Supporting ATAM with a collaborative Web-based software architecture evaluation tool

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Abstract

As software companies are becoming increasingly globalised, a number of issues arise with respect to the social and environmental aspects of conducting the Architecture Tradeoff Analysis Method (ATAM), a software architecture evaluation method developed by the Software Engineering Institute. It would be fair to question the applicability of the ATAM to commercial companies. In this paper, we show that there are important issues and potential weaknesses in the ATAM from a social context. We provide suggestions for a means of overcoming these potential pitfalls through the assistance of the ubiquitous Internet. We then describe a tool dubbed ACE (ATAM Collaborative Environment), a Web-based software system that provides a common environment where stakeholders and software evaluators alike can take part in an ATAM evaluation without having to be physically collocated.

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1. Introduction

Software architecture is a representation (or model) at a high level abstraction of the elements of a software system. A system may be composed of many levels of abstraction and many phases of operation, each with its own software architecture [3]. The architecture
of a software system is in general an important contributor to the quality attributes of a system. Hence, the purpose of software architecture evaluation is to ensure that the quality attribute requirements are met in a software architecture. The Architecture Tradeoff Analysis Method (ATAM) is an architecture evaluation methodology developed by the Software Engineering Institute (SEI) and has been tested in real-life software development projects [1]. Based on the results drawn from these real-life ATAM projects [1], it seems that the ATAM is an effective method for guiding a software architecture evaluation session. However, there has been little or no indication of the performance of the ATAM in different cultures and environments. Although software architects and engineers often have different orientations and work with specialist technical tools and analytical skills, researchers have argued about the importance of culture in forming the engineering practices and values in any organization [13]. More importantly, the ATAM is heavily reliant on stakeholder involvement, indicating a greater need for research into the social aspects of the ATAM.

This paper is organised as follows. Section 2 presents a short overview of the ATAM process. Section 3 looks at culture, its manifestations and relevance to the ATAM. Section 4 ties the ATAM and culture together and discusses the problems and issues that arise from this conjunction. To resolve these problems and issues, Section 5 puts forward our approach, a Web-based collaborative software tool called ACE. Section 6 discusses the shortcomings of this approach. Finally, Section 7 concludes the paper.

2. The architecture tradeoff analysis method (ATAM)

ATAM’s main purpose is to guide ATAM session leaders through an evaluation process via a series of nine steps (see below). These nine steps can be split into two phases. Phase 1 makes up Steps 1–6 and is more architecture-centric, involving architects, evaluators and other system developers. Phase 2 makes up Steps 7–9, which are more stakeholder-centric as it relies on stakeholder input.

2.1. Summary of the ATAM steps

We present a brief summary of the ATAM process.

Phase 1

- Step 1: The evaluation team presents the ATAM to the stakeholders.
- Step 2: The evaluation team presents the system in a business context.
- Step 3: The lead architect presents the system architecture.
- Step 4: The architectural approaches and styles are identified.
- Step 5: Generate the quality attribute utility tree which shows all the quality attributes that need to be satisfied by the system along with their level of importance to the system.
- Step 6: The architectural approaches identified in Step 4 are analysed which will result in a list of architectural approaches or styles, the questions associated with them and the architect’s response to these questions.
Phase 2

- Step 7: The stakeholders and evaluation team brainstorm and prioritise scenarios by voting.
- Step 8: The prioritised scenarios will be mapped onto the architectural approaches that were previously acquired to determine if these scenarios fit the various approaches. This step is primarily a testing phase and the hope and expectation is that little new information will be uncovered.
- Step 9: The results of the whole process will be presented.

One of the key attributes of ATAM is its strong emphasis on stakeholder involvement in the evaluation process. For instance, ATAM uses scenarios as a mechanism for fostering stakeholder interaction in clarifying quality attributes in terms of stimuli and responses. As the focus of this paper is on the stakeholder-centric steps of Phase 2 (Steps 7–9), the following section provides a more detailed account of these steps, which involves extensive collaboration between all involved stakeholders.

2.2. Phase 2 — Step 7: Brainstorm and prioritise scenarios

Scenarios drive the testing phase of the ATAM. Scenarios are utilised within this step because they are something that anyone can produce and understand and hence are a very good means of getting the stakeholders involved and making a significant contribution to the evaluation. A larger collection of stakeholders is encouraged in the brainstorming session as ideas generated by some will stimulate the thoughts of everyone else which leads to more scenarios being generated.

The main purpose of generating scenarios from stakeholders is to understand quality attribute requirements from their perspectives.

While the utility tree generation performed in Step 5 is used to understand how the architects perceived and handled quality attribute architectural drivers, the purpose of scenario brainstorming is to take the pulse of the stakeholder community. Through this, the evaluators will obtain the valuable contribution of typical system users who have, or will have, ‘hands on’ experience and will provide valuable feedback on what are the stakeholders’ needs in terms of quality attributes.

