Understanding Architecture Decisions in Context

An industry case study of architects' decision-making context

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Abstract. Many organizations struggle with efficient architecture decision-making approaches. Often, the decision-making approaches are not articulated or understood. This problem is particularly evident in large, globally distributed organizations with multiple large products and systems. The significant architecture decisions of a system are a critical organization knowledge asset, as well as a determinant of success. However, the environment in which decisions get made, recorded, and followed-up on often confounds rather than helps articulation and execution of architecture decisions. This paper looks at aspects of architecture decision-making, drawing from an industry-based case study. The data represents findings from a qualitative case study involving a survey and three focus groups across multiple organizations in a global technology company. Architects in this organization are responsible for multiple products and systems, where individual products can include up to 50+ teams. The impact is not just on others in the system; architecture decisions also impact other decisions and other architects. The findings suggest recommendations for organizations to improve how they make and manage architecture decisions. In particular, this paper notes the relevance of group decision-making, decision scope, and social factors such as trust in effective architecture decision-making.

Keywords: Architecture, Architecture Decisions, Decision Making, Decision Makers, Decision Impact, Trust, Roles, Documentation, Agile

1 Introduction

Architecture decisions can significantly affect architects and other roles. Realizing this, a vital component of any architectural approach is having a process that promotes follow through and feedback on architecture decisions. This paper presents a case study of a large technology organization with multiple business units and product lines. This study examines approaches to architecture decision-making and seeks to understand in more depth the reasons for the decision-making approaches employed by architects, as well as the challenges and context that architects must deal with. In addition, this study attempts to understand the impact of architecture decisions. The remainder of this paper describes the study.

Power, K. and R. Wirfs-Brock, *Understanding Architecture Decisions in Context: An industry case study of architects' decision-making context*, in 12th European Conference on Software Architecture (ECSA 2018), J.P. Benedí, C.E. Cuesta, and D. Garlan, Editors. 2018, Springer: Madrid, Spain.

Section 2 places this study in context through a review of relevant literature from software architecture decision-making. This study employs a survey and three focus groups as part of a larger case study into architecture decision-making. Section 3 describes the research approach used in this study and includes the research questions that this study sets out to answer. Section 4 presents the findings from the survey and focus groups. Section 5 is a discussion of the findings. Finally, section 6 presents the summary and conclusions from this study, including a set of recommendations based on the findings, and a discussion of future research that builds on this study.

2 Literature Review

This section presents a review of the relevant architecture and decision-making literature that informs this study and helps to shape its research objectives. Bass, Clements and Kazman [1] define architecture as, "*the structure or structures of the system, which comprise software elements, the externally visible properties of those elements, and the relationships among them.*" Traditionally, an architecture may be described using one or more relevant views [2]. Recognizing that some architecture decisions have a broad impact Kruchten, Capilla and Dueñas [3] propose that a "decision view" be added to existing architecture views, superimposing the design rationale which underlies and motivates the selection of design options realized in the architecture. Kruchten, Lago and Van Vliet [4] suggest that "*Architecture Knowledge = Design Decisions + Design*". Jansen and Bosch [5] go even further to assert that a system's architecture should be viewed as the composition of a set of architectural design decisions. This paper takes the position that it is a distraction to argue whether decisions should drive the selection of relevant views as do Tyree and Akerman [6], or whether selecting relevant views should drive important decisions [7]. Both the architecture and the relevant views that represent it embody design decisions. Both are important to communicate. Important to understanding any architecture are the cumulative decisions that influenced it as well as an appreciation for how those decisions were made.

Although several formal architecture decision-making approaches have been published, software engineering researchers find few to be used in practice. This may be because many published decision-making approaches describe processes for making reasoned tradeoffs between several competing options, while decision making researchers observe that many complex real-world decisions are not about making tradeoffs, but instead about finding a reasonable decision that satisfices the current situation and allows for action [8]. Rekha V. and Muccini [9] also found that none of the published methods account for differences in expertise required to make informed decisions nor do they have provisions for resolving conflicts or differences of opinion. Surveys of architects have found that over 85% of decisions made are group decisions [9, 10]. During group discussions, both shared and unshared (e.g. unknown to all members of the group) information is brought out and examined.

