthcare.gov. Users experienced problems with registration, system stability, and incorrect data (hivgov 2013). In Australia, the state of Queensland implemented a payroll system in the health sector (Eden and Sedera 2014). Problems included incorrect staff payments. Shockingly, some people were not paid at all. The total cost was estimated to be $1.25 Billion AUD. Interestingly, the principal consultant involved in this project was IBM, which one might assume would provide confidence in implementing such a system.

2.3 Defining Success and Failure

The analysis of success and failure of public sector health IS projects has largely been viewed from the perspective of health practitioners, government, and project management. Namely, the rollout, adoption, and outcomes of the developed systems. This can be viewed as user satisfaction of the IS's (DeLone and McLean 2003). However, user satisfaction may be impacted by qualities of the system.

User satisfaction can be viewed through the lens of satisfying the Software Quality Attributes (SQAs) of the system (see Figure 1). This perspective is important, given that problems in notable failed systems have pointed to attributes such as *Functional Suitability* (Eden and Sedera 2014), *Performance* (hivgov 2013), and *Reliability* (hivgov 2013). Indeed, the Software Engineering literature points to the importance of choosing architectures suitable for satisfying SQAs (Haoues et al. 2017). Given that SA underpins SQAs (see Figure 1), it is therefore important to understand what factors lead to successful development of SA. We posit that *the success factors impacting the development of SA have had little attention within the literature related to public sector health IS projects.*

2.4 Data Extraction and Theoretical Lens

Various models for examining the successful development of IS's have been proposed. For example, the Unified Model of Information System Development Success (see Appendix 2) names factors such as Individual factors, Team, and Organisation (Siau et al. 2010). These factors have been proposed in the form of inputs and processes, with the output being IS system success. To analyse factors contributing to SA success, we build upon this work for the purpose of applying a theoretical lens in analysing the literature (see Appendix 3). *Project Characteristics* relates to domain, system environment context, system type, and complexity. *Requirements* relates to suitability, requirements change, user and stakeholder involvement, and importantly, SQAs. The Individual factors category has been split into *Human factors*, and *Knowledge & Skills*.

In the following section we present a survey of the literature to examine success factors in public health sector IS projects.

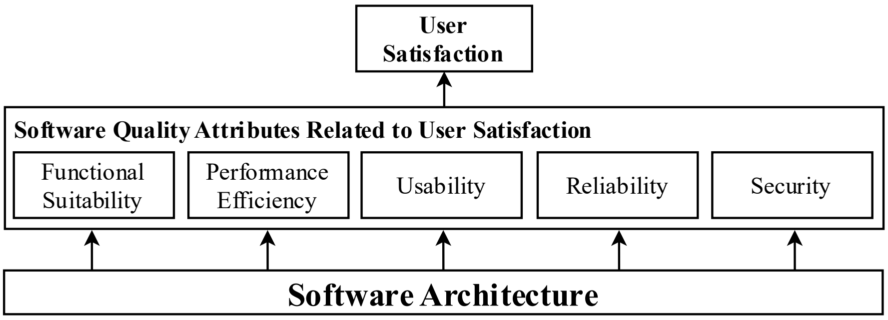

Figure 1: Software Quality Attributes Related to User Satisfaction – A subset of attributes from ISO/IEC 25010:2011 (ISO 2011). A complete set of Quality Attributes can be seen in Appendix 1.

3 Results - Factors Impacting Success and Failure

In this section, we present an overview of papers highlighting success and failure factors within public health sector IS & ICT projects. We examined papers to uncover factors which impacted the software development process, where SQAs were explicitly or implicitly mentioned (see Figure 2). Attributes such as *Performance*, *Security*, *Maintainability* are related to SA. As such, we further mapped the papers to factors represented in our theoretical lens (see Figure 3). Note that we make a distinction between the development of the system (impacts SA), and the subsequent post-development rollout/adoption phase.

