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# Group decision-making in software architecture: A study on industrial practices

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ABSTRACT

*Context:* A Software Architecture results from a comprehensive process in which several stakeholders deliberate upon the key requirements, issues, solutions and make architectural design decisions. Literature shows that most architectural decisions, in practice, are made in groups. Still, there is a limited understanding of industrial group decision-making practices in software architecture and the challenges that software architecture groups face.
*Objective:* Our study, by drawing inspiration from group decision-making theories and models, aims at understanding (i) Existing decision-making practices in software architecture groups (ii) the comparison between practice and theory, (iii) the challenges that the groups face, and (iv) the satisfaction of group members with various aspects of Group Decision Making.
*Method:* The study has been conducted through a questionnaire-based survey. 35 practitioners participated in this survey and the responses were analyzed qualitative and quantitatively.
*Results:* The analysis of individual responses reveal that software architecture groups (composed, on average, of 3–5 co-located or dispersed members) adopt a discussion based approach while evaluating alternatives, thereby lacking a structured way of decision-making. In these groups, despite the involvement of group members in the discussions, the final decision is made by an individual of authority. Not only is structured decision-making less common, the usage of dedicated software tools for decision-making too is rare. These groups face challenges that are indicative of Groupthink and Group Polarization. Group members feel that quantity of alternatives generated during discussions and tool availability are below satisfactory and they have low satisfaction with the tool support available.
*Conclusion:* This study has helped us develop an understanding of software architecture groups, their decision-making practices and challenges faced together with the satisfaction of group members. What the industry needs is integration of group decision-making principles into software architecture decision-making and design of decision-making tools that assist the architecture groups.

## 1. Introduction

*"Architecting = Decision Making"* was the title used by Hans Van Vliet for his keynote speech at ECSA 2014, the 8th European Conference on Software Architecture. It summarizes a trend initiated in 2005, emphasizing that a software architecture (SA) consists of both Architectural Design Decisions that lead to a chosen solution and a blueprint of the solution [1].

Designing a good architecture involves making the right architecture design decisions (ADDs). Therefore, design decisions can be looked at as first class entities [2]. Substantial amount of research has been carried out, in the last decade, to document and record ADDs in the form of Architectural Knowledge and the design of tools and methods to support the decision-making process [3]. While most of these tools and methods put an individual at the center of the design decision process, the industrial studies on ADDs show that decisions are taken by groups of stakeholders [4]. With several stakeholders interacting with each other to make key ADDs, it may be useful to view SA decision-making as a Group Decision Making (GDM) process. Therefore, *"Architecting = Group Decision Making"* is the way we would like to rephrase and expand Hans Van Vliet's statement. The "group" dimension adds another layer of complexity and opportunities to the current decision-making processes and methods.

Existing SA decision making tools and methods provide very little support for the GDM processes followed in organizations while architecting software [4–6]. The vast amount of knowledge and insights

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**Table 1**
Main findings.

| RQ | Key Finding | Description |
|---|---|---|
| RQ1 | Existing GDM Practice | Real world SA groups adopt a purely discussion based approach to decision-making with minimal inclination to structured approaches. There are two types of decision-making styles that are observed in SA groups: i) Democratic style where discussions happen in a group while the final decision is made by person of authority, or b) Laissez-faire styles where group has full control over the process and decisions. Autocratic decision-making style has not been mentioned by any respondent. |
| RQ2 | Alignment with GDM literature | GDM literature reveals that structured decision-making methods and heterogeneity of composition lead to better outcomes. Our study shows a preference for unstructured decision-making methods and homogeneity among SA groups. |
| RQ3 | Challenges Faced | The existing GDM practices among SA groups cause a lot of challenges like lack of diversity in perspective, not exploring the full range of risks of a specific decision, accepting low risk solutions etc. Some of these challenges indicate the presence of *Groupthink* and *Polarization*. |
| RQ4 | Satisfaction of SA group members | Group members feel that quantity of alternatives generated during discussions is below satisfactory and they have low satisfaction with the tool support available for making group decisions. |

available in GDM literature is yet to be harnessed by the SA community.

In this paper we present a study of industrial practices of GDM in SA. The research questions that guide our study are: RQ1: What are the existing Group Decision Making practices in real world SA groups? RQ2: Are the group decision-making techniques currently being practiced in line with techniques in GDM literature? RQ3. What are the challenges that SA groups face while making architecture-related group decisions? RQ4: How satisfied are SA group members with various aspects of GDM?

Guided by the research questions, a questionnaire was designed consisting of 49 questions and circulated online. Question wise analysis of the survey responses was done using quantitative and qualitative methods and the analysis yielded answers to the research questions.

### 1.1. Main findings

Our main findings are highlighted in Table 1.

### 1.2. Paper outline

Our paper is organized as follows. Section 2 presents a thorough background on GDM literature, as well as information on Architectural Design Decisions. Section 3 presents detailed information on the methodology used for collecting, organizing and analyzing our survey data. The systematic analysis of data and a summary of results is presented in Section 4. A discussion of our findings is presented in Section 5. Threats to validity are discussed in Section 5.2. Related work are presented in Section 6. We conclude and lay the foundation for our future work in Section 7.

## 2. Background and motivation

This section introduces background information on group decision-making (Section 2.1), as well as state-of-the art information on architecture design decision (Section 2.2).

### 2.1. Group decision making

Group decision-making is a research area that aims to understand and develop methods to enhance the collective decision process. This area, combined with research on negotiation, has a vast and growing literature associated with diverse areas of Economics, Engineering, Psychology and Neuroscience [7].

While studying GDM, researchers have focused on different aspects of the groups including *group characteristics* like size, composition and cohesion [8–12], the *stages in the formation of groups* [13], *information exchange* within the group [14–16], GDM *methods* [17] and *issues* faced like Groupthink, Groupshift (risky-shift) and Polarization [18–22].

Early works on GDM focus on understanding *how and under what circumstances* were groups better than individuals. Laughlin et al. have proved, through their experiments, that groups definitely outperform individuals on complex tasks and the ideal group size for an efficient performance is between 3 to 5 members [23]. Group performance is impacted by the *cohesiveness* of members. Festinger defines cohesiveness as *the resultant forces which are acting on the members to stay in a group* [24]. Cohesiveness is developed when members have worked with each other on a specific task for an extended period of time and the members have resolved issues that arises in new groups [25].

The outcome of the GDM process and the quality of outcome is significantly impacted by the *amount of information that is shared* amongst the group members [26]. A “good” GDM process should ensure that more “unshared” information (i.e., information that is known only to a few members in the group) is brought to light through a process of discussion and deliberation [14].

There are several studies on the *GDM methods* and their applications in various fields. Peniwati in [17] has used an evaluation framework with 16 criteria to evaluate the various GDM methods in literature. When it comes to GDM processes, Aldag and Fuller [27] describe a Generic Group Problem Solving Model (GGPS) that summarizes different aspects of GDM including: *decision characteristics, group structure*, and *decision-making context* that impact the overall *emergent group characteristics*. Insights derived from the GGPS model and evaluation framework of Peniwati [17] has guided the design of our questionnaire.

### 2.2. Architectural Design Decisions

Architectural Design Decisions (or simply, ADDs) are recognized to be important building blocks in the design of a software architecture. ADDs involve choosing the right architectural entities that satisfy the stakeholder concerns as well as the quality criteria set for the system.

These decisions form a vital part of architectural knowledge and hence recording and maintaining them is of utmost importance [28]. Practically, it may be difficult to change the architectural decisions since they are closely intertwined with other decisions, and any change impacts the architecture, design and the code of the system. Due to this complex interconnections, a bad decision-making process may result in the choosing of worst alternatives thereby impacting the final outcomes [29]. Hence a lot of care is taken to make (quasi-)optimal decisions that are valid for a long period of time. The ADD techniques as surveyed by Falessi et al. [29], and the tools currently available for ADD are focused on capturing and storing architectural knowledge. These tools help architects to record the requirements, decision alternatives, solutions, rationale, constraints and criteria. SA decision-making methods like ArchDesigner [30], ATAM [31], and CBAM [32] not only facilitate recording of decisions but also assist architects in making decisions. To some extent, they also support GDM by allowing multiple stakeholders to express their preferences and make optimal choices through trade-offs or pair-wise comparison. Attribute-Driven Design is an approach to designing software based on quality attribute requirements. The method requires architects to work in teams [33]. To a certain extent, $AD_{kwik}$ proposed in [34] supports collaboration by allowing multiple stakeholders to create and share architectural

knowledge. GADGET, a GDM process, helps to increase the consensus among architects, captures relevant knowledge about decisions and support multistakeholder views [35]. However, several of the existing tools or methods lack support for making collaborative decisions, though the community acknowledges that SA decision-making is largely a group process [4,36]. We wish to address this gap through our current and future work on SA group decision-making.

