The impact of criteria in system architecture selection: observation from industrial experiment

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THE IMPACT OF CRITERIA IN SYSTEM ARCHITECTURE SELECTION: OBSERVATION FROM INDUSTRIAL EXPERIMENT

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Abstract

Decisions related to system architecture are difficult, because of fuzziness and lack of information combined with often conflicting objectives. We organised an industrial workshop with the objective to choose 5 out of 800 architectures. The first step, the identification of selection criteria, proved to be the greatest challenge. As a result, designers selected system architectures that did not satisfy them without being able to explain what went wrong in their selection process. The objective of this study is to investigate the impact of criteria in system architecture selection. The recordings of the workshop were transcribed and analysed in order to identify the difficulties related to the definition and the use of criteria. The analysis highlights two issues: the interdisciplinarity of system architecture makes criteria interdependent and the lack of information is making it impossible to define an exhaustive set of criteria. This questions the applicability of most of design selection methods that assume that criteria are well defined by designers. Finally, this study provides insights and recommendations for future selection support tools dedicated to system architecture design.

Keywords: Early design phases, Product architecture, Decision making, Selection criteria

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1 INTRODUCTION

System development processes are shaped by decisions starting from the choice of working principles to the parameterization of a detailed design. Architectural decisions are those which impact the most the overall system life-cycle costs (Berliner & Brimson 1988). Designing system architecture is an interdisciplinary activity that relates to stages of system life-cycle having often conflicting objectives. That is why it necessitates trade-offs to identify the architecture that will satisfy system requirements and company objectives in the best way. The main challenge in this design phase is that information is incomplete, fuzzy and uncertain (Chapman & Pinfold 1999), making the assessment of system architecture compliance difficult.

We conducted a one-day workshop in a big aerospace company as part of a doctoral project on system architecture. Participants were asked to select a set of 5 promising architectures amongst 800 concepts of architectures which were generated automatically and characterised by four performances parameters. In a first step, the experts had to agree on selection criteria which represented the company objectives as well as system requirements. The second stage consisted in using these to select architectures. In the end they chose 5 architectures that did not entirely satisfy and convince them. The objective of this study is therefore to investigate how the choice of selection criteria impacted their selection process.

In the following section, an overview of selection methods used in product development is given to determine how criteria are customarily identified and employed. Section 3 explains the study context as well as the protocol. Section 4 describes what happened during the workshop while Section 5 develops the main insights emerging from it. Section 6 discusses issues related to criteria and provides insights regarding the requirements for future decision support system suitable for selection of complex system architectures.

2 SYSTEM ARCHITECTURE SELECTION IN THE LITERATURE

In the field of decision-making, a criterion is defined as "a function that associates each action (i.e. each alternative) *with a number indicating its desirability according to consequences related to the same point of view"* (Roy & Bouyssou 1991). When defining a criterion, authors do not always refer to the same entity but it is mostly considered as an "attribute", an "objective" or a "goal" (Henig & Buchanan 1996). In this study, a criterion is deliberately viewed in its broadest sense: it may refer to an attribute, a performance, an objective or a point of view.

Because any *"future activity focused on the chosen alternative, uses time, money and other resource and excludes any effort on the alternatives rejected"* (Ullman 2001), selection criteria used in design decision making must be carefully chosen. Generally, prescriptive design models do not develop criteria definition process. For example in systematic design, Pahl et al. (2007) emphasise the fact that criteria must be derived from product requirements in order to ensure product feasibility. Afterwards feasible concepts are selected according to *"technical, economic and safety criteria at the same time"*. A number of important points in the selection and product embodiment definition, such as assembly, transport, maintenance, etc. must also be considered. They depend on the available information which is growing as the design choices are made; and must be integrated as early as possible through detailed studies. In this respect, Ullman (2002), when discussing the ideal engineering decision making support, suggests that a comprehensive tool *"should manage incomplete alternatives and criteria generation; and allow their addition throughout the decision-making"*. Okudan and Tauhid (2009) have listed several decision-making methods that are used in conceptual design, called concept selection methods (CSMs). Based on this review, we analysed how selection criteria were considered within these methods. It appears that these methods mostly impose to use preferential independent criteria (i.e. not any criteria can be used) while assuming that the set of criteria is beforehand defined and well-known by decision makers.