3.1 Public Health Sector

Lack of acceptance/adoption has been noted (Mahdavian et al. 2014). Issues included staff resistance to the new system (*Usability*), and poor system performance (*Performance Efficiency*). Lack of domain knowledge (*Knowledge/Skills*) from the developers was named as a factor. The paper also notes an issue with "lack of data communication among the hospitals and treatment centers" (*Project Characteristics, Requirements, Compatibility*). Other factors identified included: organizational culture (*Organization*), *Communication*, *Project Management*. However, it was not stated explicitly if these factors were related to the development process itself, or the subsequent rollout/adoption phase. These findings bear similarity to those related to a Clinical IS's study (Hoerbst and Schweitzer 2015). The paper noted issues regarding *Communication* and stakeholder management.

Emphasis has been given to patients and practitioners outcomes in the development and rollout stages (Cijvat et al. 2021). This implies that the SQAs of concern include *Functional Suitability* and *Usability*. *Security* was noted as a consideration to be aware of early within projects. The stakeholder perspective has been examined (Gomes and Romão 2015) focusing on the outcomes, and practitioner resistance (*Usability*). Stakeholder management was a key concern. Success factors were related to ***Project Management and Organisation***.

Usability and stability (*Reliability*) were found to be key factors in practitioners well-being (Vainiomäki et al. 2017). User satisfaction (*Usability*) and adoption was studied (Planitz et al. 2012). Additional concerns included: *Functional Suitability, and* sufficiently fast access (*Performance Efficiency*). It was also stated that developers should be aware of other systems that may confuse the users (P*roject Characteristics, Requirements, Functional Suitability*). User involvement in the design (*Functional Suitability, Usability, Requirements*) was named as a facilitator of success in a report on eHealth interventions (Granja et al. 2018). *Security was stated as a concern.*

User satisfaction (*Usability*) featured highly in a paper naming critical success factors (Mendoza et al. 2022). Technological infrastructure (bandwidth, and compatibility with state IT platform) (*Project Characteristics*) was also named. The ability to handle different data formats (*Functional Suitability*) while taking to account *Security* and privacy was also identified. While not discussing the development process explicitly, these success factors can be viewed as qualities of the system (SQA's).

The gap between desired and delivered outcomes has been related to *Functional Suitability and Usability* (Heeks 2006). It was noted that understanding the worlds of the developer and that of the end user may help to mitigate *Requirements* gaps. Modular project delivery (*Project Management* Methodology) was proposed as a success factor.

In a report on a Clinical ICT System, issues were related to to poor planning (*Project Management*) and an inadequate understanding of *Requirements* (Doyle 2013). The vendor's quality and performance was a main factor (implies *Team, Knowledge/Skills, Project Management, Practices, Decision Making*). Other issues included: underestimated project scope (*Requirements*), and timelines (*Project Management*). The report noted that other successful systems: *"…incrementally developed with strong clinician engagement enjoy wide acceptance and support from end users."*.

A study by the CSIRO examined the suitability of *Project Management* approaches in complex healthcare software (Dendere et al. 2021). The majority of failures studied were related to inefficiencies in *Project Management* such as, insufficient resourcing, and a lack of detailed project and strategic planning. It could be inferred that the insufficient resourcing may also relate to insufficient number of people with the necessary skills (*Knowledge/Skills*).

The largest IS implementation failure in the southern hemisphere at the time, cost $1.25 billion (Eden and Sedera 2014). The 1-year project was delivered 2 years late. The main contractor was IBM, who in turn hired and managed sub-contractors. Factors named were lack of clarity regarding governance and accountability (*Organisation, Team*), lack of a formalised *Project Management* strategy, vendor performance (*Knowledge/Skills*), poor *Requirements* definition, poor *Communication* with stakeholder teams, and lack of testing (*Practices*).

In a failed EHR implementation (Ebad 2020), the system did not suit the needs of the healthcare practitioners. The system was unable to handle unexpected data (*Functional Suitability*), and hardware failure (*Reliability*). Additionally, the system did not meet the requirement of allowing access from outside of the network (*Security, Project Characteristics, Requirements*). Missing *Requirements*, lack of *Project Management* skills, and development paradigm (*Project Management*), were named as causal factors. In addition, *developer skills/experience* (*Knowledge/Skills, Team, Organisation*) were named as factors contributing to a poor database design, resulting in excessive database storage use (*Performance Efficiency*). Recommendations for success for EHRs in another study (Aldosari 2017) included: a qualified project manager (*Project Management*), *Communication* between team members and stakeholders (*Team, Organisation, Requirements*), controlling and completing the deliverables (*Project Management*), leadership skills to solve problems (*Knowledge/Skills, Team*), *Decision Making*, a better process (*Practices*) to be accepted by the stakeholders (*Project Management, Communication*). These recommendations have also been mirrored (Standing and Cripps 2015). Recommendations include user/stakeholder involvement (*Requirements, Communication*), vision and strategy (*Organisation*), *Communication* and reporting, process for implementation (*Project Management*), plan for infrastructure (*Project Management, Requirements, Project Characteristics*), and contextual factors (*Project Characteristics*). Contextual factors included decision-making authority (*Decision Making, Team, Organisation*), accountability (*Team, Organisation)*, and the passion and determination of developers (*Human Factors*).