Tyree and Akerman [6] proposed elevating architecture decisions to first-class architectural artifacts suggesting that documented decisions can provide concrete direction for implementation and serve as an effective tool for communicating to customers and management. It is unclear whether practicing architects often take their advice. In a survey by Dasanayake, Markkula, Aaramaa and Oivo [11], architects reported that 90% of their decisions were made and communicated informally. And while these architects were mostly satisfied with their informal decision-making processes, they also recognized some challenges with revisiting design rationale, communicating decisions to customers, and in knowledge gaps between engineers and architects. In our research we also found that decisions were communicated informally through a number of media, including slide decks, wikis, and meeting recordings.

Kruchten [12] proposes the following taxonomy for architecture decisions: *Existence decisions* state that some element or artifact will show up in the system's design or implementation. *Bans* or *non-existence decisions* are statements of things to not do. Kruchten [12] suggests that it is especially important to precisely document *bans* because there isn't a place for them in conventional architecture documentation. *Property decisions* affect the overall qualities of the system and may be represented by design rules or constraints. *Executive decisions* are driven by the business environment and may affect the development process or choices of technology and tools. Although they may place constraints on the architecture, Kruchten [12] asserts that executive-level decisions are often not captured or appear in documents usually not associated with the architecture. Kruchten's model, while one of the few decision categorization models that we can find in software architecture, is insufficient for handling decisions in the type of environment we are studying and for classifying the types of decisions we are uncovering.

While Miesbauer and Weinreich [13] found that architecture decisions could be mapped to Kruchten's taxonomy [12], they noted that architects themselves talk about decisions they make according to level. They proposed classifying architecture decisions according to these levels: Management typically makes *organization-level* decisions with advice from software architects. Once made these decisions are rarely revisited. Project managers, architects, and customers tend to make *project-level decisions* at the beginning of a project. Software architects or team leads typically make *architecture-level* decisions after discussion in a group. Finally, *implementation-level* decisions are made independently by developers and typically not documented. Miesbauer and Weinreich [13] suggest further investigation into whether the levels they identify are adequate to partition the decision space. A weakness in the framework of Miesbauer and Weinreich [13] is it suggests that impact is contained to a specific level. In our research, we found it fruitful to characterize decisions along multiple dimensions, including impact and scope. We also found examples where implementation-level decisions had system-wide impacts on architectural qualities.

3 Research Approach

This section presents the research questions addressed through this paper. This section then states the epistemological stance employed by the study, and how that influences the study and the choice of research methods. This study uses a case study of a large, global technology organization. A survey and three focus groups are used to answer the research questions. This section describes these methods, and how they contribute to the study. Finally, this section describes the data collection and analysis methods.

3.1 Research Questions

With regard to architecture decision-making, the topics of interest to this study relate to approaches, challenges, context, and impact. This paper aims to contribute to the body of knowledge on architecture decision-making by answering the following research questions:

- RQ1: **Approaches**: What are some examples of decision-making approaches used by architects, and how those decisions are made?
- RQ2: **Challenges**: What challenges do architects encounter associated with the current architecture decision-making approaches?
- RQ3: **Context**: How does the context influence decisions made by architects?
- RQ4: **Impact**: How do decisions made by architects impact other people?

Findings related to these questions are presented in section 4.

3.2 Research Method

Any study is shaped by the social and theoretical perspectives adopted by the researchers [14]. This study adopts an interpretivist, constructivist philosophical stance. Interpretivist research acknowledges that people have potentially widely-varying perceptions of the same phenomenon, and that knowledge is a social product [15].

This study uses a case study to "*understand complex social phenomena*" related to how architects make decisions. Case studies are well suited to research in software development because they study contemporary phenomena in their natural setting [16, 17]. This study is concerned with how and why architects make the decisions they do, and how those decisions impact others. Case studies can "*uncover subtle distinctions and provide a richness of understanding and multiple perspectives*" [18]. This research includes perspectives from multiple stakeholders, not just architects. Yin [19] notes that case studies are suitable when "*the boundaries between phenomenon and context may not be clearly evident.*" The primary unit of analysis is a Business Group, BG1, one of the largest business groups in the company consisting of approximately 5,000 people in different sites around the world. BG1 has multiple business units, each of which is responsible for multiple product lines in a particular domain. The initial survey targeted architects across BG1. The researchers decided to conduct a focus group with participants from each of three product lines. We targeted one product line per business unit in order to get a representative sample of perspectives on the topic of architecture decision-making. The case study consists of one survey from BG1 and three focus groups, FG1, FG2, and FG3.