Minimal focus on SA groups and group process as highlighted by [4,6], lack of tool support for GDM in SA as we found in our previous studies [36,37] and the challenges that SA groups face are the main motivation behind our work which is aimed at gaining better understanding of existing practices.

## 3. Methodology

In order to gain an understanding of the various aspects of GDM practices in the architecting process, we conducted a study that involved practitioners from the industry. This study was conducted by following the guidelines provided by Kitchenham et al. in [38] and by taking inspirations from state-of-the-art studies, such as the ones conducted by Torchiano et al. and Malavolta et al. in [39,40]. The steps in our research are: (a) identifying the objectives of the study, as elaborated in Section 3.1 (b) identifying the research questions, as discussed in Section 3.2 (c) designing the survey, as detailed in Section 3.3.1 (d) circulating the questionnaire, as detailed in Section 3.3.2 (e) obtaining responses, as detailed in Section 3.3.2 and (f) analyzing the responses, the details of which are available in Section 4.

### 3.1. Objectives

Keeping in mind our overall objective of understanding industrial GDM practices, we identified four specific objectives for this study:

- Understanding GDM practices in SA groups;
- Comparing GDM processes adopted by SA groups with the decision-making processes mentioned in GDM literature;
- Eliciting challenges that SA groups face when different stakeholders collaborate to take architecture design decisions;
- Understanding if SA group members are satisfied with their GDM process as well as its outcomes;

### 3.2. From objectives to research questions

As per Kitchenham's work[38], ours is a cross-sectional study of the past experiences of SA groups with respect to group decision-making practices. We translated the research objectives to four research questions which are as follows:

- RQ1: What are the existing group decision-making practices in real world SA groups?
  *Objective:* Understanding group decision-making practices in SA groups;
  *Outcome:* we expect to get an understanding of the size and composition of groups and dispersion of group members, tools used for communication, and the methods followed to arrive at optimal decision.
- RQ2: Are the group decision-making techniques currently being practiced in line with techniques in GDM literature?
  *Objective:* Comparing GDM processes adopted by SA groups with decision-making processes mentioned in GDM literature;
  *Outcome:* we aim to produce a clear and detailed map of the state-of-the-practice of GDM in the industry and draw comparisons with decision-making process mentioned in GDM literature to understand the similarities and differences together with the reasons for differences.
- RQ3: What are the challenges that SA groups face while making architecture-related group decisions?
  *Objective:* To elicit challenges that SA groups face when different stakeholders collaborate to take architecture design decisions.
  *Outcome:* we expect to get information about potential group issues, such as: power differences, ownership issues, and conflicts that SA groups face while making decisions.
- RQ4: How satisfied are SA group members with various aspects of GDM?
  *Objective:* To understand if SA group members are satisfied with their GDM process as well as its outcomes
  *Outcome:* we expect to collect information about the satisfaction of group members related to: participation of members, information sharing by members, GDM tools in SA etc.

### 3.3. Study phases

The study was conducted in three phases.

- Phase 1: a questionnaire was prepared based on the identified research questions.
- Phase 2: the questionnaire was circulated among practicing architects and those involved with SA decision-making in the industry and the responses were obtained.
- Phase 3: the responses were compiled, qualitatively and quantitatively analyzed and inferences were made.

#### 3.3.1. Phase 1: Design of questionnaire

The questionnaire had a total of 49 questions with 27 descriptive (open-ended) questions, and 22 objective-type (closed-ended) questions. The questionnaire was divided into five parts. At the beginning of the questionnaire, the objectives of the survey, the target participants and research questions were mentioned. A general introduction to SA decision-making was provided and a brief note was given regarding the privacy of the responses, assuring the respondents that their personal details will be protected. The questionnaire was divided into parts with each part answering a particular research question. Questions Q12 to Q22 help to answer RQ1. RQ2 is answered by Q23 to Q30. We mapped RQ3 to Q31 to Q35, and RQ4 to Q36 to Q47. The flow of the questionnaire is depicted in Fig. 1. The questionnaire was reviewed by 3 experts, one in the field of GDM and two experts in SA and their suggestions were incorporated.

The questionnaire can be accessed online.[1] The parts and contents of the questionnaire are as follows (where parts A-E below refers to Fig. 1):

**Part A - Participants' personal and organizational profile:** The first three questions capture the personal details of the respondents and the remaining questions are about their organization including name, location, size and their role in the company.

**Part B - GDM processes followed by SA groups:** Part B, composed of questions Q12-Q22, is focused on understanding the details of the GDM process being currently practiced in the industry. Respondents were asked if a detailed document highlighting the *goals, requirements, decision items, etc.*, circulated to group members as a way of ensuring information symmetry. The participants were asked to list down the *steps* involved in their industrial decision-making process, and to mention if each step involved *individuals or groups* of people. Participants had to mention the size and composition of the groups generally involved in GDM in their organization. We asked participants if the groups were *co-located* or *dispersed* and the medium of communication used in the case of dispersed teams.

GDM literature places strong emphasis on *tool support* (in the form of group decision support system) as it ensures sharing of information by all members [41]. To explore the presence of decision-making tools, we asked if the organizations had tools or a web portal for GDM where

[1] https://goo.gl/AmX8e3.

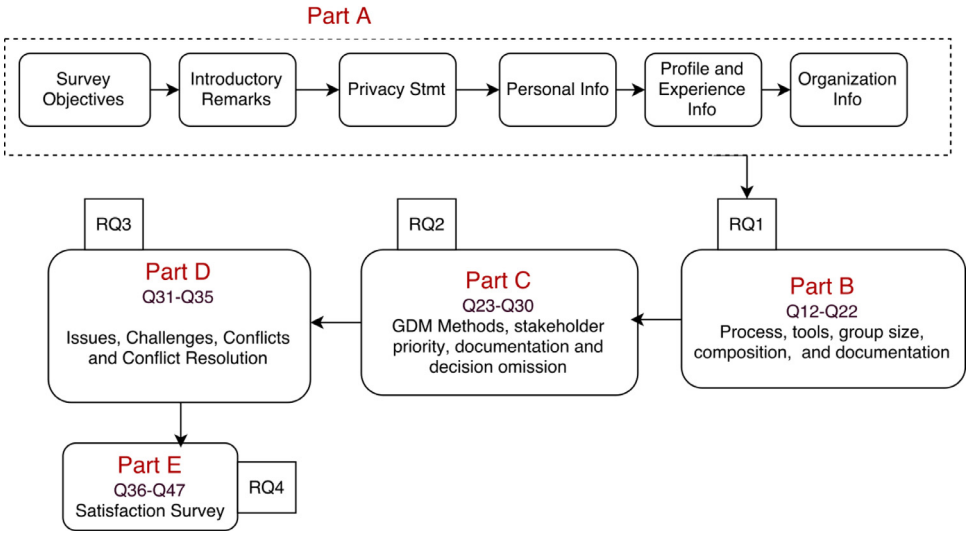


**Fig. 1.** Questionnaire flow.

group members could indicate their preferences and the features of the tools.

To understand in more detail about how the groups make decisions, participants had to describe *how several alternatives were evaluated* to make an optimal choice, and how the group arrived at a *consensus*.

**Part C - Similarity of SA GDM process with literature:** Part C of the questionnaire is composed of questions Q23-Q30. Through this part of the questionnaire we wanted to investigate *the extent to which the GDM processes in the industry matched the one in GDM literature*.

The participants were given the description of five GDM methods, namely *Voting, Brainstorming, Delphi, Consensus Based Method*, and *Analytic Hierarchy Processing* and they had to choose one or several of these methods that closely resembled the GDM method that is followed in their organization. They were asked to highlight differences between the five GDM methods and the one(s) followed in their company and also if all stakeholders were given *equal priority* and if not, what was the mechanism used to *prioritize stakeholders*. They were also asked to provide details of the *documentation* prepared after the GDM process.