Studies related to EHRs have been compared (Al Ani et al. 2022). It was found that user dissatisfaction was related to system *Performance Efficiency*. Some systems required periods of downtime (*Reliability*) and data synchronisation across remote sites (*Reliability, Functional Suitability, Performance Efficiency, Compatibility*). System *Maintainability* was viewed through the lens of modifiability. Similarly, another study (Fragidis and Chatzoglou 2018) found challenges relating to user acceptance (*Requirements*), technical infrastructure (Project Characteristics), and data protection (Security). Success factors included: *Project Management*, commitment, and involvement of stakeholders (*Organisation, Requirements*), aligning functionality with user *Requirements*, resourcing (*Team, Project Management*), ability to modify current systems (*Maintainability*), and interdisciplinary teams with IT experience (*Team)*.

Interoperability (*Compatibility*) is a concern of transnational EHRs (Lee et al. 2021). Aside from technical interoperability, other forms of interoperability exist, such as data syntactic, semantic, business processes, and *Organisation*. A framework for cross-border EHR data standardisation and interoperability (*Compatibility*) has been proposed (Schiza et al. 2015). Key concerns relate to data access authorisation (Security), and legislation (*Requirements, Project Characteristics*).

Security practices have been examined (Uwizeyemungu et al. 2019), where it was found that stored data was only encrypted in 37% of hospitals surveyed. Encryption during data transmission occurred in in only 59% of hospitals. In addition, over 40% of the hospitals would be unable to restore critical clinical information in the event of disaster, which would result in partial or complete data loss (*Reliability*).

	Functional Suitability	Performance Efficiency	Compatibility	Usability	Reliability	Security	Maintainability	Portability
Al Ani et al. 2022	X	X	X	X	X	X	X	
Aldosari 2017	X			X				
Cijvat et al. 2021	X			X		X		
Dendere et al. 2021								
Doyle 2013	X		X	X	X	X		
Ebad 2020	X	X	X	X	X	X	X	
Eden and Sedera 2014	X		X				X	
Fragidis and Chatzoglou 2018	X		X	X		X	X	
Granja et al. 2018	X		X	X	X	X		
Gomes and Romão 2015	X		X					
Heeks 2006	X			X				
Hoerbst and Schweitzer 2015	X		X	X	X	X		
Lee et al. 2021	X		X		X	X		
Mahdavian et al. 2014	X	X	X	X	X			
Mendoza et al. 2022	X	X	X	X		X		
Planitz et al. 2012	X	X		X				
Schiza et al. 2015	X	X	X	X		X		
Standing and Cripps 2015	X			X				
Uwizeyemungu et al. 2019		X			X	X		
Vainiomäki et al. 2017	X			X	X		X	

Figure 2 Quality Attributes of concern

	Input						Process				
	Project Characteristics	Requirements	Team	Organisation	Knowledge / Skills	Human Factors	Project Management	Practices	Communication	Decision Making	Techniques
Al Ani et al. 2022	X	X					X			X	
Aldosari 2017		X	X	X			X		X		
Cijvat et al. 2021	X	X		X	X		X				
Dendere et al. 2021	X	X	X	X			X	X			
Doyle 2013		X		X	X		X				
Ebad 2020	X	X	X	X	X		X		X		
Eden and Sedera 2014		X	X	X	X		X	X	X		
Fragidis and Chatzoglou 2018	X	X	X	X			X		X		
Granja et al. 2018		X		X							
Gomes and Romão 2015				X			X				
Heeks 2006		X					X				
Hoerbst and Schweitzer 2015				X			X		X		
Lee et al. 2021	X	X		X							
Mahdavian et al. 2014	X	X		X	X		X				
Mendoza et al. 2022	X	X		X			X				
Planitz et al. 2012		X									
Schiza et al. 2015	X	X	X	X			X				
Standing and Cripps 2015	X	X	X	X		X	X		X	X	
Uwizeyemungu et al. 2019	X	X		X							
Vainiomäki et al. 2017		X			X						