These four units of analysis combine to provide a comprehensive picture of architecture decision-making. Initially, the researchers conducted a survey of 62 architects located across a business group with sites in North America, Europe, Israel, and India.

We wanted to broadly understand how architects perceived their role and interactions with others and more specifically what they found to be challenging and rewarding aspects of their work. In addition to demographic information, the survey asked about their role and interactions with other architects, engineers, product owners and product management. The survey participants were highly experienced, as shown in **Table 1**. The majority (90%) had architect, technical lead, or principal or distinguished engineer in their job title. The remaining respondents were engineers or managers. Different kinds of architects were represented including customer, solutions, systems, and Scrum (team lead) architects. Following on from the survey, we conducted three focus groups specifically on the topic of architecture decision-making.

Table 1. Survey respondents' years of experience as architects

# years experience as an architect	% of respondents
10+ years	47%
6-10 years	23%
4-5 years	15%
1-3 years	13%
< 1 year	2%
No response	10%

Morgan [20] defines focus groups as "*a research technique that collects data through group interaction on a topic determined by the researcher*". Yin [21], on the other hand, says the groups are focused because they share some common experience or views. These two perspectives are complimentary for the purpose of this study. The unit of analysis is the group itself, not the individuals within the group, so each focus group is one data collection unit [21].

Table 2. Summary of focus groups conducted as part of this study

Focus Group:	**FG1**	**FG2**	**FG3**
Focus	Architecture Decision Making	Architecture Decision Making	Architecture Decision Making
# Participants	10	11	12
Location	Israel	USA	India
Domain	Security Products	Video Technology	Networking Technology
Roles	Architects, Program Managers	Architects, Engineers	Architects, Engineers, Program Managers, Engineering Managers

The survey data was collected using a Web-based survey tool. The focus groups were recorded and then trascribed. The authors analyzed the survey data and focus group data independently and reviewed the analyses together through multiple iterations.

3.3 Threats to Validity

This section discusses potential threats to the validity of this research study.

- **External Validity**. The researchers do not claim that these findings are universally applicable. They are representative of a number of business units in a specific, large global technology organization. They serve as illustrative examples that others may learn from.
- **Construct Validity**. To mitigate this threat, data was collected from multiple sources. The researchers used triangulation between the survey data and the three focus groups, thereby converging evidence from four distinct data sources. The researchers compared results across multiple groups, where the data was collected at different points in time and in different geographic locations.
- **Reliability**. Relating to the repeatability of the study, the survey instrument and focus group questions were designed over several iterations and involved other subject matter experts and architects to review these and provide feedback. Using respondent validation [21] the researchers reviewed the data with a small group of architects from BG1 to help ensure validity of the data and the findings
- **Internal validity**. This study does not attempt to establish any causal relationships, so no internal validity threats are described [17].

4 Research Findings

4.1 Survey Results

The top 6 activities surveyed architects reported in order of frequency mentioned were architecture design, 98%; collaborating with development teams, 87%; product and solution requirements specification, 84%; knowledge sharing, 82%; document review, 65%; and program and product planning, 50%. Only 18% reported coding and 15% testing. Most, 82%, interacted daily with engineering and development teams; 13% did so weekly. Frequency of interactions with product owners and management was less with 44% reporting interacting daily, 37% weekly, and 10% monthly.

When asked what impacted their effectiveness, architects identified the dissipation of knowledge, the large number of people involved in making decisions, finding reliable or up to date documentation and information, misalignment with the development team and other architects, organizational changes, time zone differences, time pressures, and overlapping/unclear roles and responsibilities.

For the most part, architects perceived that they were effective in their various roles. 77% rated their effectiveness positively. 79% rated their communications with engineering as successful. Slightly less, 60%, rated their communications with product management as successful. However, some architects, were unsure whether others in the organization considered their work valuable or necessary. Architects wanted to be heard, understood, and recognized as making valued contributions.

Surveyed architects found working with engineers to be extremely rewarding. They were gratified to receive pragmatic, concrete feedback on the architecture and the decisions they made; to see the final solution as implemented and its evolving design; to answer questions, mentor engineers, and bring information about customers and broader issues to the team; to feel part of a team working on a common goal; and to be engaged in collaborative decision-making and mutual learning. They wanted engineers to be more involved earlier in the definition of the product as well as to be more involved themselves during implementation. Learning was perceived as bi-directional: while engineers have broader view of technology and trends in the industry, architects know about customer needs, product requirements, and more broadly about the existing architecture.