**Part D - Challenges faced in SA GDM:** Part D is composed of questions Q31-Q35. The questions were targeted at finding the major issues and challenges that architects face while making group decisions. Except for Q35, all the others questions were of objective-type. Respondents were asked to choose from one or more issues These issues corresponding to the symptoms of defective decision-making as proposed in Janis' model of groupthink [18]. They were also asked to indicate the extent to which group members were vocal about their preferences. A list of challenges were given and respondents had to choose one or more of them. These options were given based on reference work related to groupshift and polarization [19–22]. They were asked to share their experiences of conflicts that occur in GDM, and were asked to choose the type of conflict resolution strategy they normally adopt (several conflict resolution strategies are discussed in GDM literature, e.g., [42–44]). We listed five popular conflict resolution strategies, namely (a) *forcing*, (b) *avoiding*, (c) *compromising*, (d) *accommodating*, and (e) *collaborating*.

**Part E - satisfaction of group members:** Satisfaction with the GDM process is key to the adoption and implementation of decisions [45]. Hence we have captured the satisfaction of the members with the GDM process and outcome. Participants were asked to share information on how often major decisions were *omitted* and the *reasons* for such omissions. This was mainly asked to understand the robustness of the followed process. The different aspects of GDM were listed based on the evaluation criteria in our previous work [37] and the two seminal works on GDM methods, namely [17,27].

In any GDM exercise, the outcome as well as the satisfaction of group members is key to the success of the process [45]. We had asked the participants to indicate their level of satisfaction on a Likert scale of 1 to 5 where 1 = highly dissatisfied, 2 = dissatisfied, 3 = moderately satisfied, 4 = satisfied, 5 = highly satisfied, with various aspects of the GDM process in their organization namely:

1. Participation of Group Members (in terms of contribution to the discussion),
2. Composition of Group (diversity of member expertise),
3. Provision/Mechanism for Preference Indication by Group Members,
4. Information Sharing by members,
5. Member Prioritizing (Giving different weights to various group members),
6. Quantity of alternatives generated,
7. Quality of alternatives generated,
8. Time taken to reach consensus,
9. Iterative nature of the GDM process (where alternatives and decisions are revisited during and after the GDM process),
10. Current tools available to support GDM,
11. Outcome of the GDM process.

These aspects helped us to evaluate the quality (as perceived by the members) of the GDM process currently practiced by industry.

### 3.3.2. Phase 2: Circulation of questionnaire and obtaining responses

As per [38], the survey was a self-administered one circulated online. We had used *Purposive Sampling* to administer our questionnaire. Specifically we had used *Expert Sampling* and circulated it through specific online forums and personal emails to people whom we knew had a certain level of expertise with SA decision-making. Answering our questionnaire that had process specific questions, required considerable experience in the organization and expertise in participating in SA decision-making. The sample is *maximum-variation sample* as the size is small but the participants belong to a diverse range of organizations of different sizes and characteristics and from different countries [46]. The target population was *Practitioners* who are/were actively involved with SA decision-making. We had left the hierarchy level open i.e. people from lower, middle and top management could participate. The study was open to respondents of all countries and both the genders.

The questionnaire was distributed through emails and posted on online forums. A message was publicly posted on online forums requesting interested practitioners to participate in the survey. . The

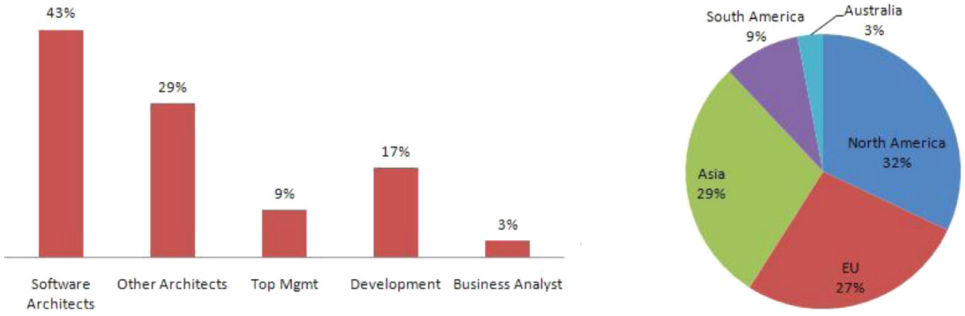


**Fig. 2.** Participant profile and company locations.

questionnaire was posted on the following forums:

- IFIP Working Group on Software Architecture
- Software Architecture Google Groups[2]
- Software Engineering and Architecture Google Groups[3]
- Software Architecture LinkedIn group[4]
- Software Engineering Facebook Group[5]
- Software Architecture Google Plus Groups[6]

*3.3.3. Phase 3: Analysis of responses*

Respondents to our survey belong to 26 different organizations (based on those who have shared their organization names) and each of them has been involved with GDM in SA. The questions have been designed in such a way that they give insights into the respondents experience and observation of SA group decision-making process in their organizations. Our study does not involve a comparison of practices across organizations but understanding of how SA groups work. Hence our unit of analysis is SA groups. We analyzed the responses both quantitatively and qualitatively. In this section, we describe in detail how we collected, organized and analyzed the survey responses. The following are the different steps in our data analysis:

**Data collection and organization**: We had distributed the questionnaire online (see Section 3.3.1). The responses were collected in a single spreadsheet and were ordered according to their serial numbers. The questions were recorded in the horizontal axis and the responses were lined up on the vertical axis as shown in.[7] Questions were listed together as well as individually for analysis.

**Question-wise analysis**: In this step, we did a question-wise analysis, as well as category-wise analysis, to gain answers to our research questions. For *objective type questions*, counting and totaling were done using spreadsheet functions. Objective questions were of the following type: Yes/No, Multiple Choice, Multiple Answer, and Likert Scale.

- For the Yes/No questions, the count and percentage of responses was calculated.
- For the multiple choice questions, the count and percentage of a specific response among all other responses was calculated.
- For the multiple answer questions, we calculated the count and percentage of each choice. For Q31 and Q33 we also calculated the percentage of responses that had mentioned only one of the responses, and those that had mentioned more than one response.
- Descriptive statistical analysis with median and frequencies was done on the Likert data pertaining to satisfaction of group members.

For *descriptive questions*, a content analysis was done [47]. The responses were coded using open coding and then quantitative analysis was done on the codes. For instance, in Q13, we had asked the contents of the documents circulated to group members before the commencement of the GDM process. We had received a diverse set of responses. We analyzed individual responses, identified common patterns, classified them under five headings and calculated the percentage of responses under each category. The codes in such questions are based on literature on SA or GDM and our experience in these domains. In questions like Q21 and Q22, where they had to describe processes, we categorized the responses based on the different stages in the processes. The responses were also categorized in terms of the impacting factors like cost or time, as mentioned by the respondents. This was followed by a quantitative analysis.

## 4. Analysis of results

In this section, we present a detailed analysis of the responses. We first present a question-wise analysis and then the answers to the research questions. The responses to each question are summarized on Fig. 2 and Tables 2–5.

### *4.1. Question-wise analysis*

**Part A - Participants' professional profile** The responses to questions Q1-Q11 provided an understanding of the participants' professional profile, and of their companies.

35 practitioners from 26 different organizations participated in the study. The organizational profile of the participants and the countries they belong to are shown in Fig. 2. Based on the Gartner IT Glossary[8] we have classified the companies into Small, Medium and Large companies. Small companies are those with less than 100 employees. Medium sized are those that have between 100 and 999 employees and Large companies that have more than 999 employees. Of the respondents, 31% are from small companies, 23% are from medium sized companies and 46% are from large companies. Overall we have 54% from the Small and Medium Business (SMB) sector and 46% from large companies.