Design synthesis methods aim at generating or selecting optimal concepts through fitness/objective functions (or equivalent), and use one or several criteria to do so. These criteria can be:

- Generic: it is based on a metric defined in literature such as cost or complexity metrics.
- Custom: designers define their own criteria depending on the product or company objectives.

Once the criteria are defined, a Pareto optimisation or an overall weighted function is often used. If so, Antonnson and Cagan (2001) emphasise the difficulty of capturing subtleties and complexities of practical designs in terms of constraints and objectives functions.

In practice, most of empirical studies focus on the decision making process when a set of selection criteria is already given (Kihlander 2011) while very few studies are dedicated to the process of defining, evaluating and selecting criteria in product development, particularly in preliminary design. Yet the study of Girod et al. (2003) suggests that the process of choosing the criteria according which the alternatives are evaluated is neither a major concern, nor a major step during concept selection: in three different groups of students and experts aiming at selecting a concept, a maximum of 10% of selection time is dedicated to definition and weighing of criteria. In return, it seems that concept selection causes many problems in practical cases (Weiss & Hari 1997) and results in waste of time and increase of costs due to the necessary rework implied by wrong decisions (Ullman 2006).
To summarise, a set of criteria is considered as the basis for any rational decision making. The choice of criteria appears when structuring the decision problem, which is recognised as one of the critical steps in problem solving. The difficulty in choosing criteria is that they may be intangible and sometimes have no measurements to guide the ranking of alternatives or defining priorities (Saaty 2008). Such cases occur when the selection problem is complex and ill-structured; in product development for example when information, and thus new selection criteria, is gathered as the selection process progresses. This study aims at analysing the impact of criteria onto the selection process of system architectures.

3 STUDY

This study concerns the architecture selection of a new generation building block to be integrated in radar active antennas. It is part of an action research where one of the authors has been working in the company for three years with the aim of supporting engineers in system architecture generation and selection. The authors developed a method to automate the generation and evaluation of system architectures (Moullec et al. 2013) regarding constraints and performances specified by engineers beforehand. This resulted in the generation of 800 feasible architectures integrating innovative technologies and mainly varying according to the technologies used as well as different physical arrangements of parts; each with advantages and disadvantages regarding system architecture performances.

3.1 Case study

The basic functions of a radar antenna are transmitting and receiving electromagnetic signals to detect the presence of objects in a given area. However, to be usable, the transmitted signals must be amplified before being radiated and the received signals must be amplified before being processed. Active antennas amplify the signals in close proximity to the radiating elements within one integrated building block. Due to cost, this building block is designed to be used in several antennas of the same family and therefore its architecture needs to allow a certain degree of customisation and may have requirements that are still flexible.
Although these products are generally incremental and require several years of development, the choice of specific technologies occurs very early in the design process and may require significant investments. To assess the impact of introducing innovations, different design alternatives are studied at the very early design stage. Such investigations are time consuming and require a multidisciplinary approach to consider interactions related to different domains. In the company, technical solution evaluation and selection usually takes place through peer review workshops. Typically these workshops mainly concern subsystems and are focused on one particular discipline. The engineers therefore are familiar with the requirements related to their own area of expertise. However, system architecture evaluation and selection is a different problem in that all domains must be considered at the same time and traded-off against each other. It requires the opinion of multiple engineers who have to choose an architecture regarding multiple criteria; and whose choice depends on performances parameters that can be assessed despite the complexity of system to be designed and the lack of information inherent to this stage of design process. Once done, architecture selection becomes nearly irrevocable.
In order to ensure a large exploration of design space and in the will to avoid design fixations, designers chose to not include many constraints on the performances of the BB solutions to be generated by the search engine. This resulted in producing 800 concepts, which represents many potential solutions. Having to select amongst 800 solutions is not typical since most often engineers

have to choose between only a few solutions. When asked if they could choose among so many solutions, engineers answered positively. A workshop was therefore organised to observe how engineers empirically select system architectures when facing numerous possibilities. This workshop was also the opportunity to test the usability of MCDA methods to help this choice.