The prioritised stakeholder scenarios are compared with the scenarios generated via the utility tree exercise to see whether they agree or disagree.

Once the scenarios have been collected, they need to be prioritised so that the outlying scenarios are filtered out and the scenarios that are more significant in the eyes of the stakeholders are kept for comparison with the utility tree. The scenarios are prioritised via a voting process. Before voting begins, scenarios representing common behaviour or quality are merged. Clements et al. in their book state that, from their experiences, it is more fun for the stakeholders to cast their vote publicly [1]. This statement raises a primary concern in the impact this public method of voting would have on other cultures who may not value a democratic system, let alone an open and visible public voting session. This is an issue that will be addressed in greater depth in Section 4 on Problems and Issues.
2.3. Phase 2 — Step 8: Analyse the architectural approaches

The new scenarios that were elicited through the brainstorming from Step 7 will be used to conduct a second analysis of the architectural approaches. The architects will need to provide some explanation of how these new scenarios align with the architecture and that the architecture satisfies the quality attributes. This is assuming that Step 7 did not discover any high-priority scenarios that were not covered from the previous analysis. Again, this is a testing phase so it is hoped that there will be little new information discovered.

2.4. Phase 2 — Step 9: Present the ATAM

This step is the final step of the ATAM where the evaluation leader summarises the collected information from previous steps. It usually takes the form of a verbal presentation with slides but may also be accompanied by a more comprehensive written report after the ATAM session.

The verbal presentation will cover each of the steps and the information gathered from each step as well as a discussion of the outputs:

- The architectural approaches documented.
- The set of scenarios and their prioritisation.
- The set of attribute-based questions.
- The utility tree.
- The risks discovered.
- The non-risks documented.
- The sensitivity points and tradeoff points found.

In order to better appreciate this study of culture and the ATAM, the following section will provide a clearer perception of culture.

3. Culture

As a significant part of this paper ties in closely with the social sciences, this section will delve deeper into this discipline and, more specifically, into the topic of culture. Every workplace has a culture and this can differ from firm to firm within a country. Cultural differences are more apparent between firms from different countries. This section firstly attempts to define culture then reflect upon the importance of culture in the workplace through some empirical research work conducted by Rasetti [12] on exploring management practices that successful multinationals employ in India to manage diversity.

3.1. Definition

Anthropologists define culture as the set of values, norms and patterns of behaviour shared by a group of individuals [4]. Hofstede refines this definition by defining culture as the collective programming of the mind which distinguishes the members of one group or category of people from another [5]; hence the reason for the title of his book “Software of the Mind”. Why does he describe culture as the software of the mind? Hofstede claims
that we are not born with a culture (nature), but culture is programmed (nurtured) into us as we age.

He views culture as an onion-like structure, consisting of layers surrounding an inner core; the most unchangeable and important manifestation of culture. Starting from the outermost layer (the most superficial characteristics of culture), the observable cultural manifestations are:

- **Symbols**: These are the most superficial indicators of culture. These include dress and language (jargon). Example: Suit and tie.
- **Heroes**: These are the people that a culture admires or aspires to be. For instance, for the US it could be Superman or George W. Bush.
- **Rituals**: These include the ways of greeting and paying respect.
- **Values**: These, being the inner-most core of the cultural model, are the least obvious and most difficult to change. Cultural values are developed in the individual for the first 10 years of their lives [6]. Examples of values include identity, gender, truth, virtue and hierarchy [8]. Fig. 1 is an image of Hofstede’s model of culture.

### 3.2. Cultural dimensions

Based on an IBM study of 72 different countries, Hofstede identifies five cultural dimensions that have been key differentiating factors of “mental programming”. The following list has been referenced from [6], which is a summary of the aforementioned dimensions:

1. **Power distance** — Power distance refers to the degree to which subordinates respond to power and authority. In high-power-distance countries such as Latin America, France, Spain and most Asian and African countries, subordinates tend to be more fearful of bosses and bosses tend to be more paternalistic and autocratic.

   On the other side of the scale are the low-power-distance countries such as the US, Britain and most of Europe, where subordinates are more likely to challenge bosses and bosses tend to be more consultative when dealing with staff.

2. **Collectivism versus individualism** — People in individualistic countries such as France, Germany, South Africa and Canada expect to look after themselves and value personal time, freedom and challenge more.
People in collectivist countries such as Japan, Mexico, Korea and Greece possess strong personal and protective ties based on loyalty to the group during their lifetime and, quite often, beyond that. They value things such as training, physical condition and the use of skills.

3. **Femininity versus masculinity** — In cultures where feminine values are more important, such as Sweden, France, Israel, Denmark and Indonesia, people tend to value a good working relationship with their supervisors. They like to work with people who cooperate well with one another and be able to work for a company for as long as they want.

In countries where masculinity is strong such as in the US, Japan, Mexico, Hong Kong, Italy and Great Britain, people tend to value having the opportunity to earn large sums of money, get recognition for doing a good job, having an opportunity for promotion, and enjoy a challenging job so they can derive a sense of achievement.

