Difficulty of Architectural Decisions – A Survey with Professional Architects

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Abstract. Much research exists on architectural decisions, but little work describes architectural decisions in the real-world. In this paper, we present the results of a survey with 43 architects from industry. We study characteristics of 86 real-world architectural decisions and factors that contribute to their difficulty. Also, we compare decisions made by junior architects and senior architects. Finally, we compare good and bad architectural decisions. Survey results indicate that architectural decisions take an average time of eight working days. Dependencies between decisions and the effort required to analyze decisions are major factors that contribute to their difficulty. Compared to senior architects, junior architects spend a quarter of the time on making a decision. Good architectural decisions tend to include more decision alternatives than bad decisions. Finally, we found that 86% of architectural decisions are group decisions.

1 Introduction

The architecture of a software system is the result of a set of architectural design decisions [1]. Architectural decisions have a key influence on the functional and quality characteristics of software systems [2]. Examples of architectural decisions are choosing development frameworks or architectural patterns. Given the importance of architectural decisions and their significant impact on system development, much interest exists for research on architectural decisions. However, characteristics of architectural decisions and factors that contribute to their difficulty have not yet been studied in industrial practice. An in-depth understanding of the characteristics and difficulty of architectural decisions would enable researchers to propose approaches that help practitioners in their decision making activities. Thus, we conducted a survey to answer the following research questions:

RQ1. What Are the Characteristics of Architectural Decisions?
To answer RQ1, we define measurable characteristics (Table 1) of architectural decisions. Previous research has shown that the concept of architectural decisions gained importance among practitioners, despite the fact that the definition of software architecture in terms of architectural decisions was not completely adopted in practice

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[3]. Another survey with practitioners provides insights on knowledge sharing for architectural decisions [4]. However, we could not find any study that investigates the characteristics of architectural decisions.

RQ2. What Factors Make Architectural Decisions Difficult?
To answer RQ2, we defined a list of factors derived from literature and discussions with experts. The resulting metrics were 22 factors (Table 2) that survey participants rated. Once we know what makes architectural decisions difficult, we can devise approaches that focus on mitigating the difficulty of making decisions.

RQ3. What Are the Differences between Junior and Senior Software Architects?
The experience of architects influences their decision making [5,6]. Thus, we propose RQ3 to investigate how difficulty and characteristics of decisions vary with the level of experience. This helps researchers propose targeted solutions to address the difficulties perceived by either junior architects or experienced architects. Previous research showed that naïve architects (i.e. undergraduate students) do not make trade-off between requirements, and do not evaluate critically their decisions [5]. Furthermore, professional architects very often search for many design alternatives in their decision making [6]. Additionally, professional architects do not consider risk assessment as very important [6].

RQ4. What Are the Differences between Good and Bad Architectural Decisions?
We propose RQ4 for studying the differences between decisions with a more preferable outcome (i.e. *good* decisions) and decisions with a less preferable outcome (i.e. *bad* decisions). Answering RQ4 highlights characteristics and difficulty factors linked to good and bad outcomes of architectural decisions.

2 Survey Design and Results

2.1 Survey Design

To develop the survey, we reviewed existing literature on architectural decisions (e.g. [2,5,6]). From the literature, we identified factors that contribute to the difficulty of architectural decisions. Next, we interviewed four senior architects, each with at least ten years of experience as an architect. We asked each architect to identify two architectural decisions they had been involved in, and discussed the difficulty factors for both decisions. Afterwards, we asked the architects to propose other items that contribute to the difficulty of a decision to be included in the questionnaire used to collect the survey data. The architects also provided thoughtful feedback on the structure of the questionnaire. We piloted the questionnaire with other practitioners, and improved it by rephrasing some questions to increase clarity.

After a welcome message, participants had to confirm that they were directly involved in making architectural decisions during the last two years. The survey continued with a few questions about the background of participants. Next, participants were asked to indicate a good architectural decision (i.e. *good* or *bad* outcome, according to their judgment), and described its characteristics (Table 1). Next, participants were asked to rate the 22 statements in Table 2 about the difficulty of their good architectural decision on a Likert scale. Similar steps had to be performed for the bad architectural decision.