3.2 Workshop organisation

3.2.1 Workshop objectives and organisation

Initially, this workshop had two objectives: 1) observe how engineers proceed when confronted with a large number of new architectures and criteria and 2) identify the relevance of Multi-Criteria Decision Aid (MCDA) methods, in particular PROMETHEE (Brans et al. 1986), that could be used for this process. The final goal for the experts was to identify 5 architectures to study more in depth amongst the 800 architectures that have been generated. Four engineers took part in this workshop. They have been invited to participate because of their domain expertise (i.e. antenna architecture, mechanical integration of antenna, RF studies and radar architecture) and involvement in the overall project. The workshop was organised in four different phases. The introductory session explained the workshop objectives, showed the software for system architecture visualisation, and allowed time for questions. In the second part, a set of criteria was chosen for architecture selection. In the third part of the workshop, the experts were divided into two groups: one group evaluating and selecting architectures without any method, and one using the PROMETHEE method. Each team had to propose what they considered the five best architecture solutions. In the last part, the experts were brought together to compare and rank the whole set of the ten selected architectures in view to their preferences.
Architecture alternatives were presented using the following information:

1. The elements of the architecture were shown in a schematic view usually employed to communicate within the company.
2. The performances of the architecture estimated by the generation method were given as probability distributions for certain performances or as single value points for others.
3. A 3D-visualisation shows the placement of architecture components.

In addition a spread sheet with all performances estimation and architecture description has been made available to experts to make architectures filtering and sorting easier.

3.3 Data gathering and research methodology

The workshop has been video recorded and transcribed using Sonal (http://www.sonal-info.com). The overall aim of the analyses was to identify how and which criteria were used during selection process. The first analysis concerns the identification of selection criteria and the order in which potential selection criteria appear and are considered in the discussion. In order to diminish the bias in data coding, two authors read through the transcript to code the occurrences of criteria. All the terms used in the workshop were in French. We translated them as precisely as possible. A lexical analysis performed using VoyantTools (http://voyant-tools.org/) depicts how the criteria frequencies evolved throughout the workshop. Finally, an analysis of the number of occurrences of given criteria and their interrelatedness has been visually represented using Gephi (http://gephi.github.io).

4 THE ARCHITECTURE SELECTION WORKSHOP

4.1 Definition of two additional criteria

As starting point, the experts were provided with the following information on the proposed architectures:

- Their configuration, in terms of technology and number of components for each function;
- Four performance factors: mass, temperature, pressure losses, depth.

The experts decided to use the four performance factors as selection criteria. They further added another criterion, "diversity of solutions", to ensure that the selected architectures would be contrasting in terms of configuration. Other aspects, like manufacturing, reliability and cost, could not have been automatically estimated, but were of interest for architecture selection. Due to time constraint, they decided to look for two additional selection criteria, which would give them an indication of cost. The identification of these new criteria led to a two hours debate: twenty minutes were necessary to choose the criteria, and one hour and forty minutes was required to develop the corresponding evaluation metrics. The first chosen criterion was “number of elements”: the experts consider that the more components in the architecture, the more expensive. However, “number of elements” is only representative of assembling costs, but not manufacturing costs which also should include the difficulty to produce the components (a high number of functions integrated in an electronic component require advanced technology which will have a significant impact on the production cost). This issue has been addressed through a “complexity" criterion that reflects the difficulties in manufacturing and thus considers the cost of each individual component. The engineers defined their own complexity metric, which took about 1h40. In the end the value range for the criterion “complexity” spanned from 18 to 448. As for number of components, the value range was from 5 to 164 components.