4. **Uncertainty avoidance** — When uncertainty avoidance is strong in a culture, such as South Korea, Japan and Latin America, there is a tendency to perceive unknown situations as threatening so that people tend to avoid them.

Cultures with weak uncertainty avoidance include the US, the Netherlands, Singapore, Hong Kong and Britain. The people of these countries tend to be more adventurous, risky and open to innovation.

5. **Long-term versus short-term orientation** — Countries that have a long-term orientation include China, Hong Kong, Taiwan, Japan and India. They are characterised by persistence and perseverance, a respect for hierarchy of the status of relationships, thrift and a sense of shame.

On the flip side of the coin are the short-term oriented cultures that exist in countries such as Britain, Canada, the Philippines, Germany and Australia. Short-term oriented cultures are characterised by a sense of security and stability, a protection of one’s reputation, a respect for tradition, and a reciprocation of greetings, favours and gifts.

3.3. **Case study: Cultural dimensions of Indian companies**

This section summarises Rasetti’s findings during her study of companies located in India which were of Canadian, Japanese and US origin, which are compared to the Indian culture. The approach taken here will be an analysis of Indian culture as well as the cultures of the aforementioned countries based on the five dimensions that were defined by Hofstede. An analysis of the impact of modernisation on Indian culture will then be made to address the feasibility of groupware on the Indian culture.

The purpose here is to highlight some examples of cultures that possess different combinations of Hofstede’s dimensions. In order to validate the need for a groupware system, it is important to analyse the cultures of existing countries and their cultural characteristics. These characteristics will be evaluated with the characteristics that would be ideally suited towards a collaborative software or groupware system.

**Collectivism versus individualism**

The Japanese and Indian cultures hold similarities in this respect as they are both collectivist. This collectivism stems from extended family tradition which is common in
both countries. Living in densely populated countries also makes them learn to live with others in harmony.

Japanese corporations foster collectivism through a tradition of lifetime employment. Indians are similar, in that skilled workers usually seek lifetime employment. Appraisal systems are highly subjective, taking into account characteristics such as caste, religion or language, for example.

One interesting point made by Rasetti was the distinction between high- and low-context communication. This concept of contextual information was studied by Hall in his book “Beyond Culture” written in 1981 [5]. Hall describes two types of cultures, those that use “high-context” communication and those that use “low-context” communication.

Low-context communication is characterised by a high dependence on verbal communication to convey meaning or information. Rasetti gives the USA, Canada, Germany, Switzerland, Scandinavian and former USSR countries as low-context cultures.

High-context communication, on the other hand, revolves around other forms of non-verbal communication, such as body language, feelings, attitudes and physical environment, in addition to verbal communication. In these cultures, pure verbal communication can be full of ambiguities if not put into context. Collectivists tend to be high context since the very presence of the person is gratifying enough; hence, India is one such culture. Other examples of high-context cultures include most Asian, middle-east and African countries. Some European countries such as the UK, France, Italy and Spain are mixed.

Power distance

The large power distance in India’s culture is manifested through its elaborate caste system and its emphasis on hierarchical relationships. These hierarchical relationships are derived from their extended family tradition, where children are taught to respect elders and, in the workplace environment, their boss or senior members of the company.

Uncertainty avoidance

India is a low-uncertainty-avoidance country. That is, they do not experience much anxiety about uncertainty. This is explained by India’s aversion for formal rules and procedures. On the other side of the coin is Japan, having one of the highest uncertainty cultures. In order to mitigate the possibility of uncertainty, Japanese society imposes formalised procedures and determines rules for its citizens to follow.

Femininity versus masculinity

Indian and Japanese cultures are strongly male oriented, stressing the importance of the female role of raising children and educating them, while the male is usually the bread winner.

Long-term versus short-term orientation

Indian culture has a long-term orientation characterised by their strong adherence to hierarchy and the caste system.
3.4. Indian culture and the modern world

Based on the profile of Indian culture through Hofstede’s five cultural dimensions the following findings were made by Rasetti [12] from her research on the impact of modernisation in Indian culture.

Indian cultural dichotomy exists due to pressures to modernise, especially due to the booming high-tech industry. This duality is more common among skilled workers due to greater exposure to western values through education and employment. The majority of Indian society maintains Indian social values such as marriage and religious rituals but might adopt westernised behaviour such as dressing, music preferences and vocabulary.

As core values are harder to change, modernisation results in a dichotomy of cultures in India. On the one hand are the deeply rooted collectivist values of seeking lifetime employment, and on the other hand are the individualist practices seeking career advancement. Rasetti’s research found that there is a growing trend in cultural adaptation for a particular Indian demographic: highly educated (usually employed in the high-tech industry) young professionals at approximately 25 years of age, many of whom have completed masters or MBA degrees. They have witnessed the exposure of Indian culture to foreign influences due to the liberalisation of the economy as they were growing up from childhood to adolescence. Because of this fact, their core values consist of this fusion between traditional Indian and the Western. Although respectful of their Indian social principles, they are easily able to incorporate foreign values as their own, which conflict with the Indian culture. This is the sacrifice they need to make in order for success in the high-tech industry.