Figure 3: Factors impacting software architecture

4 Discussion

It appears that success within public health sector IS and ICT projects has been largely viewed within the context of user acceptance and adoption. The literature does name factors which impact development, albeit often incidental or implied. Themes of outsourcing, vendor capability, team skills, and coordination appeared various times within the literature. It is important to address such issues, as vendors may also outsource development (Nuwangi and Sedera 2020; Wang and Wang 2019).

The papers surveyed refer to qualities of the system which allude to the ISO/IEC 25010 quality attributes (see Figure 1). Some problems named appear as performance, reliability, availability, and data consistency. There appears to be a lack of attention to the assessment of these qualities. That is, a lack of focus on SQAs. Digging deeper, given that SQAs are underpinned by SA, it is important to consider how the SA is developed. For example, *when the impact on end-users is perceived as poor performance, instability, and data inconsistency, it is possible that the underlying architecture is not* suitable. That is, the SQAs have not been satisfied by the architecture (Bass et al. 2003). Within the SA literature, exists the notion of SA Tactics (Bass et al. 2003). SA Tactics are building blocks used to design SA's to satisfy

SQAs. A successful system would achieve successful SA outcomes by taking into consideration SQAs throughout the development process. This is depicted in Figure 4.

Our derived theoretical lens (see Appendix 3) depicts inputs, processes, and outputs. There are success factors which appear more prevalent within the literature. *Requirements*, *Project Management*, *Organisation*, and *Project Characteristics* feature heavily. The prevalence of these factors may indicate a stronger influence on success. It is also notable that the *factors impacting success, appear to be related, and impact each other*. For example, the literature draws attention to *Project Management*, which can influence ways of *Communication* within the *Team* and with the stakeholders in the *Organisation*. This may also influence the specificity of the *Requirements*.

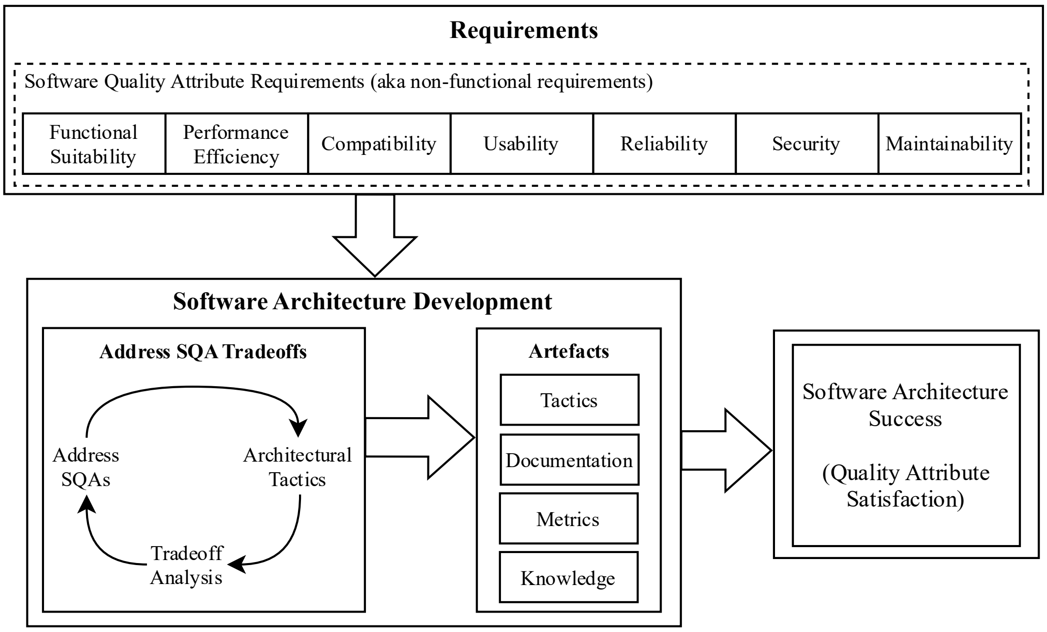

Figure 4: Requirements Impacting Quality Attributes and Architectural Tactics

4.1 A Framework for Software Architecture Success

The multi-dimensional relationships between success factors, requires a wholistic view of SA success. To bring much needed awareness to factors which impact SA success, we introduce:

A Framework for Addressing Multi-dimensional Factors Impacting Software Architecture Success (see Figure 5).