Architects expressed frustrations when engineers misunderstood their designs or when engineers lacked product knowledge. Other architects expressed frustration with engineers' seemingly short-term focus or focus on functionality to the exclusion of system qualities. It was also frustrating when engineers didn't contribute to or value architecture documentation, or when the code was viewed as "the only source of truth" about the design.

When asked one thing they would like change to make their practice of architecture more effective when working with engineering, several themes emerged: better knowledge sharing, improved documentation including documentation of decisions, and improved feedback and review of the architecture and its implementation.

Surveyed architects who regularly engaged with product owners or product management (not all did, and some architects were also in the role of product owner) were mixed in their perceptions. Some architects found it rewarding that they could influence product management's understanding of significant architecture requirements, clarify or remove unnecessary requirements, and influence product features and their delivery roadmap. They found it rewarding to get deeper insights into the customer and the product provided by product management.

Architects were frustrated by conflicting requirements or when product owners changed requirements or priorities too rapidly. Another frustration was inflexible product managers who didn't listen. Other architects expressed frustration with product owners' lack of current product or customer knowledge or when they made architecture decisions without asking their advice. They were also frustrated when those decisions seemed shortsighted or overly focused on satisfying a single customer.

When asked one thing they would like change to make the practice of architecture more effective working with product management, architects on the whole wanted to improve communications, increase collaboration, increase their visibility into and influence on the overall product strategy and backlog, and be involved in joint decision-making on architecture.

4.2 Examples of Decisions

Focus group participants were asked to share their experiences with recent architecture decisions. Examples of decisions are sown in Table 3.

Table 3. Examples of decisions identified in focus groups, and their context

Category	Example from this study	Scope	Impact	Source
Technology	Investing in micro-services frameworks	System	Business Unit	FG2
Technology	Moving to containers and microservices	System	Business Unit	FG2
Technology	Moving to open standards	System	Business Group	FG2
Design guide-line	Defining a standard for defining and publishing APIs	System	Business Group	FG2
Product implementation	Using incompatible technology	Product	Business Unit	FG2
Product implementation	Deciding to use platform native encryption components	Product	Business Unit	FG2
Product implementation	Taking a short-sighted, simple decision due to client pressure	Component	Business Group	FG1
Product implementation	Taking a decision quickly instead of analyzing new information brought up in a meeting	Component	Business Unit	FG1
Product implementation	Designing a backwards incompatible end-to-end solution	Component	Business Unit	FG1
Product implementation	Extending an existing solution, trying to fit a design to an incompatible platform	Product	Product Line Team	FG3
Product implementation	Repeatedly bringing up a design problem due to lack of understanding of an existing solution	Component	Product Line Team	FG3
Infrastructure	Investing in a separate infrastructure group	System	Business Unit	FG2

The researchers found it difficult to classify these decisions according Miesbauer and Weinreich [13] levels or to line them up with Kruchten's taxonomy [13]. Consequently, we characterized decisions as being technology, design guidelines, infrastructure, or product implementation level decisions. Analysis revealed that technology, design guidelines, and infrastructure decisions were viewed positively, while product implementation decisions were not. The data in Table 3 relates the decision examples to the case study. The scope of decisions relates to a component, a product (composed of many components), or a system (composed of many products). The decision impact is expressed in terms of whether the decision impacts the product team, the business unit, or the business group. Table 3 also notes the source focus group for the example.

4.3 Approaches to Decision Making

Architects described their decision making as mostly informal, e.g. the right people get in a room or on a phone call and discuss. While decision-making can be informal, it can also be political. One respondent in FG1 recounted a situation where those who dissented were removed from further discussion. Another observed that conversations, and persuasion and interpersonal relationships often drive decisions, and that this was not always positive. Depending on the decision, certain people had veto power, and for some decisions, it was agreed that product management rightfully should make them, although architects would like to be consulted.

The survey raised several questions about who made decisions about the architecture. One respondent noted that in some cases project managers and product managers make technical decisions without consulting architects. A different respondent expressed a desire for "*more formal tracking of decisions*" to help collaboration with product managers and product owners.