An interesting finding by Rasetti was the importance of middle management to act as interface between role models and subordinates. This is used to bridge the large power gap that exists in Indian culture. This can be alluded to the use of groupware such as the one being proposed in this paper. As middle management acts as mediator between subordinate staff and higher management, so too does groupware act as an interface between subordinate staff and higher management, on the assumption that the identity of these individuals is protected.

To add further weight to the applicability of groupware, high-tech companies enable intensive communication throughout the corporation by means of corporate networks, thus providing broader communication channels across various locations around the world. Wider communication channels help to increase cultural exposure, increasing one’s cognitive abilities and facilitating employee behavioural changes through the awareness of new realities.

3.5. Indian culture and the ATAM

Using Rasetti’s findings, we can infer that there may be possible conflicts as well as congruous characteristics in the Indian culture with the ATAM. Firstly, being very hierarchical (large power distance and long-term orientation) and collectivist, Step 7 of the ATAM would not produce a useful result as there would be a strong bias towards what upper management want as the higher priority quality attributes. This ensures that the harmony within the group is preserved. Secondly, the ATAM is a well structured process
with a number of rules and steps to abide by, indicating a tendency towards aversion to uncertainty. As Indian culture has a low uncertainty avoidance, they are not disposed to following rigid controls and formal rules. Thus, they may have problems or be less productive with the rigidity of the ATAM.

On the other hand, there are attributes of Indian culture that pertain to the ATAM such as its tendency towards high-context communication. The ATAM is conducted in meeting environments, whereby communication is conducted face to face within an enclosed area with a number of participants. This is highly conducive towards high-context communication.

Since these are inferences and have not been empirically validated, these are areas that will require further exploration and research.

4. Problems and issues

We now analyse some problems and issues with the ATAM from a social science perspective. This perspective incorporates three key social influences that impact on the ATAM — cultural, economic and environmental. As Fig. 2 illustrates, the social aspect of the ATAM is an amalgamation of these elements, which possess some commonalities that will be more apparent in the following discussions. As Perlman et al. [11] have proven, a large majority of computer scientists are “uninformed about what social science is, what disciplines constitute it, and what practices it encompasses”. More interestingly, they find that “most computer scientists are favorably disposed to increasing collaboration with social scientists”. On the other hand, they do add that “this seems to be more in principle than in practice”. However, as there has been scant research done in this field and, more importantly, because of the significant role people play in the ATAM, there is potential for further research to be done to fill this void.

4.1. Cultural

Workplace politics

It is well known that managers hold much of the power in many decisions and usually have the final say. If a decision is not appropriate in their eyes they may even find ways of pressuring employees into taking certain actions to suit their whim. Furthermore, different stakeholders have differing agendas. For example, managers tend to place a greater emphasis on quality attributes such as interoperability and security; end-users are
more concerned with speed, reliability and usability; and software maintenance personnel place a greater importance on expansibility and portability. These differences may lead to tensions during one of the key steps (Step 7) of the ATAM and may cause further delay and unnecessary conflicts between work colleagues.

Workplace cultures

Another important issue to consider with the ATAM is the different workplace cultures. Culture is not necessarily defined by countries or races. Different workplace cultures can exist within the same country as well as in different countries. For instance, not all firms in America follow a liberal, democratic and individualist workplace culture and, equally, not all firms in, say, Japan or India follow a strict hierarchical workplace culture. Having said this, though, these generalisations are often true.

The ATAM has been predominantly tested on US military software. Clements et al.’s findings were that many participants of the ATAM responded positively with the open style of voting where every participant is able to see the votes of others [1]. From this, an inference or assumption can be made on the fact that ATAM has had little exposure outside the realm of the US government/military institutions. With this, arises a concern on the effectiveness of ATAM in other workplace cultures. What if the ATAM were to be employed in institutions with a stronger hierarchical workplace culture like those in India?

As Rasetti [12] points out, those coming from a strong hierarchical workplace culture tend to be more group oriented and collectivist rather than individualist. Inherent to this culture comes a devoted group of “followers” that will follow along with any decisions made by upper management. This deems Step 7 of the ATAM redundant as this type of workplace culture defeats the purpose of voting and brainstorming.

Recruiting the right stakeholders

It is emphasised by Clements et al. that there should be as large a representation of relevant stakeholders as possible as “a critical step of any architecture evaluation is to elicit exactly what the goals for the architecture in fact are, and the stakeholders who own those goals are the ones from whom they are elicited” [1]. Due to the immaturity of the ATAM and lack of exposure to commercial applications, ATAM evaluations would often require management to outsource an evaluation team possessing the expertise. These evaluation teams are responsible for recruiting the participating ATAM stakeholders. This raises two issues.