4.2 Architecture selection

Depending on the technology used, the alternatives fell into three families of solutions. The experts wanted to select at least one architecture belonging to each family. This requirement is represented by the criterion “diversity of solutions”, and had to be checked at every step of the selection. This induced numerous additional iterations within the process.

The architecture selection has been carried out in two phases. First, a pre-selection based on the criteria “mass” and “temperature” resulted in 100 preselected architectures. These criteria were primarily used because of their selectivity, i.e. their ability to remove a high number of alternatives at once, and relative easiness to define thresholds given that they refer to system requirements. Nevertheless the criteria thresholds had to be revised several times in order to ensure solutions diversity. This stage lasted about 70 minutes. At that time, the retained architectures had very similar performances in terms of “depth” and “pressure losses”: these performances were very dependent on architecture families and no differentiation was possible unless going beyond the criterion “diversity of solutions”. The experts decided to filter architectures according to “complexity” but experienced difficulties in determining a threshold value because they perceived the complexity metric, although they defined it, as “completely subjective”. Finally, the median of complexity values of the preselected architectures was adopted as filtering threshold. After 1h50, the experts finished choosing the five architectures which have been regrouped with the five architectures chosen by the other group using the PROMETHEE method in order to compare and rank them.

4.3 Architecture comparison and ranking

The five solutions selected by each group were displayed on a same screen so that the experts could navigate easily between 3D visualisations and performances of the ten selected solutions. When discovering the 3D visualisations of the solutions selected without method, all the experts have been surprised. The solutions did not match with the solutions that they would have spontaneously selected: although their performances were acceptable, their configurations were not ideal. In order to rank the architectures, the engineers reviewed every architecture explaining why they have selected them, thus listing theirs strengths and weaknesses. Despite this, they did not manage the ranking of the solutions, including for those belonging to the same family. The workshop ended up on this general impression of confusion, with the feeling to have missed something.

5 ANALYSIS

This failure in finding satisfying architectures led us to explore 1) how and why these criteria have been chosen and 2) how and why they did not result in the choice of architectures that satisfy the experts.

5.1 Criteria identification

In the second step of the workshop, experts had to identify two additional selection criteria, which resulted in intensive discussion. A total of 16 terms have been used by experts to describe potential and effective architecture selection criteria. Based on the recording a timeline has been drawn (Figure 1): it represents the moments when different criteria have been mentioned during the identification stage of the two new selection criteria. The vertical line shows the order in which the criteria came up.

An dot in the matrix represents a reference to the corresponding criterion. Several dots in a single column mean that several criteria were addressed at the same time.