The framework is intended to be viewed within the context of addressing the required SQAs (see Figure 4). That is, the *Process* stage of the framework relates to the "*Address SQA Trade-offs*" cycle of Figure 4. *Note that for brevity, the sub-categories seen in our theoretical lens* (see Appendix 3) have been omitted from the diagram in Figure 5).

The *Input* and *Process* factors may be considered in the depicted order (top down). Indeed, the literature shows a marked prevalence of the factors related to *Requirements*, *Organisation*, *Project Management*, and *Project Characteristics*. This later factor sits at the top of the *Input* factors due to considerations such as business justification, domain, and risk, which may be viewed as drivers for the project. Likewise, *Organisation* structure may influence *Requirements* gathering. Hence *the intent of this framework is to be viewed as procedural (top down)*, rather than declarative. For example, a high-risk project (*Project Characteristics*) in a complex *Organization*, may mandate high security (*Requirements*). This informs the vendor (delivering the project) to form a sufficient *Team* composed of individuals possessing domain and security *Knowledge & Skills*, who are motivated (*Human Factors*) to effectively satisfy the requirements of the system. The methodology (*Project Management*) may require an up-front architectural decision (Waterman 2018), involving additional *Communication* with specific stakeholders (*Organization*). More rigorous automated testing (*Practices*) may be necessary, using state of the art *Techniques* and tools. These factors may all feed into the SA *Decision-Making* process.

The dotted arrows in Figure 5 indicate information loops which may necessitate actions. For example, a chosen SA Tactic may strongly satisfy a security metric, however its complexity may require specialized *Project Management* and *Communication* with the stakeholders (*Organization*). The development *Team* may then require further *Knowledge & Skills* for the implementation. However, due to disagreement among the stakeholders about *Requirements,* the individuals within the *Team* may be biased (*Human Factors*) toward simpler solutions. They may argue that this is an appropriate trade-off which scores higher in a maintainability and changeability metrics. This results in a lower score on the security metric, effectively reducing the satisfaction of the requirement. However, this approach allows the team to adapt in the future if the stakeholders change the *Requirements*. These complex relations require further study.