Our target population was software architects who were directly involved in making software architectural decisions during the last two years. To reach our target population, we sent survey invitations to architects in our personal networks. Furthermore, we posted survey invitations on LinkedIn groups and ran paid ad campaigns using LinkedIn and Google. We received 43 valid responses from 23 countries on five continents. Twelve participants had up to two years of experience as architects, ten participants had three to five years of experience, thirteen participants had six to ten years of experience, seven participants had eleven to fifteen years of experience, and one participant had more than fifteen years of architecting experience.

2.2 Results for RQ1 - Characteristics of Architectural Decisions

Participants indicated the actual and the elapsed time (i.e. actual time is spread over the elapsed time, as architects are also involved in other activities) they spent for making the 86 architectural decisions (Table 1). On average, architectural decisions took about eight working days, and elapsed over around 35 working days. Participants indicated how many people were involved directly and indirectly in making the architectural decisions. The number of indirectly involved persons excludes the directly involved persons. The results are shown in Table 1. On average, each architectural decision involved three persons that were directly involved. When making an architectural decision, more alternatives are considered. We asked participants to indicate the number of alternatives they considered at the beginning of their decision making process, and the number of alternatives they studied for an extended period of time. Results are shown in Table 1. Architects consider quality attributes in their decisions. However, it is not clear how many quality attributes they consider in practice, so we asked them to indicate this number for their decisions (Table 1).

Table 1. Metrics for actual/elapsed time (in working days), number of directly and indirectly involved persons, number of alternatives considered in the beginning/extended time, and number of quality attributes considered when making the architectural decisions

Metric	Actual	Elapsed	Direct	Indirect	Begin	Extend	#QA
Average	7.85	34.74	3.12	7.05	2.91	1.96	4.74
Std. dev.	9.22	70.59	1.54	8.91	1.43	0.84	4.19
Min.	0.50	0.63	1	0	1	0	0
Max.	44	600	8	50	8	4	30
Mode	1	5	3	3	3	2	3

2.3 Results for RQ2 - Difficulty of Decisions

Participants rated 22 factors (Table 2) on the difficulty of their architectural decisions, indicating their level of agreement with the statements, using the following values: *(strongly) disagree*, *neutral*, *(strongly) agree*, and *not applicable*.

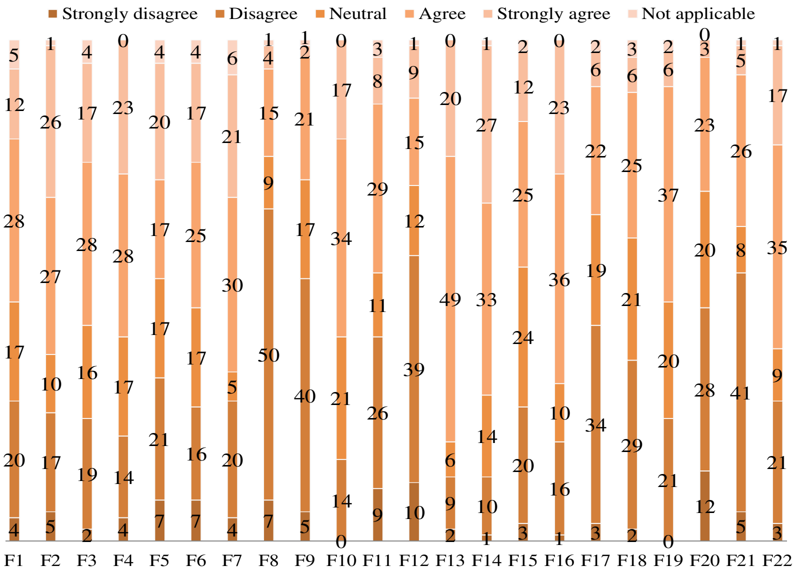
Results for each factor are summarized in Fig. 1 (left). From the bar charts, we notice the following. Participants indicated **most agreements** (including strong agreements) with statements on *dependencies with other decisions* (F13 for 69 decisions), *major business impact* (F14 for 60 decisions) and *serious negative consequences* (F16 for 59 decisions). Participants indicated **most disagreements** (including strong disagreements) with statements on *having too many alternatives* (F8 for 57 decisions), *too many people involved in decision making* (F12 for 49 decisions), *lack of domain-specific knowledge* (F21 for 46 decisions), and *having too few alternatives* (F9 for 45 decisions). Participants indicated **most neutral** standpoints with statements *on respecting existing architectural principles* (F15 for 24 decisions), *needing lot of effort for analyzing decision alternatives* (F10 for 21 decisions), and *having much peer pressure* (F18 for 21 decisions).