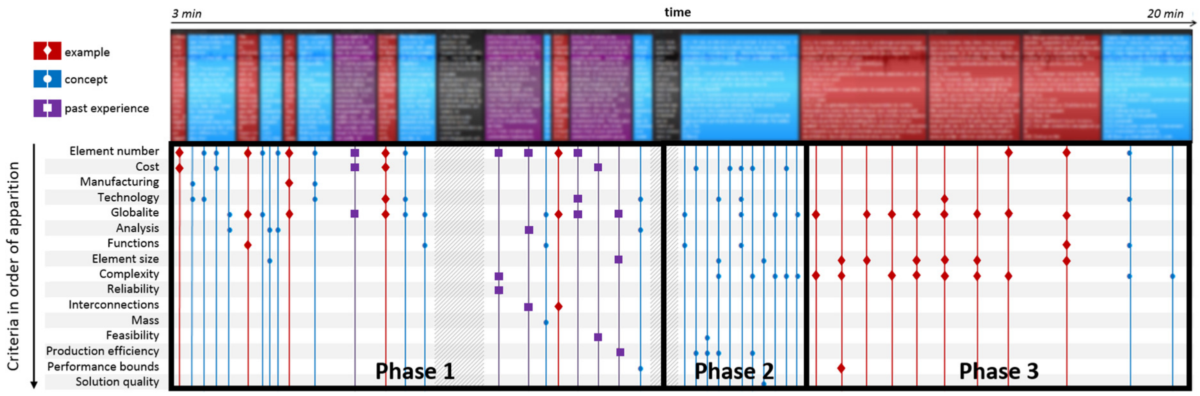

Figure 1. Timeline of identification of the new criteria

This timeline draws a precise outline of the discussion around criteria. It can be observed that after many criteria appeared in the discussion (Phase 1), a process of reflection about how to use these criteria (Phase 2) resulted in the identification of three criteria considered of interest to use in architecture selection (Phase 3): “complexity”, “globalité” (a French term proposed by the engineers to represent the number of functions embedded in each component) and “element size”. The video recording has also been divided in several extracts classified in three categories according to the information/system architecture the experts are referring to:

- Example (in red) refers to hypothetical case given to illustrate a statement about specific criteria.
- Conceptualisation (in blue) refers to the engineers reasoning about these criteria and their mutual effects.
- Past experience (in violet) refers to discussion of past products as reference points.

This shows that most of criteria are not easily identified but require to be applied to past experience and conceptualisation so that the engineers can define the scope of architecture selection.

5.2 Difficulties encountered for architecture selection and comparison

During the architecture selection step, the experts struggled with setting filtering thresholds of criteria. They faced two main problems:

- Conflicting criteria: the criterion “diversity of solutions” conflicted with most of other criteria. Different families had very different performance ranges making an acceptability thresholds hard to define. Other conflicts have also been noticed between “mass” and “technology”, as well as “complexity” and “number of elements”.
- Lack of preferences: when the criteria represent a rating more than a physical performance (i.e. complexity) the experts did not know what the acceptable value ranges were. They finally preferred to keep “complexity” and “number of elements” scores around median values.

During the pre-selection phase forty-two and twenty-six minutes were necessary to select a criterion, respectively “mass” and “temperature”, and then apply a filtering. This is due to the experts' difficulties in choosing the order of criteria and their threshold values. In the following, they changed their strategy and used pair-wise comparisons, but examined only ten architectures out of the hundred architectures still competing. They decided that four of them were acceptable, and selected them, which took 24 minutes. As we can observe, time constraints as well as the essence of the selection problem which consists in identifying the 5 solutions out of a total set of 800 potential solutions make the experts to choose a specific criterion or threshold regarding its selectivity rather than acceptability thresholds. This strategy allowed a rapid selection but has also the big disadvantage of disregarding acceptable architectures that might be far better than those selected regarding the other criteria. Moreover, the fact that the time allocated to system architecture selection was short suggests a hasty selection that could explain, in part, why selected solutions were finally not satisfying.

5.3 Evolution of criteria during the workshop

The timeline drawn for the entire workshop revealed an important change in the criteria during the whole workshop. In order to better visualise the evolution of criteria during the experts discussion, we used VoyantTools to perform a lexical analysis of transcripts and determine the frequencies of the selection criteria discussed and/or used by the experts during the workshop. Their evolution over time is illustrated using four "streamgraphs" (Byron & Wattenberg 2008) built for definition, pre-selection, selection and comparison steps (Figure 2).