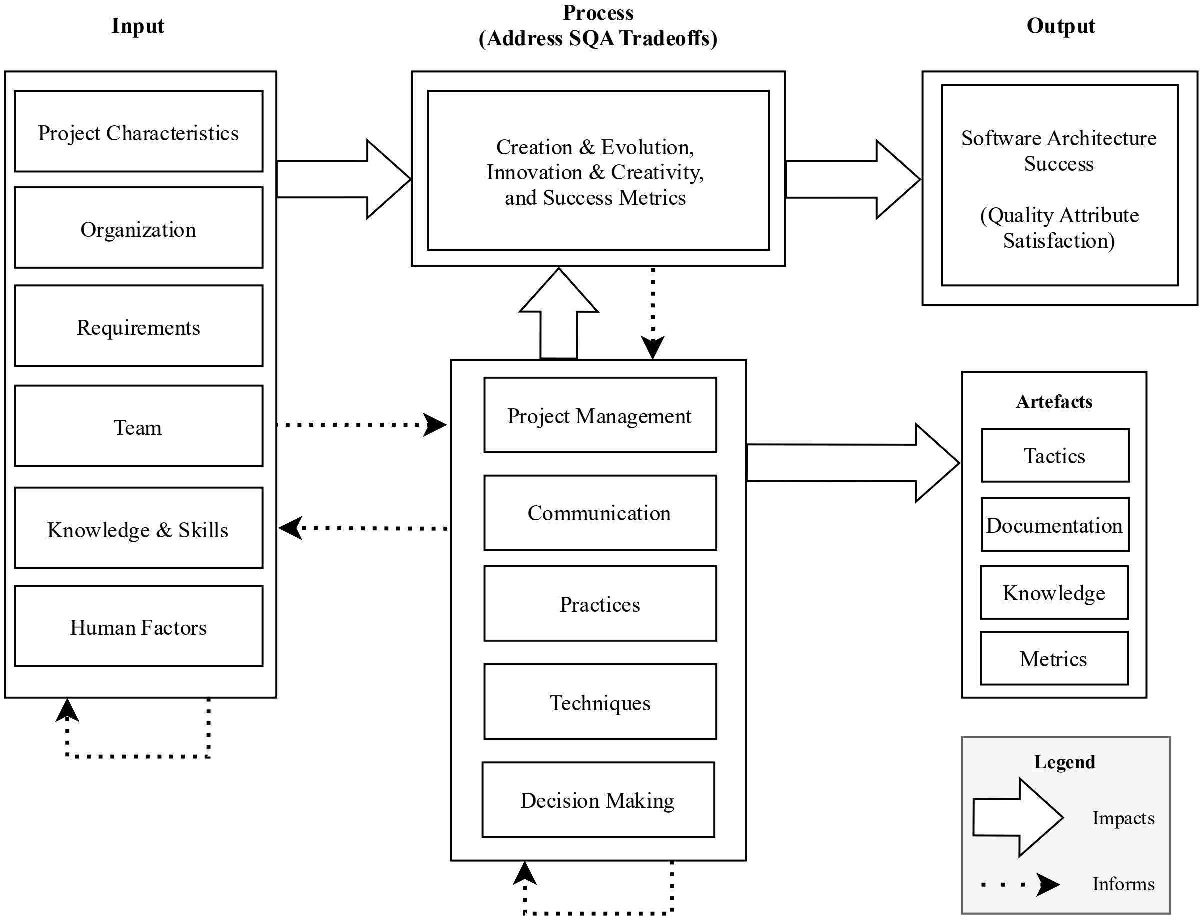

Figure 5: A Framework for Addressing Multi-dimensional Factors Impacting Software Architecture Success

5 Conclusion

In the public health domain, success of IS projects has been viewed through the lens of adoption, user satisfaction, delivery time, and cost. Negative outcomes for users and practitioners have often been named in relation to system performance, reliability, availability, and data consistency. There has been little research into underlying architectural factors which positively impact these qualities of the systems. These qualities are related to SA. More research is clearly required to address the factors leading to suitable architectural outcomes. Addressing this blind spot in understanding Health IS implementation in the public domain will positively impact both user and practitioner outcomes. We have hence introduced: *A Framework for Addressing Multi-dimensional Factors Impacting Software Architecture Success*. Evaluation and refinement of this framework will be addressed in future work by means of case study tracing, and conceivably field testing at a later stage. In addition, it is intended to establish the broader applicability of this framework outside of the public health domain.

The wholistic view of our framework poses some open questions for future work. For instance: *How do these factors relate to each other? Are any factors more important than others? What is the consequence of some factors not being satisfied? Do factors exist which are specific to the public health domain? Can this framework be applied to other domains? If so, what adjustments may be required?*