*Highlights:*
*-35 practitioners have participated to this study.*
*-They are almost equally distributed among North America, Europe and Asia.*
*-72% of them are (software, system, solution, lead) architects.*

[2] https://groups.google.com/forum/#!forum/softarch.
[3] http://groups.google.com/group/softwareengarchitecture?lnk=.
[4] http://www.linkedin.com/groups/Software-Architecture-2967358/about.
[5] https://www.facebook.com/groups/softengcom/.
[6] https://plus.google.com/u/0/communities/109949335281772260399,https://plus.google.com/u/0/communities/115709350143858469283.
[7] https://www.dropbox.com/s/e5t7q70vny1tz1i/anonymizedResponseAnalysisV1.xlsx?dl=0
[8] http://www.gartner.com/it-glossary/smbs-small-and-midsize-businesses

**Table 2**
Questionwise summary of responses: Part B - GDM processes followed by SA groups .

| | |
|---|---|
| Q12 | To your knowledge, is detailed document with the requirements, goals, decision items etc. shared with participants before the commencement of the decision-making process? (Yes/No)<br>83% of the respondents have mentioned that a detailed document is prepared and shared with the group before the GDM process starts. 17% of the respondents say that such a document is not shared with the group. |
| Q13 | If you are aware of its contents, please list down them broadly. (Descriptive Type- Optional)<br>Based on the content analysis of the responses, we have classified the document content into 5 categories. a) Goals and Requirements of the system: 87% of the participants mentioned that the document contains business requirements, functional and non functional requirements, goals and objectives;b) Architecture, Views and Viewpoints: 21% say that the document contains architectural design, views and viewpoints; c) Design Issues/Alternatives/Decisions: About 26% share that the documents contain design related issues, alternative solutions, architectural significant decisions; d) Use cases and Actors: 26% mention that the document contains use cases and actors; e) Other information: 70% of respondents mentioned that in addition they also had other information like time lines, risks, assumptions, stakeholders, drivers, constraints, technology choices, market choices, resource details, and code reviews. |
| Q14 | Broadly list down the various steps involved in the decision-making process while architecting software systems in companies that you have interacted with. Against each step please indicate whether an individual or group is involved, e.g., listing of alternatives: group activity (Descriptive Type)<br>Based on the analysis of literature, we have identified different stages in the GDM. They are: a) Problem Identification, b) Development of Alternatives, c) Preference Indication, d) Prioritizing Group Members, e) Provision for Conflict Resolution, f) Group Decision Rules, g) Information Exchange and Recall, h) Revisiting Information. By performing a content analysis of the responses, we see that 71% of the participants have explicitly mentioned a Problem Identification stage in the form of requirements elicitation, or identifying the problem space, or generating use cases. About 58% of them have mentioned about the development of alternatives where individuals or groups enlist alternatives. 17% of them have indicated that there is provision for members to indicate preferences and evaluate the alternatives, 29% have mentioned about the priority given to group members, 17% of them have indicated about GDM rules followed i.e how a decision is made and who makes the decisions. Nearly 51% of them have talked about exchange of documentation but only 11% have said that an iterative process is followed. Nearly 26% of the respondents have indicated a ”discussion only” approach. |
| Q15 | How many people are generally involved in the group decision-making process to create the systems architectures? (Descriptive Type)<br>The percentage responses for various group sizes are as follows: 24% of group size upto 3 members, 32% of size upto 5 members, 15% of groups with size upto 7 members, 11% with upto 10 members and 18% with greater than 10 members. |
| Q16 | Briefly describe the general composition of the group in the group decision-making process e.g., architects, customers, business heads, etc. (Descriptive Type)<br>We have identified 39 distinct roles mentioned in the responses. Some of the roles are Architects, System Engineers, Project Leaders, Business Heads etc. 86% of them have mentioned the presence of ”Architects” in the groups. Only 43% of the responses have indicated the presence of ”customers” or ”developers”. |
| Q17 | Does the group decision-making process involve people from multiple sites? (Yes/No)<br>83% of the respondents say that GDM process in their organization involves people from multiple sites while 17% say that the team members are in the same site i.e co-located. |
| Q18 | If you answered Yes for the previous question, what is the common medium of communication for the group across multiple sites? (Descriptive Type - optional question)<br>45% of the total respondents have mentioned that both synchronous and asynchronous medium of communication are used by dispersed team members. 55% of the respondents say that the medium of communication is purely synchronous in nature like phone and video conferencing. None have mentioned a purely asynchronous medium of communication. |
| Q19 | Is a web portal or tool available in companies for group decision-making through which participants can communicate their preferences? (Yes/No)<br>57% of the respondents have mentioned that a web portal or tool for GDM is available in their organization. 43% say that no such tool is available. |
| Q20 | If Yes, briefly describe the web portal/tool with its name and features. (Descriptive Type - optional question)<br>85% of those who responded ”Yes” to the previous question have responded to this question. Each company has a different platform for making decisions. 45% of them use platforms like Microsoft Sharepoint or a similar portal created in-house. 10% of them use company wikis for making decisions. 25% of them use video conferencing tools like skype and webex. 5% of them have mentioned that they use SA domain specific decision-making tools like ADDSS and ArchDecisions. 15% of them use simple media like emails or collaborative tools that vary with projects. |
| Q21 | In group decision-making, when several alternative solutions emerge, how do group members normally evaluate the alternatives before choosing the optimal one? (Descriptive Type)<br>The methods used to evaluate alternatives differ from company to company. We analyzed the descriptions provided by them and classified them into 7 different categories. 46% of the respondents have mentioned a combination of alternatives evaluation methods while 54% have mentioned only one method. 20% of them use discussion, 26% of them have mentioned a pros-cons analysis, 17% of them have mentioned trade-off analysis, 11% of them say that prototypes are created, 9% of them say that empirical data is used , 14% of them have mentioned past experience, 23% of them say that score based evaluation is used and the remaining 34% use other factors like expert opinion, customer inputs, top management views and sometimes even intuition to evaluate the alternatives. |
| Q22 | Briefly describe how group members arrive at a consensus when multiple people are involved in the decision-making process (Descriptive Type)<br>Equal number of people have mentioned that they arrive at a consensus and make a decision either by a) entirely group discussion process b) a group discussion followed by decision by a competent authority. Only 17% of them have mentioned the use of GDM rule based methods like voting or scorecards to arrive at consensus. All others (83%) have mentioned a discussion based approach like brainstorming, presentations and arguments. |

**Part B - GDM processes followed by SA groups** The responses to questions Q12-Q22 provided an understanding of the current GDM practices adopted by teams in companies.

Based on the responses the detailed analysis of which is available in Table 2) we understand the following:

**Documentation [Q12-Q13]:** SA groups pay importance to documenting key information about the problem space and the decisions. The documents contain information pertaining to client requirements, the problem space, the high-level architecture of the system, the design issues, some proposed alternatives, use cases and miscellaneous information like risks, constraints and assumptions. The content of the document is quite comprehensive and more than 80% of the responses indicate that the document contains the goals and requirements of the system.

**Group structure [Q15-Q16]:** We have analyzed the structure of existing groups by analyzing the responses related to the size and composition of the group. 56% of the responses indicate a group size of 3–5 members. As per the research of Larson et al. [48], the groups are ideally sized. However, it is to be noted that 29% respondents have mentioned a group size of more than 7. Research on group size reveals that, though productivity increases when group size increases from two members to 3, 4 or 5 members, the productivity tends to drop when it goes beyond 5 members [9]. With respect to the group composition, we found that 43% of the responses indicated involvement of customers and only 2 respondents have mentioned a balanced team comprising of people from different levels in the organization. Only 14% of the responses indicate the involvement of top management. These responses indicate that SA groups tend to be homogeneous in their composition.

**Decision making process [Q14, Q17-Q18, Q21-Q22]:** A content analysis was done on Q14 (i.e., the various steps in decision-making process) and we applied the framework discussed in [37] to the responses. The framework in [37] has eight criteria to evaluate if the existing SA decision-making methods are suitable for group decision-making. The results are detailed under Q14 in Table 2. The *problem identification stage* (i.e., the stage where the problem is identified and defined, broken down into sub-problems or issues and mapped to specific requirements) has been explicitly mentioned by about 71% of the respondents. Analyzing the company size and approach, large

companies predominantly follow an approach that involves a more democratic process while in small and medium companies an authority makes the decision. One significant difference between the GDM in other domains, as mentioned in literature [7], and SA GDM is that respondents have mentioned about the design of a *proof of concept, or a high-Level architecture, or a draft design* which is evaluated by the group members before making the final decision. Preparation of a prototype in order to evaluate and choose the alternatives has been indicated by 11% of the respondents to Q21. Regarding the location of teams (Q17), we see that 83% of respondents have mentioned about dispersed teams. Discussions happen via synchronous and asynchronous media and decisions are made through online collaborative platforms. When SA groups are in a situation where they have to choose from several alternatives, an equal number of people have mentioned about a discussion based approach, listing of pros and cons of each alternative and evaluating alternatives against certain criteria (about 26% and 23% respectively). This indicates that there is a mix of formal approaches like voting or ranking as mentioned by Peniwati [17] as well as purely discussion based, to evaluate the alternatives. More than formal methods like voting or Analytic Hierarchy Processing, SA (83%) groups adopt a discussion based approach to make a final decision. Constraints like cost, time and availability of manpower could impact the process of arriving at a decision.