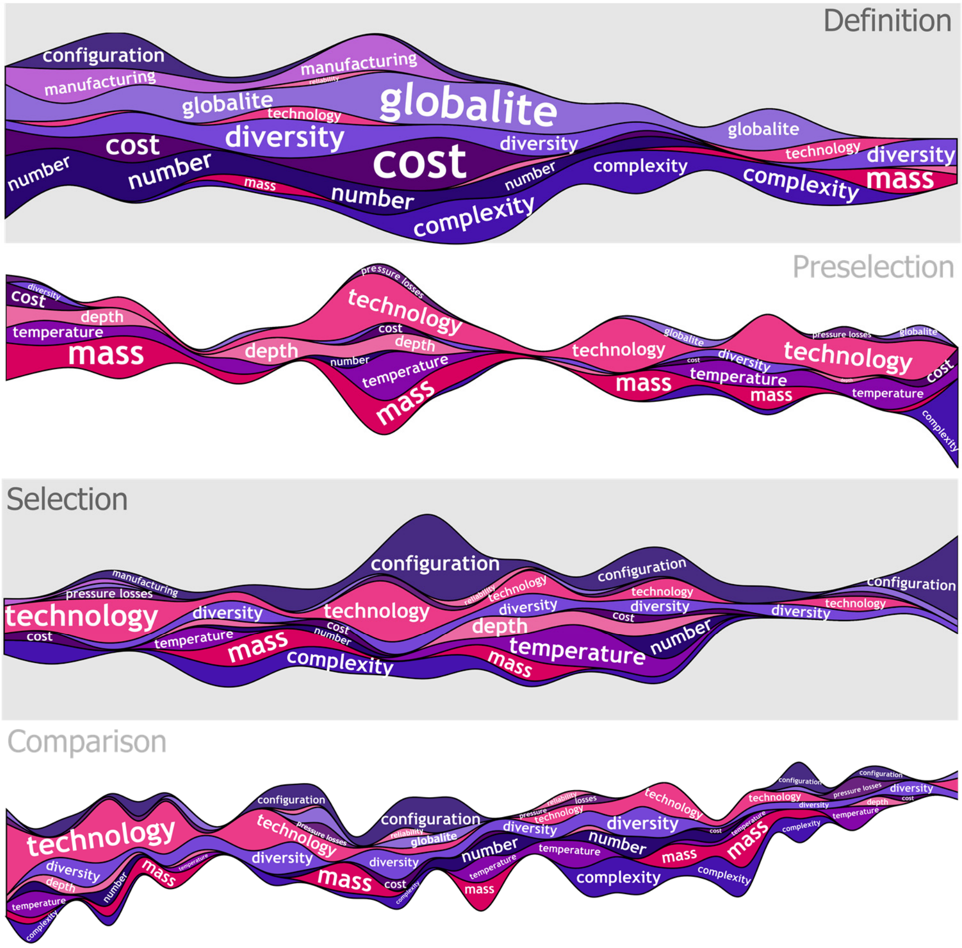

Figure 2. Streamgraphs showing the evolutions of criteria frequencies during the workshop

This figure shows that the criteria discussed in the criteria identification phase were not the same as those used in the selection phase. In particular the criteria chosen by the experts, "complexity" and "number of elements", taken together represent only a small part of debates during the pre-selection and the final selection (8%). This visualisation also shows that the evolution of criteria does not follow a specific scheme but rather that the number of parallel layers tend to increase over time which means that more and more criteria were discussed at the same time. This can be explained by criteria interrelatedness.

5.4 Impacts of Interdependencies between criteria and missing information

Totally, 35 different interrelations have been mentioned by the experts during the whole workshop. For a better legibility, these relations have been mapped using Gephi into an undirected graph (Figure 3). A post-interview with experts allowed to determine the objective (minimization or maximization) associated to each criterion as well of the consistency of each pair of criteria (indicating concordances or conflicts between their respective objectives).

The resulting network reflects the intricate relations between criteria; and one can imagine the cascading impact of a decision on a criterion on the other criteria. This increased the difficulty for experts to express their preferences: they did not know which criterion should be prioritised and what threshold to choose. A second important point is that one can observe that "complexity" and "number of elements” were not strictly complementary in the sense that they were related to the same criteria, which potentially introduced redundancy and interferences between them. This particular example illustrates well the difficulty related to lack of information which implies finding proxy criteria that are themselves not interrelated and that can be quantified, assessable and meaningful.