Firstly, given that management is responsible for outsourcing these evaluation teams, there is some potential for management to have some influence on the choice of participants in the ATAM. Secondly, evaluators are not familiar with staff in the company. They may only associate stakeholders with those directly involved with the system such as software architects, developers, testers, etc. but have little awareness of the end-users. This is compounded by the fact that the evaluation team is responsible for determining the stakeholder participants.

From these two issues, there is an apparent need for transferring some of the responsibility from the evaluation team and high ranking staff, to the stakeholder in order to ensure the appropriate stakeholders are well represented. Having said that,
the responsibility of selecting the stakeholders and leading the evaluation should still be in
the hands of the evaluation team.

4.2. Environmental

This section discusses facets of the ATAM that could potentially be improved upon to
ensure ATAM sessions are efficient, effective and productive with respect to the workplace
environment.

Collocated meetings

Currently, the ATAM session environment is defined by the evaluation team and
stakeholders collocated within the same physical meeting room. In the modern world, staff
often travels to other countries for work-related business. In particular, key stakeholders
such as the software architect or integrator will be the individuals least likely to have time
to attend ATAM meetings.

As stakeholder involvement plays a large part in the ATAM, remote collaboration will
be of particular benefit to the ATAM process. The possibility for an effective means
of conducting a disparate ATAM session is very real with the rapid advancement of
technologies. In particular, the ubiquity of the Internet allows stakeholders to be present
at ATAM meetings without needing to be geographically collocated.

Having said this though, it is important to note that there is no replacement for
face-to-face meetings and, in the authors’ opinion, it still remains the most effective
means of communication within the meeting environment. Face to face communication
conveys thoughts and ideas faster and is more memorable, because more human senses are
stimulated. Most importantly, it is more enjoyable than interacting with a screen interface,
which ensures that these sessions are motivating and interactive. Synchronous meetings
are frequently cited as necessary because it is believed that factors such as group synergy
improve the output of meetings [10].

Low-fidelity meetings

The tools used in ATAM meetings, as evidenced in literature and in [9], are low fidelity
such as markers and butchers paper and pens, pencils and paper as scribing tools. There
are advantages and disadvantages to using low-fidelity techniques for meetings.

Advantages

1. Inexpensive — The cost of paper and markers/pens/pencils/highlighters is much lower
when compared to high-tech means such as laptops, PCs, PDAs, etc.
2. Easy to set up — Computers require the installation of appropriate collaborative
software, networks as well as various configurations.
3. Requires few skills — Just requires literate people, as opposed to high-fidelity means
where participants will need to have some knowledge of computing and typing skills.
4. Portable — Easy to transport the equipment from one place to another.

Disadvantages

1. More personnel — The ATAM evaluation team will need more personnel when using
low-fidelity techniques. For instance, a case study performed by Clements et al. on a
system called ECS (EOSDIS Core System) required four members [1]:
(a) Team leader, Evaluation leader
(b) Scenario scribe, Questioner
(c) Proceedings scribe, Questioner
(d) Timekeeper, Questioner.

This clearly indicates that a large proportion of team resources are devoted to scribes and a timekeeper, both of which can be easily automated or put in the hands of the stakeholders. That is, collaborative software could provide an opportunity for the stakeholders to be their own scribe. Not only does this reduce the cost resulting from a smaller evaluation team, stakeholders are more willing and likely to contribute to the ATAM evaluation session because they are more empowered.

2. Data not accessible — As the ATAM session goes over approximately 3 days it is imperative that the data collected after each day be accessible to all participants of the ATAM in order for the following day’s session to be more productive. Using low-fidelity methods to conduct an ATAM session, the papers containing all the information from each day are in the hands of only one individual. By making this data more accessible, stakeholders can read through results discovered from earlier steps or revise over concepts explained that they were not able to understand.

When using a database back-end to a distributed software system, the data collected during sessions can be easily compiled and stored permanently onto a centralised data store. This data can then be processed and presented over via the Internet, which is easily made accessible 24 h a day. Furthermore, multiple stakeholders can access this data concurrently, as opposed to having to share around a single set of papers.

3. Difficult to update — Correcting errors and updating data on a piece of paper can involve more effort than on a software application.

4. Difficult to maintain traceability — Maintaining relationships between ATAM steps is easily done over a software application but difficult with a stack of papers. Traceability is important because many of the steps of the ATAM are dependent upon other steps.

A collaborative software tool will be particularly useful to stakeholders for earlier phases, such as Phases 1 and 2, which can be read over prior to the start of the ATAM as this tool will allow the evaluation team to upload their presentation slides up on the system. This will help stakeholders to be better prepared, more productive, more inclined to contribute and provide more useful contributions to the process.

4.3. Economic

Economic perspective includes looking at aspects such as costs, time and resources used.