**Tool support for communication and decision making [Q19-Q20]:** To ensure effective communication, the teams use synchronous (phone, video chat, etc.) as well as asynchronous media (e-mail, shared docs, etc.) to discuss the requirements and make architectural decisions. Though the groups have to stay well connected to make decisions, we see that there is a lack of formal tool support to assist the decision-making process. While 57% of them have indicated the presence of a web portal or tool, by analyzing the details of the tools actually in use, we understand that they are mostly video conferencing tools or wikis, or cloud-based shared documents, and not collaborative decision-making-specific tools. An important aspect of GDM is creating provision for storing valuable information about the decisions including the questions, the alternate solutions, the decision made, the stakeholders involved, how the decision has evolved, preferences of stakeholders, etc. [28]. Without tool for this, SA groups may end up losing "historical" perspective on the decisions.

*Highlights:*
*-Documentation is common practice, with goals and requirements almost always documented.*
*-Several responses indicate homogeneous team composition;*
*-Only 43% of respondents mention participation of customers in GDM;*
*-Proof of concepts or prototypes are used, differently from traditional GDM practices, to guide the final decisions.*
*-Constraints like cost, time and availability of manpower could impact the process of arriving at a decision.*
*-There is a lack of dedicated tools to assist the decision-making process.*

**Part C - Similarity of SA GDM process with literature [Q23-Q30]:** Responses to Q23 to Q30 help us to understand the SA GDM process in comparison to those in GDM literature. The detailed analysis is available in Table 3. To summarize the findings:

- A combination of GDM methods are used by SA groups. Responses regarding the GDM methods adopted by practitioners are summarized in Fig. 3.
- Taking insights from the evaluation and classification of GDM methods done by Peniwati [17], we observe that the combination involves more of unstructured approach like Brainstorming and less of highly structured approaches like AHP. Peniwati's framework has 16 criteria (like Leadership Effectiveness, Cardinal separation of alternatives etc) to evaluate and judge the merit of various GDM techniques.
- Respondents say that the existing practices differ from well-known GDM methods due to project-based factors, such as a. group politics b. time constraint c. budget constraints.
- The data reveals that members of the SA groups recognize that different group members are given different priorities, based on their experience in the organization or expertise in a particular domain or technology (Q25-Q26). Such unequal treatment is recommended especially when the opinions of different members have to be aggregated to make the final decision [17].
- With respect to omission of major decisions, 87% of the respondents have acknowledged that there is an omission of major decisions. Of these, 40% have said that such omission happens quite often. The causes are lack of: time, communication among members, member expertise and sufficient exploration of requirements.

*Highlights:*
*-Unstructured decision-making practices are more common in contrast to structured methods advised in GDM literature.*
*-Different group members enjoy different priority and this aligns with best practices mentioned in literature.*

**Part D - Challenges faced in SA GDM [Q31-Q35]** The responses to the RQ1- and RQ2-based questions provide an overall understanding of the current processes. The responses to RQ3 (discussed in this part), instead, provide a picture of the **challenges** that SA groups face. The detailed analysis is reported in Table 4.

The first question, Q31, had details related to the symptoms of groupthink as proposed by Janis [18]. The analysis of responses to this question suggests the presence of groupthink (which may have to be investigated further) since nearly 50% of the respondents have chosen 4 out of 6 issues listed in Q31. Summary of issues faced by SA groups is shown in Fig. 4. When it comes to participation of group members and sharing their opinions, which is key to the success of any GDM process, nearly 58% of respondents have mentioned that many members do not express freely and often keep quiet in group discussions. This is indicative of groupthink since group members, in a pressure to arrive at a quick consensus, hold back their opinions [18]. Non-participation of members also arises when there are dominant power centers in the group leading to decisions being made in favor of those who speak up with authority [49]. Most respondents have mentioned that the groups face challenges in arriving at timely decision and experience differences in the power structure of the groups where there may be dominant members steering the course of discussions. Tamburri et al. indicate that when there is member diversity i.e putting juniors with senior experts, there is a certain power distance created which could lead to mistrust and wastage of time [50]. One commonly experienced challenge is the shift of group members to low-risk solutions or extreme solutions based on the preferences of the group members rather than their individual preferences [22] which is known as *Risky Shift or Group Shift*. We also see from the responses that many groups experience conflicts while trying to satisfy goals of multiple group members. While diversity is preferred, conflicts arise because of socio-cultural issues in the group. Sometimes, old organizational practices also cause conflicts. Since everyone acknowledges the presence of conflicts, a conflict resolution mechanism has been put in place in each organization. A *Collaborative style* of conflict resolution seems to be most favored (70%), where the members cooperate with each other to seek solutions which are mutually agreeable and beneficial (Q35).

**Table 3**
Questionwise summary of responses: Part C - similarity of SA GDM process with literature.

| | |
|---|---|
| Q23 | Which of the following closely resembles the decision-making method commonly followed in the company. (Multiple Answer)<br>We had given 5 popular methods in GDM literature namely: a) Brainstorming, b) Voting, c) Delphi Technique, d) Consensus Based method, and e) Analytic Hierarchy Processing. 71% of the respondents have mentioned Brainstorming. 17% of them have mentioned Voting method. 11% of them mentioned that their company process resembles Delphi technique. 65% say that what they follow resembles Consensus based method. Analytic Hierarchy Processing figures in 9% of the responses. 51% of the respondents have chosen more than one of the listed methods while the remaining 49% said that their company GDM method resembles only one of the methods listed. |
| Q24 | If the process followed in the company significantly differs from the above mentioned methods, please explain how it is different. (Descriptive Type - optional question)<br>This was an optional question and 17% have responded to this. The various ways by which the process differs are a) Company/Project specific methods like Risk and Cost Driven Architecture methods are used b) Weighted Score cards are used c) Delphi method with arbitration and escalation is used d) Consensus method is adapted for a subset of a team or without worrying about hierarchy of members |
| Q25 | In the SA group decision-making process that the company follows, are all stakeholders given equal weightage? (Yes/No)<br>71% of the respondents have said that all stakeholders are NOT given equal priority. The remaining 29% said that stakeholders enjoy equal priority in their organization. |
| Q26 | If you answered "No" to the previous question, briefly describe how the stakeholders are prioritized.(Descriptive Type)<br>Of the respondents that mentioned that different stakeholders are given different priority, 65% say that stakeholders are prioritized based on Seniority, 9% say that it is based on Expertise, 26% say that is based on specific factors like type of system, time criticality, political factors and whether it is a business or a technical decision. 9% say that certain individuals make decisions under special circumstances. |
| Q27 | Is a detailed document prepared after the decision-making process is complete? (Yes/No)<br>60% of the respondents agree that a document is prepared after the completion of the GDM process in their organization. The remaining 40% say that this document is not prepared. |
| Q28 | If Yes, please list down the major contents of the document. (Descriptive Type)<br>Based on the responses of 60% of the total survey respondents, we have categorized the contents of the documents into the following: A. Requirements, B. Alternatives/ Rationale/Decisions/Dependencies, C. Pros and Cons, D. Supporting Documents, E. Architectural Design. 33% of them have mentioned A, 38% have mentioned B, 14% have mentioned C, 3% have mentioned D and 23% have mentioned E. |
| Q29 | How often have major decision been omitted in the GDM Process? (Multiple Choice)<br>13% of them have responded that never has a major decision been omitted in their GDM process. 47% have mentioned that "rarely" a major decision is omitted. The remaining 40% said that of10 a major decision is omitted from the GDM process followed in their organization. |
| Q30 | If major decisions have been omitted, can you give top 3 reasons why this may have happened? (separate the reasons with commas)(Descriptive Type)<br>Based on the responses given, we have broadly classified the reasons into the following categories A) Time Constraints - 13% B) Lack of Communication and Consultation - 13% C) Certain top management policies, politics and customer lobbying - 25% D)Lack of Knowledge and Expertise - 13% E) Poor Exploration of Requirements and Solutions - 13% F) Behavioral Reasons like Work Habits, Stubbornness of group members, lack of confidence in speaking in meetings and dominance of certain members leading to others keeping quiet 25% G) Uncertainty - 13% H) Customer side issues like lack of proper requirements articulation 258% I) Lack of formal process like adhering to Architecture Centric Approach - 13%. |