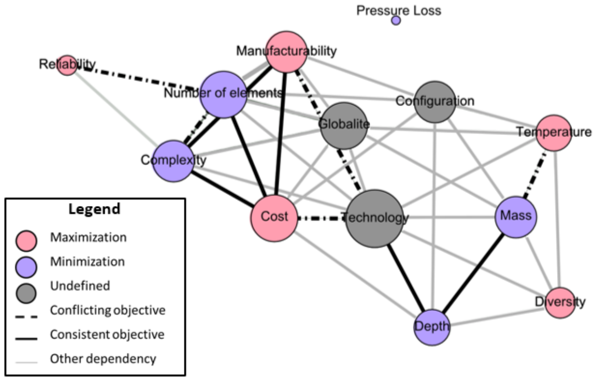

Figure 3. Criteria interdependencies

6 DISCUSSION & PERSPECTIVES

6.1 Discussion

This workshop included a number of biases that must be kept in mind when interpreting the results. First of all, the issue related to the evaluation and selection of a high number of architectures is very specific. However, this high number of solutions was the choice of the engineers. Secondly, this workshop was “only” an exercise on a real industrial case. The architecture selection had no consequence on the ongoing project: it is not sure whether the experts would have been more so inclined to avoid conflicts if their own responsibilities would have been engaged. Also, the short duration of this workshop finally might have biased the engineers towards hasty choices of selection criteria and/or use of evaluation formula in order to quickly sort the architectures and save time. However, we believe that the situations observed in this study are still representative and even magnified in real circumstances. This exercise revealed the difficulty of choosing system architecture, and the complexity of the reasons that motivate the choice of a particular architecture. In addition, the fact that a meeting has a limited duration is a situation usually encountered in industry.

Choosing the right criteria for architecture selection can be cumbersome since they may be defined in several ways with all different consequences. In particular, one must be very careful in deciding whether they must be:

- Quantitative or qualitative: while it is true that quantitative criteria present various advantages such as allowing optimisation, ranking and statistical analysis, it is not necessary the most suitable way to handle fuzzy and conceptual criteria like “complexity”. An ordinal classification, for example [too high; high; medium; low; too low], may have been easier to handle in that context since it would have prevented the experts from wondering whether a difference of 5 in the complexity scores, for example, is important or not when comparing two architectures. However, preferring a formula rather than a classification arises from the experts needing to evaluate 800 architectures since it bypasses the questions of the number of evaluators and the weight attributed to each of them (if they are specialist or not) by establishing a consensus on the evaluation of criteria.
- Generic or custom: research in product development proposes sets of criteria on which the architecture selection could be based (Scaravetti 2004). However, sometimes these criteria are not appropriate. For example, many complexity metrics have been proposed in design field (Summers & Shah 2010). In this workshop, the experts defined a complexity measure that decreases with the increasing number of elements: when defining the criterion “complexity”, the experts had in mind issues of industrial feasibility and cost, and therefore considered the internal complexity of the architecture components, rather than the complexity of the architecture itself. This is very specific to the electronic application and runs counter some other complexity metrics which increase with the number of elements. Therefore, the complexity metric defined by the

experts cannot be extended to every system. Likewise, air temperature would have never appeared in a set of generic criteria. However, in the case of the building block, the temperature has to be a criterion because the internal functioning is strongly depending upon it.

Contextualisation is therefore necessary to identify criteria, especially when information is lacking, like in system architecture design. The experience of engineers and previous designs pointed to issues that played a significant role in the selection or rejection of specific architectures, and aided the identification of the main elements that merit consideration. Remembering major complications due to the choice of a particular architecture is particularly important to identify new constraints or preferences. However, as one of the engineers explained after the workshop, a major part of the shared information is implicit. This may lead to different interpretations from experts and examples are critical to ensure a common understanding within the experts group.