Table 2. List of 22 factors that contribute to the difficulty of architectural decisions

ID	The decision was difficult because…
F1	you received conflicting recommendations from various sources about which decision alternative to choose
F2	there were no previous similar decisions to compare this decision against
F3	it was hard to identify a superior decision alternative from the alternatives under consideration
F4	the decision required a lot of thinking from you
F5	it was hard to convince stakeholders to accept a certain decision alternative
F6	stakeholders had strongly diverging perspectives about the decision
F7	you needed to influence some stakeholders without having formal authority over them
F8	the decision had too many alternatives
F9	the decision had too few alternatives
F10	analyzing alternatives for this decision took a lot of effort
F11	some quality attributes were considered too late in the decision making process
F12	too many people were involved in making the decision
F13	dependencies with other decisions had to be taken into account
F14	the decision had a major business impact
F15	you had to respect existing architectural principles
F16	serious negative consequences could result from the decision
F17	too little time was available to make the decision
F18	you had a lot of peer pressure
F19	of the trade-offs between quality attributes
F20	you lacked experience as an architect
F21	you lacked domain-specific knowledge (e.g. new customer)
F22	more information was needed to reduce uncertainty when making the decision

Fig. 1 (right) shows average values for all factors, calculated as follows. We assign numerical values to the Likert scale: *strongly disagree* (1), *disagree* (2), *neutral* (3), *agree* (4), and *strongly agree* (5). *Not applicable* values are ignored. We acknowledge challenges with treating a Likert scale as either an interval or categorical data. Still, we use averages because they are easy to understand for a large audience.

From Fig. 1 (right), we notice that *dependencies with other decisions* (F13) and *major business impact* (F14) have highest average agreements across participants. *Negative consequences* (F16) received second highest average. *Effort for analyzing alternatives* (F10), *lack of similar decisions* (F2) and *requiring a lot of thinking* (F4) received high agreements from participants.



ID	Avg.
F13	3.88
F14	3.88
F16	3.74
F10	3.63
F2	3.61
F4	3.6
F7	3.55
F22	3.49
F3	3.48
F6	3.35
F19	3.33
F1	3.3
F5	3.27
F15	3.27
F18	3.05
F11	3.01
F17	2.93
F21	2.82
F20	2.73
F9	2.71
F12	2.69
F8	2.52

Fig. 1. Survey results for each factor (left), and sorted average values for factors (right) - a higher average indicates stronger agreement with the difficulty of a factor

We notice that some factors have averages that suggest disagreement that they contribute to the difficulty of architectural decisions, i.e. have averages smaller than three (neutral). For example, *too many* (F8) or *too few* (F9) alternatives contribute little to difficulty, similar to *lack of experience* (F20) and *domain-specific knowledge* (F21). However, the last two factors need to be considered in the context that many participants were senior architects, who might have enough experience and knowledge.

2.4 Results for RQ3 - Differences between Junior and Senior Architects

We divide survey participants in junior and senior architects as follows. Junior architects have up to five years of experience as architects, and senior architects have six or more years of experience as architects. Based on this criterion, 22 junior and 21 senior architects answered the survey.