4.4 Challenges with Current Approaches to Decision Making

Architects were not always involved in architecture-related decisions. Survey respondents indicated that architects did not always have the influence that they thought they should have: *"significant decisions are completely centralized within the senior leadership team and architects/POs/PMs have less influence than they should."* This was echoed by another respondent who noted, *"Not all the information is shared with architects which could affect some architecture decisions in the initial phase of the project"*. There was no indication that the lack of information sharing or centralizing of decision-making was designed to deliberately to exclude architects, but several architects certainly felt the impact.

Focus group participants cited several challenges that they associated with current decision-making approaches. Decisions are often made without considering the technical feasibility of implementing the solution, and the long-term consequences associated with that. An example cited by one architect related to a build vs buy decision. In the system he worked on, there were several instances where the team decided to build the required functionality, rather than buy a commercial solution. This had the effect of adding to the system's technical debt.

Participants in FG2 noted that it is difficult to reverse poor decisions, and when decisions are reversed or changed, it does not happen quickly enough. Participants in FG1 noted an unwillingness to change decisions: "*the first decision is accepted as the final* *one and the project leader doesn't adjust or change direction when problems or new information is found*".

The survey highlighted several examples where architects felt decisions were not followed through. In one case, an architect felt that people do not follow through on implementing architecture decisions because they are unaware of them, or they do not trust the decision. One architect noted that architects are often out of the loop during development and that decisions and feedback would be improved if the team were to "*…involve architects on the problems raised during the implementation*".

4.5 Context in Which Architects Make Decisions

Architects didn't directly share many thoughts on why decisions were made the way they were. But some decisions seemed to be made under time pressure. In those cases, decision makers had to make tradeoffs between short-term project considerations and longer-term architecture sustainability. Decisions sometimes were made in the narrow context of delivering the next feature; in this case expediency drove the decision-making process. People got together, discussed, and made a decision. One participant in FG1 noted that it was difficult to make longer-term decisions, so he didn't: *"It's too hard to get enough convergence or consensus or agreement around a long term decision, so I often find that I'm making a small, local decision that serves a particular local need and that is locally optimized, and I'm not able to take any long term wide-ranging considerations into account".* At other times when it was important to gain consensus, it took time to make decisions. One architect in FG2 noted that, *"Because we're focused on getting consensus over multiple engineering teams and architecture teams all over the place, the process has just gotten more complicated."*

A large number of distributed teams is also an important part of the decision-making context. The participants in FG2 are part of a group of 50+ teams working on a single product. Geographic distribution between teams and multiple time zones adds to the difficulty of their context. As one architect from FG2 stated, "*we're not compartmentalized enough that we can make these decisions in one timezone, or even a couple of timezones*".

The distribution among multiple countries, time zones, and teams results in it taking a long time to make "big" decisions. Participants cited situations where consensus-based decisions were necessary and referred to "big" and "consensus" as attributes of decisions that take a particularly long time. As one architect noted about working with teams spread over 5 countries, it takes a long time "*... to sell the idea, right? You have to build consensus around that, and that does take a lot of time*".

Trust is also a factor in decision-making contexts. Focus group participants agreed that decision-making is "*more productive*" when there is a higher level of trust between the people directly involved. Participants cited situations where trust is not present. One example is where there are "*pockets of ... technical feudalism*" where an architect is making decisions in isolation.

The agile development process is also a factor. One surveyed architect noted, *"Agile development as currently practiced ... does not have a place for Architecture. So this needs to be fixed before we can have a meaningful discussion about how developers* *and architects interact."* Another expressed frustration about the way decisions are changed, *"The thing that frustrates me more is when the implementation doesn't match the design because there is a misunderstanding and the developers make their own decisions without checking with the architect. I'm all for letting the development teams as much freedom as possible but the architect needs to be consulted."*

4.6 Effect of Architecture Decisions on Architects and Other People

There are examples where architecture decisions are not followed through. In one system discussed by participants in FG2, architects defined a high-level architecture (HLA) for several subsystems. The perception of architects is that the teams responsible for implementing that HLA exhibited *"passive aggressive non-compliance"*. They did not challenge the HLA decisions directly. Instead, they disregarded the decisions in the HLA. The perception of the architects was that "*people on various scrum teams ... decide they know better*". Participants related this problem to the context of operating within a "giant" multi-country, multi-time zone project with 50+ teams. This context added to a lack of visibility by architects into what teams are actually building.