Time and cost

A large amount of resources for the ATAM process are devoted towards work that can be easily automated in a software application tool. This includes scribing, timekeeping, collating data, integrating and processing data, and compiling information and findings into a report. Furthermore, a considerable amount of time is used in scribing the information and there are additional difficulties in restoring this information in later stages to all those involved in the meeting for referencing.
With such a tool, it should substantially reduce the time involved in information processing, documentation and consistency checks. Time and human resources spent on documentation will be reduced because information processing and evaluation will be mostly automated. Information is collected onto a permanent data store, the system’s database and this information is displayed on one common interface. This is contrasted to meetings where information is verbalised to stakeholders and contributions made by those in the meeting are handwritten or verbalised. Such information can easily be misunderstood by those involved in the meeting.

**Required expertise**

As companies increasingly expand their operations overseas, getting hold of the right personnel in each country can be difficult. For instance, a country may lack in the necessary skills and expertise in their population; or, there may be few in the country who are familiar with the company’s systems and architectures and require the presence of current staff with the right expertise to commute to the country and establish the necessary infrastructure. Flying employees around the world can be costly, exhausting for the employees and inefficient as valuable time is spent on travelling.

A Web-based collaboration tool can enable companies to “virtually” allocate their personnel resources with the required skills and knowledge to locations around the world, providing needed expertise. There may even be a possibility to allow software architecture experts from around the world to be contracted out by companies to assist in conducting the ATAM process.

5. Approach: ATAM collaborative environment

This section outlines the approach that was taken in this paper to build the **ATAM Collaborative Environment (ACE)**. We first conducted a broad and extensive survey in the fields of software architecture, software architecture evaluation and culture. During the survey, a number of questions arose on how the brainstorming session should be conducted in Step 7 of the ATAM process:

- Should it be done asynchronously via a message-board-style interface?
- Should all ideas brainstormed from each stakeholder be submitted but not shown until a set date/time, by which time the voting should begin?
- Or should each idea be submitted individually and displayed instantly for all other stakeholders to see during the brainstorming session?
- How should it be done? Via ICQ-style communication where it is restricted to two people at a time to simulate a person-to-person, face-to-face conversation?
- Or should the communication be visible to all to simulate a meeting room situation?
- Although the latter maps well to how the ATAM is conducted, is it an effective brainstorming technique?

The approach used to answer these questions has been to conduct an empirical study on the effectiveness of different brainstorming techniques. The data was collected by the form input from students after completing various exercises based on tutorial/laboratory questions for the Human Computer Interaction course in our School.
The first exercise required the students to individually brainstorm as many ideas as possible on a topic specified by tutors. They were given 5 min to complete this task. The second exercise required the students to work in pairs to brainstorm as many ideas as possible on another topic specified by tutors. The students were allowed to communicate through any means, including oral and visual. They were given 5 min to complete this task.

The third exercise required the entire tutorial class to brainstorm another different topic on the whiteboard. The ideas were projected to the entire class verbally and immediately written on the whiteboard. The time allowed was 10 min. The final exercise involved computer-supported brainstorming. Using ICQ-like software called iChat, students were free to communicate with anyone within the same tutorial. However, communication was limited to a one-on-one conversation and the rest of the class was not privy to this conversation. This activity was limited to 10 min.

These exercises were conducted with over 20 classes of approximately 15 students per class. Fig. 3 depicts these statistics. Note that the most effective means of brainstorming is through the class brainstorming.

5.1. ACE: The tool set

A set of requirements for the ACE tool is now presented. A detailed description is made on what ACE is all about and how it should be used. The following vindicates the use of ACE as a means of overcoming many of cultural, economic and environmental issues.

Cultural

The cultural aspect is the major focus of this paper. There were three issues identified from the cultural aspect:

• Workplace politics — This refers to upper management pressuring staff to vote for a particular quality attribute scenario in order to achieve what management desires. In order to prevent such politics from encroaching into software architecture evaluation decisions, a need arises for an anonymous means of voting when deciding on quality
attribute priorities. ACE is the ideal solution to this need since it takes advantage of the anonymity that the Internet provides. The voting process in ATAM can, instead of being conducted with other members of staff in the same vicinity, be done online anonymously.

- **Workplace cultures** — This refers to the cultural differences that may exist within an organisation as well as between organisations, especially those that originate from different countries. The key issue here are the sensitivities some cultures may have towards the concept of an open, democratic voting process. ACE provides a means of anonymous voting in a disparate environment without needing to force an alien cultural practice onto the participants.

- **Recruiting stakeholders** — A feature of ACE is that the recruiting process is done through a request and response protocol as opposed to giving the evaluation team full authority over choosing stakeholders. So, in order for a stakeholder to join an evaluation, they must first request the evaluation team for permission to join, and then wait for a response. This also ensures that stakeholders who participate in each evaluation would most likely be more motivated as they participate out of their own choice, which considers one of Dingsøyr’s success criteria in knowledge management: “Using knowledge management tools and sharing knowledge with others requires employee motivation” [2].