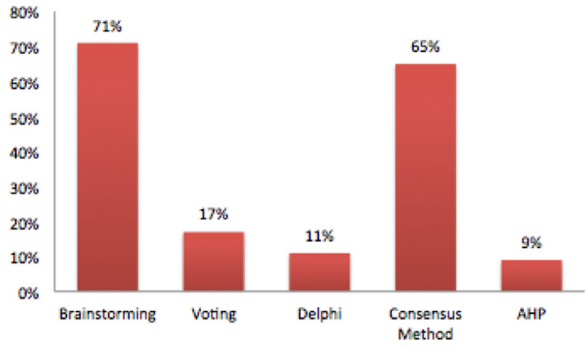


**Fig. 3.** GDM methods followed.

*Highlights:*
*-Respondents view timely agreement among group members and conflicts resolution as important aspects of GDM.*
*-Most conflicts are related to behavioral and social factors.*

**Part E - Satisfaction of group members [Q36-Q46]** Each question from Q36-Q46 represent an individual aspect of GDM. Hence we have considered the scores to be ordinal values.[9] We ran a descriptive statistic test for the satisfaction based questions and obtained the median and frequencies the details of which are shown in Table 5.

**Median scores:** Q36, Q37, Q39 and Q46 have a median of 4 which indicates a higher satisfaction level on (a) group member participation (b) composition of group and (c) information sharing (d) outcome of the GDM process. For all other questions the median score is 3.

**Percentage scores:** When we analyze the satisfaction of group members at a granular level, relatively more respondents (25% as compared 6%, 13% and 19% in other questions) have expressed dissatisfaction with (a) Quantity of alternatives generated (b) Current tools available to support GDM. Respondents have comparatively better satisfaction with (a) Participation of Group Members (56%) (b) Group Composition (44%) (c) Information Sharing by members (44%) (d) Outcome of the GDM process

*Highlights:*
-Common areas of dissatisfaction are: Quantity of alternatives generated, Current tools available to support GDM

### 4.2. Answers to research questions

Our study was aimed at gaining a rich understanding of the existing GDM processes in the industry. Based on the analysis of the survey responses, we present the answers to each RQ:

*RQ1: What are the existing Group Decision Making practices in real world SA groups?*

- Practitioners make Architectural Design Decisions in groups that are reasonably sized, i.e., composed of 3 to 5 members. This very well aligns with experimental studies of Laughlin et al. [23] on the right size of groups for optimal performance.
- Responses indicate a concentration of middle management employees in a group. This tends to create homogeneous teams. A key disadvantage of homogeneous teams is that it could lead to groupthink like situations [18].
- Respondents indicate a preference to discussion based approach (unstructured) rather than formal GDM process in SA groups. Research points out that structured approaches yield better results in terms of enhancing the group performance and the decision outcomes [17]. Lack of structured ways of group member participation can lead to fewer members contributing to the discussions.

[9] http://www.joe.org/joe/2012april/tt2.php

**Table 4**
Questionwise summary of responses: Part D - challenges faced in SA GDM.

| | |
|---|---|
| Q31 | While making decisions in a group which of the following issues have you experienced or are aware of? (Multiple Answer)<br>We proposed six different issues the respondents had to select from: A. Incomplete listing of Alternatives, B. Incomplete listing of Objectives, C. Failure to examine risks of preferred choice, D. Lack of Multiple Perspectives, E. Failure to reevaluate previously rejected alternatives, F. Poor information search. The percentage of responses indicating specific issues are : A - 71%, B - 60%, C - 71%, D - 57% , E - 34% and F - 43% . 26% of the respondents have chosen all the options. about 28% have listed factors other than those mentioned in the list. The factors include a) lack of accountability and ownership b) time pressure and delay issues c) biased opinions |
| Q32 | To your knowledge/based on personal experience, which of the following has been true about group decision-making. (Multiple Choice)<br>We offered six multiple choice answers to this question: A. All members express their opinion freely, B. Only few members express freely, largely they keep quiet, C.Few members prefer to keep quiet, D.No one speaks E. None F. Other. 43% indicate A (of which 53% have mentioned only A), 51% indicate B , 29% indicate C (of which 50% are C only), 3% indicate D and E each. Those who have chosen F have mentioned that members talk when there is a need and the role of facilitator is very important. Sometimes the members lack a bigger picture while discussing the issues) |
| Q33 | In the group decision-making process, what are some of the challenges generally faced in the company. (Multiple Answer)<br>This is a multiple-answer question. All participants have chosen more than one response. The challenges are as follows: A. goals are not understood by the entire group, B. takes a long time to arrive at final consensus, C. presence of power differences where few people seem to have more power over others, D. accepting low-risky simple solutions instead of best solution, E. People sometimes tend to make more extreme or radical decisions in a group than individually. 63% face challenge A, 66% face challenge B, 54% face challenge C, 28% experience challenge D, 17% have faced challenge E. |
| Q34 | Briefly share your experience/knowledge of the occurrence of conflicts, if any, while making decisions in groups (an help text in the questionnaire suggested to mention what causes conflicts, when do they normally occur, etc.). (Descriptive Type)<br>Based on the responses, we classified the factors influencing conflicts into 5 categories namely A. Socio-cultural, i.e., when conflicts occur due to social relationships/ differences between people or different cultures, B. concerns- (skill-) driven, i.e., due to different technical skills or stakeholders with different concerns/goals in mind, and C. Cost-driven, i.e., due to conflicts happen due to limited resources or budget. D. Power-based (i.e., decisions are made in case of conflicts by the top management), E. old practices/decisions cause conflicts. 28% have mentioned factor A, 28% have mentioned factor B, 14% have mentioned factor C, 14% have mentioned factor D and 10% have mentioned factor E influencing conflicts. |
| Q35 | The strategy that the team/company commonly follows to tackle conflicts in the SA group decision-making process? (Multiple Choice)<br>We provided five options to this question (all explained in the questionnaire): A. forcing, B. avoiding, C. compromising, D. Collaborating, E. Accommodating. Collaborating seems to be the most favored strategy with nearly 70% of them choosing it. Compromising and Forcing are favored equally with 12% each. Only 6% of the respondents have mentioned that they "avoid" conflicts. None of them have chosen the Accommodating strategy. |

This can cause groupthink as well as information asymmetry [14]. Information asymmetry can be a serious threat to the team performance [16].

- There is prevalence of Laissez-faire and democratic style of decision-making [51].
- A formal tool to make decisions in groups is not prominent among practitioners. This could lead to Information asymmetry within the group [14].

*RQ2: Are the group decision-making techniques currently being practiced in line with techniques in GDM literature?*

- The GDM methods practiced by real world SA groups resemble a combination of methods in the GDM literature, such as voting, brainstorming, etc., and predominantly match unstructured methods like brainstorming rather than structured ones like AHP.
- Groups are not able to fully adopt a systematic approach to GDM due to various factors including time and cost constraints and organizational politics.
- Most SA groups prioritize group members and hence different stakeholders preferences have different weights when decisions are made. Such prioritization is helpful so that the experience and expertise of members are valued.
- Sometimes major decisions are omitted; this may happen due to time constraints, poor communication among stakeholders, lack of resources, etc. Omitting major decisions, especially in the context of

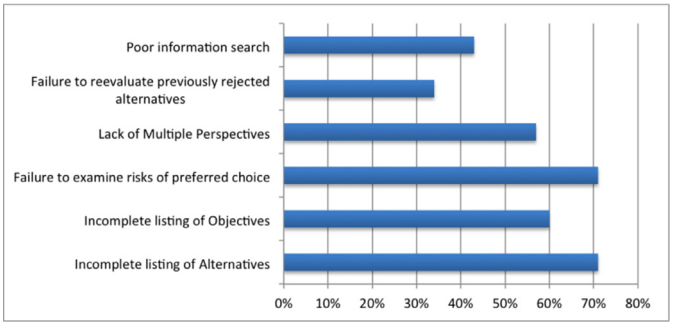


**Fig. 4.** GDM issues faced.

**Table 5**
Part E - Satisfaction of group members (columns numbered 1–5 report on the frequency of responses in the 1–5 Likert scale, ranging from 1 = highly dissatisfied to 5 = highly satisfied).