This paper mainly demonstrated that the choice of criteria to select system architecture was far from straightforward. However, most of concept selection methods in design do not support the choice of criteria, thus questioning their applicability. Understanding the causes of these difficulties constitutes a first step towards the design of a method/tool supporting the choice of these criteria and thus complementing existing approaches.

6.2 Perspectives

The analysis of this workshop has provided insights into the characteristics of useful criteria. An "ideal" criterion for system architecture selection should be a property or an attribute of the system architecture which is, if possible, representative of a single objective. If it is integrated or related to several objectives, these must not be conflicting. In this sense, a preference (maximisation or minimization) would be clearly identified, and would remain consistent in case of multiple objectives. These findings are in accordance with criteria definitions and requirements proposed in decision making (Keeney & Gregory 2005). However finding criteria that satisfy these characteristics is not easy. First of all, the architecture selection problem must be understood in its entirety, which is challenging in view of the wide impacts of system architecture (Crawley et al. 2004). Generic metrics are difficult to use because they are either impossible to be assessed in view to the information available or inappropriate for the considered system. Instead selection criteria may be customised according to the system being evaluated. For that purpose, a step of problem definition clarification is needed. This could rely on Problem Structuring Methods adapted for architecture selection combined with a process of alternation between moments referring to "past experience", "conceptualisation" and "examples". A list of generic criteria found in literature could ensure that no critical aspect of the problem is forgotten. Also, due to the number of considerations involved in system architecture selection, a prioritisation seems necessary and should be done regarding the main objectives and the available information. Such a clarification step would be interactive and ideally would allow the designers to add or remove alternatives and selection criteria. We recommend to choose a set of architecture attributes as selection criteria, given that they are measurable and assessable. However, they have to be carefully chosen in order to reduce the number of interdependencies. Keeney (2005), when looking into a general decision-making process, provides advice on the nature of criteria to be chosen (natural, proxy or constructed), as well as a method that helps experts to define usable criteria. Finally, an interesting possibility for architecture selection process would be the integration/adaptation of methods coming from project portfolio selection problems. Archer and Ghasemzadeh (1999) define project portfolio selection as "*the periodic activity involved in selecting a portfolio, from available project proposals and projects currently underway, that meets the organization's stated objectives in a desirable manner without exceeding available resources or violating other constraints*". In our workshop, integrating such considerations (by satisfying the criterion "diversity of solutions") induced many problems and iterations during the selection process, because the experts did not know how to apply it.

7 CONCLUSION

In this paper, we highlighted the difficulty to identify the right selection criteria when it comes to system architectures selection. System architecture, because impacting many stages of the system life-cycle, makes identification of selection criteria difficult:

- objectives are conflicting and sometimes interdependent;
- architecture attributes are all related;
- crucial information, such as cost, is missing and such performances may not be assessable.

As result, the experts may get lost in the selection process. Because the solution is only as good as the criteria used in selection, a methodology to support the identification of criteria is needed. No method to support the choice of criteria have been noted in the field of engineering design, despite the existence of many concept selection methods based on already defined criteria. Pursuing this work should therefore encompass several steps necessary to propose an adequate and generic selection method. First of all, similar workshops in other industrial contexts should be organised in order to identify common practice and recurring difficulties. In addition, the effects of the biases addressed in the previous sections should be analysed in order to measure the impacts of each of them. More generally, this work opened up new questions specific to system architecture selection issue. In particular, it showed the diversity of criteria that could be taken in consideration when selecting architectures. However, one can ask which types of essential decisions, common to every system, are taken during the architecting stages. This would lead to build an ontology of related decisions, and associated selection criteria when defining system architecture. These criteria are likely to be highly interdependent and diverse due to the multiple disciplines and issues that need to be considered. This motivates the development of a decision support method that, contrarily to the current ones, is able to handle dependent criteria. Likewise, the lack of information and the uncertainty associated to these specific criteria need to be better integrated to ensure robustness of selection. Finally, the increasing use of computer aided methods requires development of selection methods appropriate for a high number of alternatives.

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