Values within a culture are the most difficult to observe and very difficult to alter [7]. However, on the other hand, practices are more easily observed and easier to change. Fig. 4 illustrates the importance that values and practices play in various levels of society from the national to occupational to organisational. It is the latter that is of the greatest concern to this paper. This figure shows that practices play a greater role in the organisational context, that is, within the workplace.

ACE aims to take advantage of the malleability of practices and overcome organisational differences in culture. This is achieved by using a communication medium that attempts to enforce a culturally neutral protocol of communication.

**Environmental**

This section describes how ACE can assist in overcoming some of the work environment issues with ATAM. Two issues revealed in Section 4 are:
• **Collocated meetings** — As the ATAM is traditionally performed within a room and all participants are physically collocated, it limits the choice of participants available for participation. ACE overcomes this as it is Web based, and hence, available to anybody with a decent browser and internet access.

• **Low-fidelity meetings** — ACE is a means of distributing that scribing responsibility to the stakeholders. This is demonstrated in ACE through its brainstorming and voting functionality whereby stakeholders can submit their ideas concurrently via an HTML form. The stakeholder inputs are immediately stored in the database and are displayed on the browser screen.

**Economic**

This section explains the advantages that ACE brings to the ATAM to resolve the economic issues:

• **Time and cost** — ACE automates scribing, timekeeping, collating data, integrating data, processing data as well as presenting that data, and thus, eliminates a substantial proportion of costs involved in running an ATAM session.

• **Required expertise** — Being a Web-based application, ACE can be used as a bridge between the skilled labour (such as software architecture evaluators, software architects, managers) unable to attend the meeting, and the organisation undergoing an ATAM evaluation session.

5.2. **ACE: A detailed description**

ACE is a collaborative environment specifically built for the ATAM. Its aim is to support an entire ATAM session, from the presentations to the brainstorming and voting steps until the final report generation step. ACE is built upon a Web-based framework in order to ensure the system is accessible anytime, anywhere. It consists of a number of features that follow every step of the ATAM to ensure that the ATAM process is not corrupted. The following is a listing and explanation of the key currently implemented features in ACE.

**Main features available to all users**

Request to join an evaluation — All users can request to join an existing evaluation session.

Scenario brainstorming — Brainstorming and Voting of the ATAM. In ACE, users are not restricted to the scenarios they can place and these scenarios are immediately displayed on the browser in a table after submission.

Chat — This is available at all times to the user. The purpose is to map this collaborative system as closely as possible to a real life meeting by providing a synchronous means of communication with all other participants. Another use of this facility is to assist with the brainstorming process. As was indicated in Fig. 3 brainstorming was most effective when in the class situation.

Although this is valuable information, the most significant information comes from asking: “What is it about the class situation that makes brainstorming much more effective?”. To answer this, the characteristics of the class situation need to be analysed.
Firstly, and most obvious, is the number of direct participants in the brainstorming activity. This has greater numbers than the other three techniques used in the aforementioned experiment (individual, pairs, ICQ chatting) with between 10 and 15 participants as opposed to a maximum of two directly communicating parties for the other techniques. The larger number of participants means ideas reach a greater number of people. This stimulates the minds of the participants, leading to a greater network of ideas branching out from each individual.

Secondly, it is a synchronous means of communication. That is, communicating live with others, such as verbal communication; as opposed to something asynchronous such as a message forum where a reply to a message post is not likely to be immediate.

Thirdly, there was a well established context and focus on the topic. As facilitators, we found that most of the two-person brainstorming techniques (pairs and ICQ chat) tended to drift off on a tangent, away from the task at hand, and towards a more casual, social conversation. This occurred because, even though they knew what their task was supposed to be, there was no mediator to maintain that context and discipline.

Finally, continuing from the previous point, the individual, pair and ICQ-chat brainstorming techniques did not enforce some form of obligation to the larger group. That is, they just had some obligation to the partner or to themselves. Whereas, in the class situation, seeing students participate spurred on others in the class to add more ideas.

In developing the ACE tool, the initial conception was to implement the brainstorming function as a “submit and display”-style message board. However, this lacked one of the characteristics of a good brainstorming technique; it was asynchronous. Being asynchronous, participants could procrastinate in submitting brainstorming ideas. Moreover, ideas come about more slowly, leading to a slower growth in ideas.

Stemming from this as well was the lack of obligation to contribute to the brainstorming effort. That is, synchronous communication would have a higher obligation to contribute as all participants, knowing that this will not be a permanent opportunity, would feel that they should make their contribution as early as possible. Hence came the need to include a live and dynamic chat forum facility.