While verbal communication related to follow-through on architecture decisions happens, it is unpredictable. One architect expressed in the survey their desire for engineers to contribute more to design documentation, noting "*I wish engineers would have contributed more to the knowledge sharing via documentation (and not only verbally, which they do very happily)*".

Lack of information related to past decisions have a significant effect on architects currently working on the product. The need for a trail of decisions and their context came through as architects noted challenges associated with joining a product team where the architecture already has a long history, e.g., "*the very long history of the project and the decisions that were taken before I joined the project*".

Engineers don't always have enough context about the architecture. Sometimes engineers encounter cases where the architecture does not seem to support what they need to do. One architect noted in some cases "*they don't care too much about the design; if it seems it doesn't work, they may "adapt" the implementation, not in line with the design (that may well be wrong or incomplete) but without necessarily telling the architects or updating the documentation*". A further risk here is that if architects don't get this feedback, then any architecture decisions recorded earlier become out of date without an appropriate feedback loop.

5 Discussion

The geographic and time zone challenges reflected by FG2 indicates that the organization in question did not give enough consideration to the impact of these factors on architecture decision making.

5.1 Perceptions of Agile Development on Architecture Decisions

Agile development emerged as a particularly strong theme from survey results and the focus group data. The organizations that these groups were part of made decisions and assumptions about what it meant for agile and architecture to co-exist. Architects tend to bring up longer-term perspectives on the architecture. Some feel that short-sighted decisions are made when the decision makers focus only on feature delivery at the expense of architecture integrity or increased maintenance costs. An architect in FG2 noted, "*We do have this type of organization problem. I think it's because a combination of agile and I'm not sure the journey to Agile Architecture is ... It's still a journey ... We haven't quite figured it out.*"

Several survey respondents and focus group participants echoed a common theme around agile methods contributing to a loss of a paper trail. One survey respondent noted, in connection with the adoption of agile methods, "*we seem to have forgotten that paper-trail is important for adequate product maintenance*".

5.2 Feedback

Architects desire more feedback on their decisions and want more follow through with engineering. One architect in the survey stated, *"In my book software architecture implies that you have to work with the engineers and also be part of the development teams…[It] helps validate the design ideas you have as an architect."*

Some architects want more defined processes: *"I believe the lack of formal development lifecycle processes leaves the architect with a design that no one has to comply with". "The 'old way' of architecture process is gone and we don't really have a new one yet".* Another architect offers that one way to improve feedback "*…is for the architect to be a "virtual" member of the development team, going to some of the stand-ups, user story reviews, retrospectives, etc.*"

5.3 Group Decisions

The findings revealed that groups often make architecture decisions informally. Often decisions are not recorded and so the nuances behind the decisions are lost or become tacit knowledge held only by those initially involved with the decisions. Decisions coming from several sources impact the architecture. Product management, with or without architects' involvement, sometimes makes architecture decisions. Still other architecture decisions are "strategic" and made by senior management. Architects wanted more involvement in all these decisions.

5.4 The Roles of Architects and their Decision-Making Scope

The roles of architects and their scope of decision-making are not always clearly defined. There are different types of architects, ranging from those embedded in development teams (Scrum Architect) to customer and end-to-end solutions architects. Some architects are also Product Owners, which means they define features as well as product architecture. Architects are communicators, and often are the bridge between customer needs and engineering. However, decision-making responsibilities are not always clear. Responsibilities of various architect roles sometimes overlap. Architects would like more clearly defined roles that were better understood and agreed to.

5.5 Scope and Impact of Decisions

The data shown in section 4.2 indicates that the impact of decisions is generally quite high. Relating the decisions examples to the organization structure, 16.7% impact the product line team. 58.3% impact the business unit responsible for the product line. 25% impact the business group responsible for the business units. The majority of examples that impact the business group are architecture decisions that have a system scope, while one decision example has a component scope. This illustrates that, from an architecture perspective, a decision made at the component level can have a wide-reaching impact well beyond the team. Of the example decisions shown in section 4.2, the architecture decisions at the product scope impact either the product line team or the business unit. The architecture decisions at the system scope impact either the business unit or the business group.

5.6 Characterizing Decisions

During the data analysis we realized that none of the decision frameworks discussed in the literature review adequately captured certain dimensions of a decision. During the coding process we identified decision categories, which we noted as “Technology”, “Product”, etc. It also proved useful to identify the level of abstraction that a decision related to or impacted, i.e., systems, sub-system, component, etc.