To compare the answers from junior and senior architects, we use the Mann-Whitney U test, a non-parametric test. We investigate the differences between junior and senior architects with regard to the 22 factors in Table 2, and the metrics in Table 1. We obtain significant statistical differences (p-values less than 0.05) between junior and senior architects for five difficulty factors and one characteristic. Junior architects considered *conflicting recommendations on what to consider for a decision* (F1) as more significant to making a decision difficult. Also, in contrast to senior architects, junior architects found that if *lots of thinking is required* (F4), decisions become more difficult. In turn, senior architects found that decisions become more difficult if they *have a major business impact* (F14). There are differences between junior and senior architects on *experience* (F20) and *domain-specific knowledge* (F21); these differences can be expected to some extent, because senior architects have more experience and domain-specific knowledge. Additionally, senior architects spend four times more actual time on their decisions than junior architects.

2.5 Results for RQ4 - Differences between Good and Bad Decisions

Comparing participants' answers on their good and bad architectural decisions increases our understanding on the quality of architectural decisions, by analyzing the link between the two aspects of quality: difficulty (the 22 factors in Table 2) and outcome (good and bad decisions). Furthermore, we analyze the link between the characteristics of architectural decisions and their outcome (e.g. are there differences between the time spent on good or bad decisions?).

We compare differences between the 43 good and 43 bad decisions using the Wilcoxon signed ranks test, a non-parametric statistical test for comparing groups of two related samples. We treat *'not applicable'* answers as missing values. Similar to the analysis in Section 2.4, we investigate the differences between good and bad decisions related to the data in Table 1 and Table 2.

We found statistically significant differences on *having too few alternatives* (F9), with a tendency for disagreement with F9 on good decisions, and for neutral with F9 on bad decisions. For bad decisions, participants indicated that *some quality attributes were considered too late* (F11), in contrast with good decisions. Also, *dependencies with other decisions* (F13) are more difficult for good than bad decisions. Participants disagreed on *too little available time* (F17), *much peer pressure* (F18), and *lack of experience* (F20) for the good decisions, in contrast with the bad decisions.

Regarding the decisions characteristics, we found statistically significant differences between the number of alternatives considered at the beginning of the decision making process, number of alternatives studied for an extended period of time, and the number of quality attributes. For all these, the good decisions had higher numbers.

3 Discussion

An architectural decision takes an average actual time of around eight working days, over an average elapsed time of 35 working days (Table 1). The survey results indicate no significant differences between good and bad decisions regarding actual and elapsed time. However, participants considered they had enough time for the good decisions, and not enough time for the bad decisions.

The actual time junior architects spend on making a decision is one quarter of that spent by senior architects. We expected senior architects to spend less or similar amounts of time to junior architects, because of their extra experience. A possible explanation is that senior architects might deal with higher impact, time-consuming decisions than juniors. A future comparison should use a ratio of time per decision impact, which can be quantified as the estimated cost of reversing the decision.

Another insight from this survey concerns the number of people involved in architectural decisions. The importance of stakeholders in architectural decisions is widely recognized in the literature. Stakeholders are always involved indirectly in decision making. However, no studies mention the direct involvement of stakeholders in decisions, as decision makers, rather than decision influencers. Researchers need to know if architectural decisions are typically made by one person (i.e. the architect) or by groups of persons (i.e. one or more architects, and other stakeholders). For example, researchers can propose group decision making approaches, if a relevant proportion of architectural decisions are made in groups. A surprising result is that only 14% of the decisions in the survey were made by individuals. The typical architectural decision has three decision makers (Table 1). We consider that group architectural decision making is a much needed research direction.

Regarding difficulty of decisions, we notice that dependencies with other decisions contribute much to difficulty of decisions. Results from a related survey [6] indicate that architects often come across such dependencies. Moreover, researchers proposed various approaches for handling decisions dependencies (e.g. [7]). Our survey confirms the relevance of the topic, and the need for disseminating research results to practitioners. We also found that analysis effort and lack of similar (or previously made) decisions increase difficulty of decision making. This suggests that practitioners welcome approaches that help them analyze decisions, and appreciate examples of similar decisions as opportunities to reuse architectural knowledge.

Regarding differences between junior and senior architects, we found that junior architects need help to address the difficulties of analyzing decisions, such as handling conflicting recommendations. This is not relevant for senior architects. We consider that existing documentation approaches help junior architects. However, documentation could be improved by adding capabilities for analyzing decisions.