This did not mean that the brainstorming message board was obsolete because it was still one of the most effective and practical means of sharing information over a Web architecture. As Web information is obtained via a request and response protocol, there is no way of dynamically broadcasting every message sent from participants to all the other participants. Further, it is very efficient and easy to maintain persistence in the brainstorming ideas. The purpose of the live chat facility is to help incorporate the characteristics that were inherently lacking within the brainstorming message board.

Vote — Like brainstorming, this is performed in Step 7. Once the brainstorming session is over, the evaluator needs to start the voting session before anyone can vote. ACE calculates the number of votes allowed based on the number of scenarios that were brainstormed. The number of votes allowed is 30% of the number of scenarios brainstormed. So, for instance, if there were 21 scenarios brainstormed, then each user gets seven votes. The user may place all their votes on a single scenario, or distribute their votes to different scenarios.
Evaluator specific features

Create an evaluation project — Evaluation projects can be created by any evaluator. The identifier for each evaluation project is determined by the name of the evaluation project.

Accept a stakeholder — When a stakeholder has requested to join an evaluation project, it is the evaluator’s responsibility to accept the stakeholder based on their occupation and other credentials.

Start/Stop a step — To indicate to the user what stage in the evaluation the ATAM session is up to, ACE provides the evaluator with the facility to start and stop a step in the ATAM. The active step is indicated on the interface as a green button.

View/edit utility tree — This is a Java applet that allows the evaluator to view and edit a utility tree. It will be saved on the evaluator’s local machine and can be reloaded as well.

6. Potential shortcomings of the approach

This section outlines the potential shortcomings of our approach.

6.1. Difficulties with using software tools for knowledge management

Dingsøyr found four factors that are considered important [2]:

1. A culture for sharing knowledge. Using knowledge management tools and sharing knowledge with others requires employee motivation. Due to the reduced obligation for attending face-to-face meetings and the increased anonymity, it would be easy to postpone such activities because of lack of time or because they feel their knowledge may not be valued. Further, if management “requires” it and employees are not motivated, it is easy to “fake” reporting of knowledge. A culture for sharing knowledge has to be rooted in all employees.

2. Stable focus on knowledge management. Key champions who leave the company, or frequent changes in an organisation cause initiatives to be abandoned before they start working. Knowledge management requires stable focus over time.

3. Incremental development. Show benefits during development. There is no such thing as a perfect knowledge management tool. Tools need to be updated.

4. Good coupling to business goals. The company who invests in knowledge management tools must really need them. Many companies have tried to apply knowledge management without having a clear idea of which needs they have. If the direct benefit is not obvious, it is harder to motivate employees to contribute, and also harder to get management support over time.

Point 1 suggests that users of ACE will need to be motivated. To make this point clearer, compare the obligation felt by participants when they attend a meeting where participants are physically collocated, as opposed to a ‘virtual’ meeting such as with ACE. Once participants physically enter the room they are already obligated to stay there and participate. If meetings were to be held online, participants may procrastinate because they are not provided that meeting context, and so, would feel less obligated to participate. However, on the other hand, this is an inherent difficulty when trying to provide for a distributed collaborative environment.
6.2. Impersonal nature

Following on from the previous point, ACE is inherently impersonal. Naturally, as you are interacting with a computer interface instead of a human, this can be a primary cause of reducing the motivation level of stakeholders and evaluators to participate.

7. Conclusions

The ATAM is a software architecture evaluation method that specialises in identifying risks, sensitivity points and tradeoff points in a software architecture. This paper aims at adding value to the ATAM by probing for weaknesses or for aspects that have potential for improvement and widening the scope of the ATAM. The approach taken in this paper is slightly different to that which is traditionally taken by technical research. This is because there is often a greater emphasis on the technical, process or methodical aspects within technical research and, especially in the case of the ATAM, there is a lack of emphasis on other disciplines, such as the social sciences.

From this perspective, a number of weaknesses and areas of improvement have been found in the ATAM that would warrant further investigation. There were issues with the working environment such as geographical distance; economics such as costs and allocation of skilled resources; and culture such as how hierarchy is viewed in different cultures. A strong focus has been placed on the latter due to its interesting but challenging abstract nature, contrasting with the ATAM’s certainty from its well-defined phases and steps to guide the stakeholders and evaluators through the process.

In this paper, we presented a tool set called the ATAM Collaborative Environment (ACE). ACE is a collaborative Web-based application that supports the entire ATAM process where the current prototype focuses on the brainstorming and voting process. As it is currently in an incomplete state, empirical testing to completely verify these hypotheses was not yet possible.

As with most solutions to difficult problems, this approach has some inherent shortcomings or tradeoffs. The primary shortcoming is the impersonal nature of interacting with a computer instead of a human. As a consequence, this may have a mitigating effect to getting stakeholders and evaluators motivated to participate in an ATAM evaluation via ACE.

Future work will involve conducting the ATAM (without ACE) in cultures of differing combinations of dimensions. Additionally, completion of the ACE tool set and testing this on different cultures will provide some insight into the effectiveness of such a solution to the problems and issues outlined in Section 4.

References