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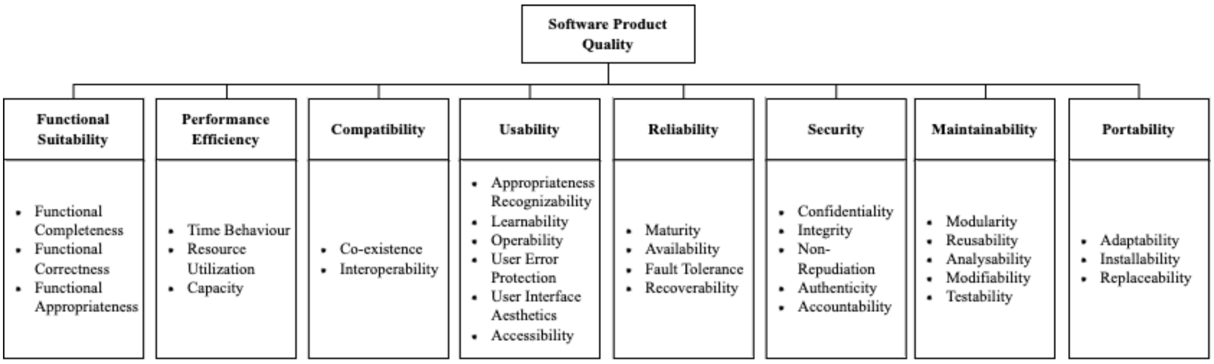
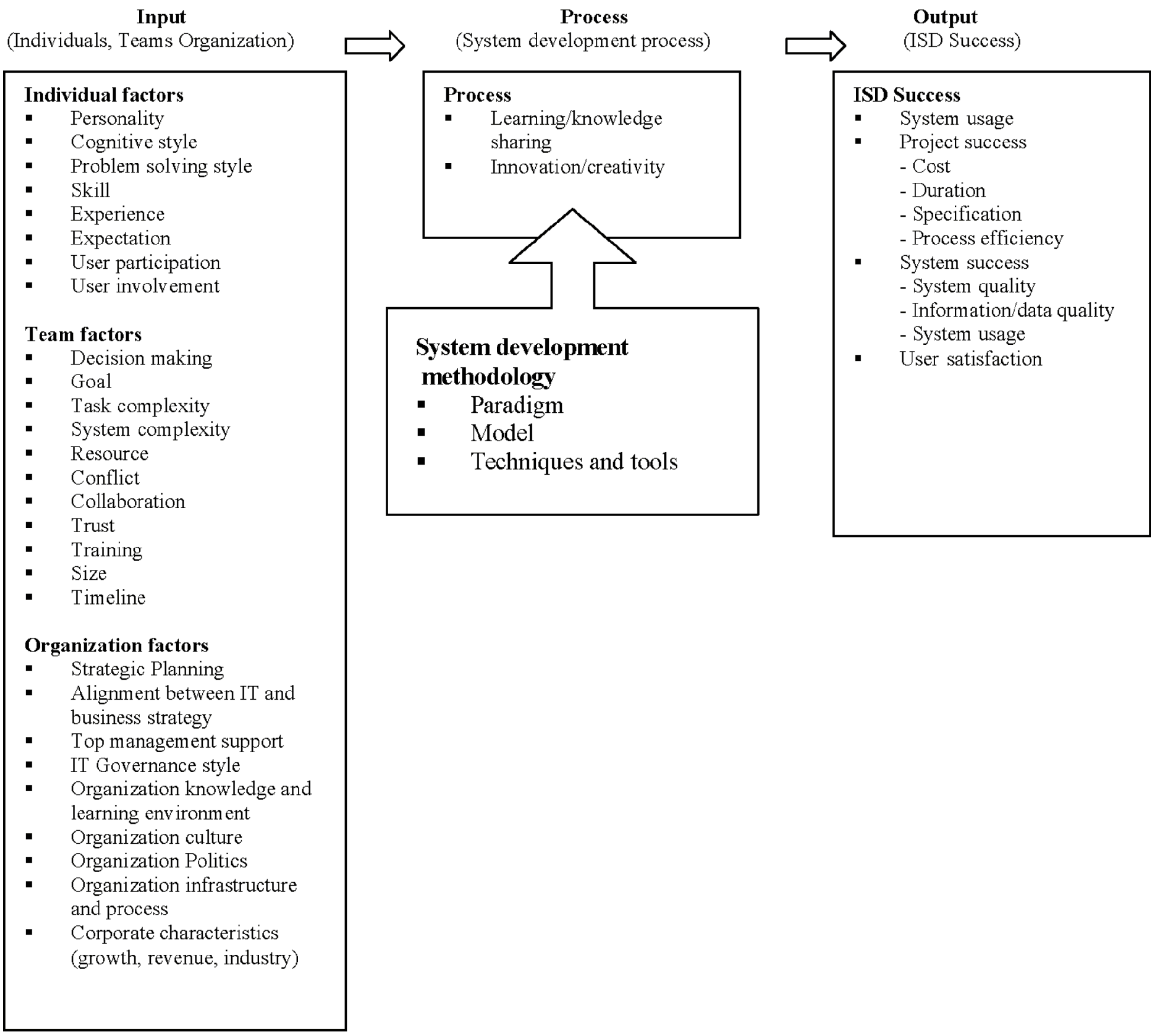
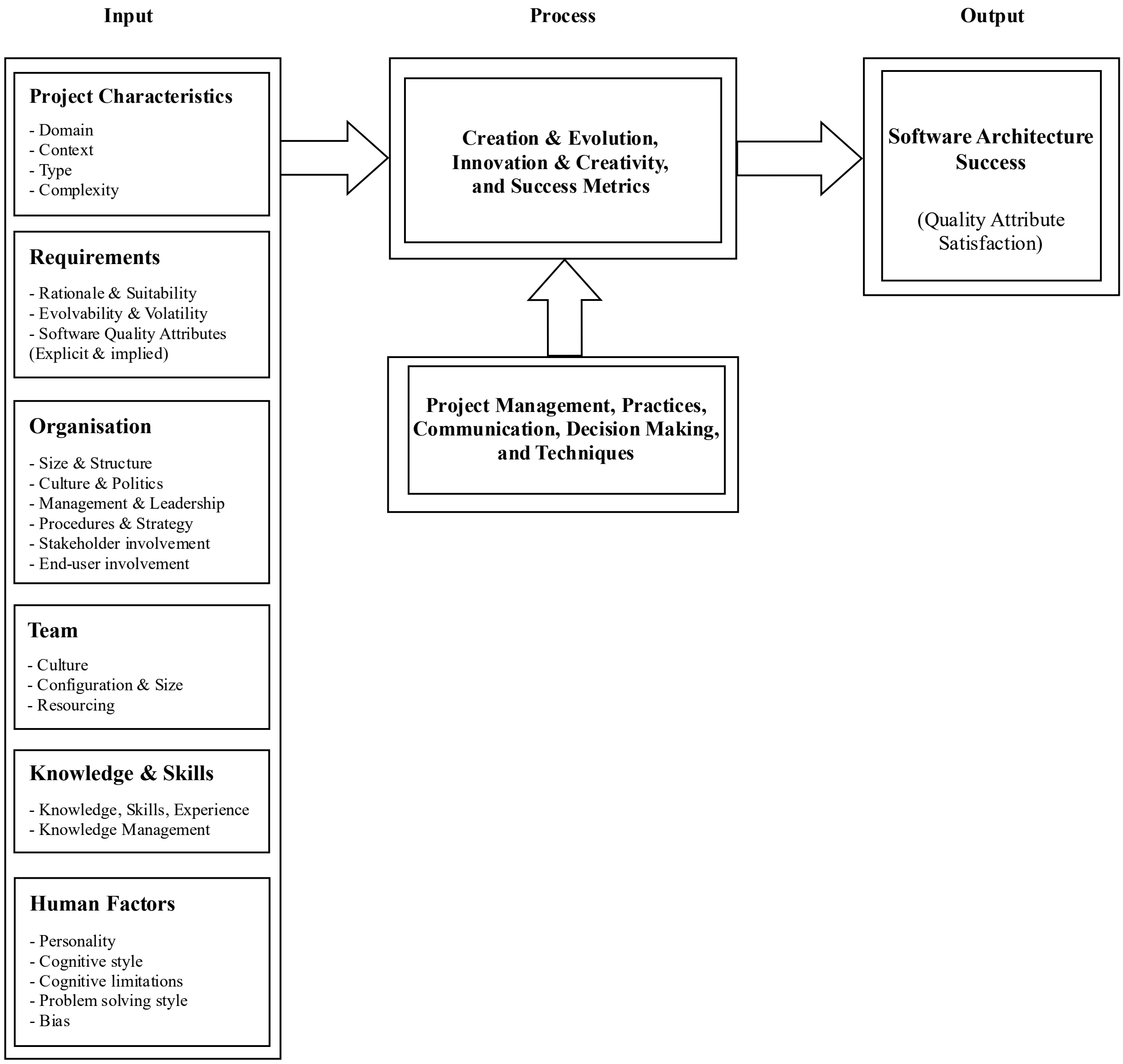
Appendix 1 - Software Product Quality according to ISO/IEC 25010:2011 (ISO 2011)



Appendix 2 – Unified Model of Information System Development Success (Siau et al. 2010)



Appendix 3 - Theoretical Lens for Software Architecture Development Success



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