| Q.No | Aspect of GDM | Median | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| Q36 | Participation of Group Members (Contribution to the discussion) | 4 | 0% | 0% | 19% | 56% | 25% |
| Q37 | Composition of Group (Diversity of member expertise) | 4 | 0% | 6% | 31% | 44% | 19% |
| Q38 | Provision/Mechanism for Preference Indication by Group Members | 3 | 0% | 6% | 56% | 25% | 13% |
| Q39 | Information Sharing by Members | 4 | 0% | 13% | 19% | 44% | 25% |
| Q40 | Member Prioritizing (Giving different weights to various group members) | 3 | 0% | 19% | 38% | 31% | 13% |
| Q41 | Quantity of alternatives generated | 3 | 0% | 25% | 25% | 44% | 6% |
| Q42 | Quality of alternative generated | 3 | 0% | 19% | 31% | 31% | 13% |
| Q43 | Time taken to reach consensus | 3 | 0% | 13% | 50% | 38% | 0% |
| Q44 | Iterative nature of the GDM process (where alternatives and decisions are revisited during and after the GDM process. | 3 | 0% | 13% | 44% | 25% | 19% |
| Q45 | Current tools available to support GDM | 3 | 0% | 25% | 44% | 25% | 6% |
| Q46 | Outcome of the GDM Process | 3 | 0% | 6% | 38% | 50% | 6% |
| Q47 | If you indicated "dissatisfied" or "Highly Dissatisfied", please share with us why or what you are dissatisfied about.<br>Some of the reasons for dissatisfaction are: a) Unequal commitment of stakeholders b) Lack of formal GDM process c) Long meetings and boredom d) Lack of GDM tools e) Less communication among members f) sometimes no alternatives are listed g) skewed power structure which leads to biased participation and final decision-making h) Unequal representation of views g) not revisiting discarded alternatives h) Escalation to top management which tends to avoid risks i) Insufficient group diversity | | | | | | |

Software Architecture can impact other dependent architectural decisions.

*RQ3. What are the challenges that SA groups face while making architecture-related group decisions?*

- Industrial SA groups face a number of issues and challenges due to lack of communication among group members, skewed power structure and lack of understanding of the problem. The issues they face are indicative of issues mentioned in GDM literature namely: groupthink, groupshift and group polarization. Presence of these issues can impact the quality of decisions and performance of groups [18].
- The occurrence of conflicts is common and this happens due to socio-cultural, cost, and skill factors. They are resolved collaboratively by SA group members. Collaborative style of conflict management, which many respondents have mentioned, can positively impact team performance [52].
- Time pressure plays a significantly impacts the process adopted by the groups, the conflicts that arise, and how they make decisions. In a haste to arrive at a quick decision, teams fail to evaluate all alternatives and this also leads to situations like groupthink.

*RQ4: How satisfied are SA group members with various aspects of GDM?*

- The median scores indicate that respondents are satisfied with the group composition of the groups, member participation, information sharing and outcome of the GDM process.
- However, respondents are less satisfied with the quantity of alternatives generated. We can infer that while members discuss freely in the group, in-depth exploration of alternatives does not seem to be happening. This is also evident from the responses to Q31 and Q32.
- Lack of tool support for GDM is evidently a factor for dissatisfaction.

## 5. Discussion

Based on the question-wise analysis, we derived answers to individual research questions as presented in Sections 4.1 and 4.2. We summarize our main findings and discuss the findings in the light of literature as follows:

- **Predominance of unstructured approach**: Based on the insights derived from Part A and Part B of the questionnaire, especially Questions Q14, Q17-Q18, Q21-Q22, Q25-26 we see that SA groups prefer a discussion based approach which is less structured compared to structured approaches like Voting or AHP. This has also been observed by Groher and Weinreich [53] in their study of 25 architects. The process of exploring the problem space, evaluating alternatives and finalizing the solutions are predominantly through discussions. While GDM literature supports the freedom of organizations to choose the approach that best suits them, it does point out that unstructured approaches can be less effective and can impair decision quality [45]. Unstructured approaches do not encourage systematic participation [54] and this can bias the information shared in the group leading to information asymmetry [14]. Tamburri et al. in their study of 51 architects observed the presence of *excessive informality* in groups due to absence of information management and control protocols. This led to low accountability. Taking cues from their work, there is a possibility of SA groups losing valuable information due to the informal unstructured approach to decision-making [50]. Understanding the existing preference for unstructured approaches but at the same time taking into account the challenges that arise due to that, it may be good for SA groups to consider adopting a blended approach that uses structure at appropriate phases.
- **Decision making style**: Most respondents indicate a democratic or Laissez-faire approach. Of the several styles to make decisions, 3 ways of leading the group to decision-making are significant [51]. In the democratic approach, the person of authority allows the group to discuss but takes control of the final decision. In the autocratic approach, the person of authority takes full control over the discussion and the decision. In the Laissez-faire approach, the group members are completely free to discuss and make their own choices. Literature points that democratic style leads to better group stability and keeps the members happy. However, in situations of conflict or when the decision-making process takes too much time, an autocratic style can bring closure. Laissez-faire approach is seen as detrimental to groups [55].
- **Indications of groupthink and polarization**: Responses to Part C of the questionnaire give insights into the challenges that groups face. The issues and challenges that the group face indicate the antecedents and symptoms of Groupthink and Group Polarization [18,20]. The causes include homogeneity of SA groups where members belong to more or less the same experience level, tendency to arrive at quick decisions and not spending sufficient time in exploring the objectives and potential alternative solutions. Groupthink and polarization can lead to low probability of successful outcomes as Janis proposed [18].
- **Lack of tool support**: Lack of tool availability or usage to assist the decision-making process is evident from the various responses. This is echoed by the work of Tofan et al.[6] in their review of SA decision-making literature. Lack of tool support is also a key factor for dissatisfaction among most respondents. Tools can help to structure the decision-making process and can also ensure that valuable information is available to all stakeholders concerned [28].
- **Time constraints**: According to the respondents, arriving at a decision takes considerable time and efforts to hasten the process have resulted in omission of key decisions, conflicts or dissatisfaction with the decision as indicated in the responses to Part C and D of the questionnaire. Trying to get a consensus from everyone can lead to groupthink [18]. A process like *Voting* can help to speed up the decision-making process without compromising on the quality of decisions.

### 5.1. Recommendations for future research

The data collected and analyzed in this paper reveals details of the group structure, composition and the issues that the SA groups face as seen in Sections 4.1 and 4.2. We envision future research along the following lines:

- **Adaptive model of GDM for SA**: In our study, we have been able to observe some structural and process related issues with the GDM process in SA. Taking insights from GDM literature and developing a better understanding of industrial needs, a GDM model could be created that is adaptable to organizational needs and supports the following:
  a. optimal group structure that can minimize conflicts and maximize participation
  b. group member heterogeneity for diversity of ideas and avoidance of Groupthink or Polarization
  c. a decision-making process that blends structured and unstructured approaches i.e using structure wherever required. Information symmetry requires that the members have access to knowledge and get equal opportunity to share the knowledge. A blended approach can improve information symmetry in a significant way. This can also quicken the decision-making process whenever needed. Though it may take time for groups to adapt to the new method of making decisions, the outcomes of such a process may prove beneficial over time.
- **GDM-specific tools**: Group decision-making requires, among other things, collaborative discussion and documentation of alternatives,

concerns, rationales, and solutions. Different companies use different GDM methods, strategies, and processes and their own ways to deal with conflicts. We advocate the realization of a *GDM-specific* tool that, in addition to supporting the collaborative discussion and documentation of architectural decision artifacts, adapts to the companies internal GDM strategies and policies. While we advocate the inclusion of a configurable policy-system where each company may adjust the tool to its own GDM needs, we do not propose a tool that adheres to only one specific GDM method (that restricts the participants to use only a specific ready-made method, such as AHP, Brainstorming, Voting, etc.). Such a tool will also provide a set of metrics to analyze, for example, the average or mean time to make decisions, how frequently group members have participated to discussion, who are the most influential group members etc. This information may be used as a driver to improve the practiced GDM; Dan Tofan el al [56] have proposed a GDM process called GADGET that helps architects arrive at a consensus while making decisions. Tools that reflect such processes will be highly useful for the industry.