Regarding differences between good and bad decisions, the survey results indicate that good decisions have more alternatives than bad decisions. Therefore, as a rule of thumb, we recommend practitioners to identify three or more alternatives. Also, this study confirms that practitioners should pay attention to quality attributes and decisions dependencies while making architectural decisions.

To increase **internal validity**, we piloted and refined the questionnaire to ensure that participants could understand it. Also, we added explanatory text with small examples to the questions, so that participants could easily interpret the questions. To address **construct validity**, we discussed our conceptualization of decision difficulty with experienced architects, who helped us refine it. The very low numbers of 'not applicable' answers to survey items indicates that the survey items indeed measure difficulty of decisions. We increased the **external validity** of this survey by recruiting participants from multiple venues.

4 Conclusion and Future Work

We have two take-away messages for practitioners. First, since architects make decisions that have major business impact, it is important (especially for junior architects) to use decision making tools and processes that help them analyze alternatives and dependencies with other decisions. For example, based on our previous work [8,9], we are developing an open-source tool [10] that will include support for group decision making, analyzing alternatives and dependencies with other decisions. Second, during architectural decision making, considering more alternatives and more quality attributes leads to better decisions.

This paper encourages researchers to conduct future descriptive work on real-world architectural decision making (e.g. provide more data about decisions). Also, researchers can propose decision making support for architects based on their experience levels, and the actual difficulties faced by architects. Finally, this paper provides evidence for the need of future research on group architectural decision making.

References

1. Jansen, A., Bosch, J.: Software Architecture as a Set of Architectural Design Decisions. In: 5th Working IEEE/IFIP Conference on Software Architecture, pp. 109–120. IEEE (2005), doi:10.1109/WICSA.2005.61
2. Zimmermann, O.: Architectural Decisions as Reusable Design Assets. IEEE Software 28(1), 64–69 (2011), doi:10.1109/MS.2011.3
3. Clerc, V., Lago, P., van Vliet, H.: The Architect's Mindset. In: Overhage, S., Ren, X.-M., Reussner, R., Stafford, J.A. (eds.) QoSA 2007. LNCS, vol. 4880, pp. 231–249. Springer, Heidelberg (2008)
4. Farenhorst, R., Hoorn, J., Lago, P., van Vliet, H.: The Lonesome Architect. In: Joint Working IEEE/IFIP Conference on Software Architecture & European Conference on Software Architecture, pp. 61–70. IEEE (2009), doi:10.1109/WICSA.2009.5290792
5. van Heesch, U., Avgeriou, P.: Naive Architecting - Understanding the Reasoning Process of Students. In: Babar, M.A., Gorton, I. (eds.) ECSA 2010. LNCS, vol. 6285, pp. 24–37. Springer, Heidelberg (2010)
6. van Heesch, U., Avgeriou, P.: Mature Architecting - A Survey about the Reasoning Process of Professional Architects. In: 9th Working IEEE/IFIP Conference on Software Architecture, pp. 260–269. IEEE (2011), doi:10.1109/wicsa.2011.42
7. Jansen, A., Avgeriou, P., van der Ven, J.S.: Enriching Software Architecture Documentation. Journal of Systems and Software 82(8), 1232–1248 (2009), doi:10.1016/j.jss.2009.04.052
8. Tofan, D., Galster, M., Avgeriou, P.: Capturing Tacit Architectural Knowledge Using the Repertory Grid Technique (NIER Track). In: 33rd International Conference on Software Engineering, pp. 916–919 (2011), doi:10.1145/1985793.1985944
9. Tofan, D., Galster, M., Avgeriou, P.: Reducing Architectural Knowledge Vaporization by Applying the Repertory Grid Technique. In: Crnkovic, I., Gruhn, V., Book, M. (eds.) ECSA 2011. LNCS, vol. 6903, pp. 244–251. Springer, Heidelberg (2011)
10. Tool for Repertory Grid Technique, `https://github.com/danrg/RGT-tool` (accessed April 2013)