We find it more useful to characterize decisions along multiple dimensions rather than try to fit them in to a single taxonomy. Our approach was to start with the data, and identify suitable characterizations for the data, rather than start with a framework and force-fit the data to the framework. This approach helped us, and the participants in our study, to gain a deeper understanding of the decisions and their context.

6 Summary and Conclusions

This section presents a summary of the research findings. Section 6.1 shows how the research questions have been addressed. Section 6.2 provides a set of recommendations for architects and organizations based on the research findings. Section 6.3 presents conclusions from the research. Finally, section 6.4 outlines directions for future research by the authors that builds on the topics and findings in this paper.

6.1 Answering the Research Questions

This paper sought to address five specific research questions, as outlined in section 3.1. This section summarizes how each research question has been addressed.

- RQ1: **Approaches**. Sections 4.2 and 4.3 presented findings that show examples of current decision-making approaches used by architects. The findings identified a range of approaches, notably the prevalence of informal, group-based decisions. There are also examples of scenarios where architects are not involved in architecture decisions which were made by product management or management, or where they had insufficient information to make an informed decision.
- RQ2: **Challenges**. Section 4.4 articulated challenges encountered by architects related to decision-making approaches. The findings identified some architecture decisions were made without considering the technical feasibility or longer-term consequences and other decisions were made without adequate information.
- RQ3: **Context**. Section 4.5 described some conditions within which architects make decisions. The findings identified that architects worked with large, distributed teams to make decisions which often required consensus building and gaining trust. Architects did not directly offer explanations for their decision-making approaches. Some decisions are made more quickly under time pressures while "bigger" decisions take more time and involve gaining group consensus.
- RQ4: **Impact**. Section 4.6 showed how decisions made by architects, and their decision-making approach, impact other people. The findings suggest that decision-making was viewed as more effective when architects followed through with engineering or decisions were made collaboratively.

6.2 Recommendations

The following recommendations are drawn from the survey and focus group findings:

1. Consider the space-time separation of teams, and how that impacts architecture decisions. When dealing with teams who are separated in space (through multiple geographies) and time (through multiple time zones), make an effort to compartmentalize the scope of responsibility of teams such that coherent architecture decisions can be made in each location.
2. Establish clear decision-making boundaries. Articulate who is responsible for which type of decisions. This can be based on scope of decision (product, system, component, etc.), nature of decision (product, technology, etc.), or something else.
3. If your organization is using an agile development approach, then take the time to articulate how architecture fits.
4. Understand who is impacted by decisions made by architects. Establish a feedback loop so that architects understand that impact in a timely manner.
5. Start with why. Architects in this study expressed a much higher degree of success in decision adoption when other people understood why a decision is being taken. This is an important part of the context of architecture decisions.
6. Take the time to foster trust among architects and those impacted by decisions.
7. Consider how architecture decisions are retained and communicated. We see a need for retaining and communicating architecture decisions and their rationale, especially when decisions have broad impact. Documenting decisions, to be effective, should fit into existing processes.

8. Some decisions are necessarily made for short-term expediency, e.g. to address an immediate customer need. Perhaps there needs to be some mechanism to flag these types of decisions and manage them, perhaps in a product debt backlog (especially those that will incur architecture debt) for periodic review.

6.3 Conclusions

Having multiple dimensions that help characterize different decisions, as shown in section 4.2, provides deeper insights into the types of decisions architects are dealing with. Architects are generally experienced decision makers operating in an environment characterized by time pressure, insufficient information, poorly defined or non-existent procedures, and a need for coordination across hundreds of people in multiple global teams. Their perception is they are most effective in making decisions where they have formal and direct collaboration with engineering and product management. The findings showed several examples that help the researchers understand how architects approach decision-making, and the challenges, context and impact of those decisions. The findings did not reveal sufficient data about the reasons why architects choose the decision-making approaches they employ.

6.4 Future Research

Future research based on this study will focus on the following:

- Understanding how architecture decisions constrain other decisions. It is hard for developers who get involved later, long after a decision is made, to understand the initial design context. This research points to the potential need for a cumulative history of decisions.
- Understanding the trade-offs and benefits between documenting decisions, and other aspects of the architecture. In particular, is it more important to document decisions than it is other aspects of the architecture?

The authors also intend to reproduce this study with additional organizations to understand how approaches to architecture decision making vary in different contexts.

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