- **Empirical studies**: While this work has been oriented towards a better understanding of GDM practices in industry, other empirical studies have to be conducted in order to have a sharper understanding on industrial GDM practices and specific needs that can enhance the effectiveness of the decision-making process through tools, GDM methods, group structural changes etc. As proposed earlier, an adaptive GDM model that blends insights from GDM literature and SA industry needs can be designed and its impact on the SA group performance and decisions can be experimentally studied.

### 5.2. Threats to validity

In our study we have tried to capture as much information as possible about the existing practices. However, we do understand that there could be shortcomings and threats to validity. This section analyzes the threats to validity in our study.

**Construct validity:** Construct validity refers to the generalization of the results to the concepts or theory being studied [57]. To ensure that there are no *design* threats, we have included concepts that are well researched and experimented with. The research questions and the questionnaire are based on literature in GDM as well on SA. Wherever there has been potential ambiguity, we have made sure that we do not make a final conclusion but rather mention that it may be indicative of the phenomena, thereby creating space for further research. For instance, the challenges faced by SA groups are indicative of “Groupthink”. This cannot be ascertained unless a deeper study is done on it or experimentally verified. We have also ensured that there are a mix of descriptive and objective questions leading to a concept so that there is a stronger evidence of the occurrence/presence of that particular phenomena. The questionnaire was also vetted by experts in the field to ensure the mapping to relevant theoretical models. Each choice to a question was elaborated so that the question clearly indicates what we desire to capture or measure. This has helped us minimize construct validity.

**Internal validity:** Internal validity refers to the accuracy of the cause-effect relationship among variables, i.e., the impact of the independent variables on dependent variables [57]. To reduce threat to internal validity, we have backed our findings with what has been stated in literature and map to a cause or consequence as stated in literature. Research works from both GDM and SA domains have helped us to understand and discuss the findings as applicable to the SA industry. Wherever we have not been able to do a direct mapping, we have acknowledged the need for further investigation.

**External validity:** External validity refers to the generalizability of the observations to the population [57]. While we do understand that the sample size is small (35), we have ensured a certain degree of generalizability by including respondents playing different roles in the organization and hierarchical levels, from different countries, working or collaborating with companies of different sizes as a representative sample. We also see that our findings regarding the group structure, processes and challenges match well with the conclusions in literature thereby making it generalizable.

## 6. Related work

The literature on architecture design decision being quite vast (as already briefly discussed in Section 2.2), we restrict our discussion to *those papers that provide a specific contribution on the advancement of group decision-making knowledge*.

**Survey of practitioners** A study of 43 real-world practitioners was conducted by Tofan, Galster and Avgeriou and the findings have been reported in [4]. Their study is aimed at understanding the characteristics of architectural decisions, the factors that make architectural decisions difficult, the influence of seniority (experience) on decision-making and differences between good and bad decisions. They found that, in general, about three persons are directly involved in making architectural decisions. They also found that dependencies among decisions and high-impact decisions added to the difficulty of architectural decisions amongst various other factors. Good decisions, as per their finding, are those that are chosen among several alternatives (instead of fewer alternatives). The key finding is that more than 85% of the decisions are made in groups. Miesbauer and Weinreich conducted a survey of practitioners from six different companies in Austria [5] to understand the decision-making process in practice, the kind of decisions made and how they can be classified and the factors that impact design decisions. Some of their findings are: (a) *technology* and *structural* decisions are the primary focus of architects and designers, (b) user requirements and constraints influence the decisions, (c) design decisions are well documented. However, the usage of AK tools is not widespread among practitioners. In our previous work [36] we had studied 22 practitioners and 7 researchers. These responses form a subset of the responses we have analyzed in the current paper. Based on the insights, to further our understanding of industrial practices, we expanded the number of practitioners to 35 and also did a deeper qualitative and quantitative analysis. In this current study, we have analyzed the satisfaction level of SA group members on various aspects of GDM. We have combined data from related questions to perform horizontal analysis. We have also been successful in expanding our respondent sample size from 30 to 50. Overall, in this study, an enhanced statistical analysis, horizontal analysis of responses and expanded data set have helped us get a clearer picture of the existing practices in the software industry. Groher and Weinreich [53] have interviewed 25 architects from 22 companies. According to their findings technical, cultural and individual factors played an equally important role as business factors that influence decisions. Education and experience of the participants played a significant role in the quantity of alternatives generated. Decisions were often made ad-hoc as a reaction to an issue. A consensus-driven process is used for making decisions.

Tamburri et al. [50] conducted a study of 51 Software Engineering professionals, to understand the issues (referred to as smells) that architects have to cope with, the possible solutions to those issues and the communities types that are commonly formed. Time Warp, Cognitive Distance and Disengagement are some of the ”smells” they have listed. They also have suggested mitigation strategies. For instance, to reduce the Cognitive distance, they suggest ”Architecture knowledge exchange through redocumentation, workshops, and presentations”.

**Studies on SA tools** Tang et al., in [3] have presented a comparative study of several architectural management tools. They have compared ADDSS, AREL, Archium, PAKME and Knowledge Architect tools. They use a framework with ten criteria to compare the tools. The relevant finding is that ADDSS and PAKME alone support multiple users while the other tools have been designed for single users. A revisiting of

the AK tools has been done by the same authors in 2016. The findings presented in [58] too highlight that only ADDSS and PAKME support collaboration. Tofan el al in [56] have proposed a new process called GADGET for SA decision-making. GADGET combines insights from the Repertory Grid Technique and Delphi Technique. The experiments conducted with students using GADGET shows that GADGET helped to increase the consensus and focus among decision makers.

**Literature study** Tofan et al. have conducted a systematic literature review of 144 research papers on SA decisions [6]. They have explored answers to six research questions. Among them, one is strongly related to group architectural decisions, and 15% of the surveyed papers refer to GDM in SA. The relevant findings are that tool support for GDM is very limited, more work is needed in the area of GDM in SA and more empirical studies are needed.

Our study differs from the above papers in that we try to understand various aspects of GDM practices right from the structure of groups to the outcomes, in a more holistic manner. In our previous work [36], we had studied 22 practitioners and 7 academic researchers. The responses in the previous study are a subset of the data in the current study.

## 7. Conclusion and future work

Being aware of the transition of SA from being a solution to set of Architectural Design Decisions, the SA architecture community is keen in capturing as much information as possible about these decisions and enhancing the quality of these decisions. A preliminary literature survey led us to the open-ended question - *How do architects make group decisions?*. This study is a step to understand the larger context of decision-making practices and effectiveness of SA groups.

The study was conducted through an online questionnaire and we had 35 participants from all over the globe. The responses were analyzed in using quantitative and qualitative methods. From the responses, we understand the following about SA groups:

- ▷ prefer unstructured approach to decision-making;
- ▷ equal prevalence of democratic and Laissez-faire style of decision-making;
- ▷ the GDM methods vary from those in literature due to constraints of time, budget and resources thereby creating challenges and conflicts as mentioned by the respondents;
- ▷ very few team involve customers and members from all levels of hierarchy and these groups face several challenges leading to omission of decisions or conflicts within the group;
- ▷ certain issues and challenges mentioned by the respondents may be indicative of Groupthink, Groupshift, and Polarization, and these are useful aspects to explore solutions for;
- ▷ creation of prototype is an important step in the GDM process;
- ▷ conflict resolution strategies vary from organization to organization. Interestingly, most groups arrive at consensus through collaboration. This seems to be a healthy practice in conflicts resolution;
- ▷ tool support for GDM is still very limited in these companies.

Based on the results of this study, we propose a number of potential future work:

- ▶ other systematic studies and experiments have to be conducted, in order precisely understand how GDM theories and methods from the business domain may be brought to software. More specifically, a study on industrial needs that will help design SA decision-making tools and experiments to analyze the effectiveness of structured GDM methods on the quality of SA groups and decisions, will be beneficial;
- ▶ a GDM “layer” can be used to enrich existing architecture design decisions methods. Along these lines, we are currently analyzing how certain architecture decisions method can be enhanced with GDM features. A meta-model incorporating both architectural knowledge and GDM has been presented in [59];
- ▶ tool design is another important work we propose to carry out in the near future. GDM tools in SA has to do with collaborative design of software architectures, collaborative reasoning, and shall support a GDM process improvement so as to limit conflicts and uncertainties in architecture decision-making.

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## Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.infsof.2018.04.009.

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