A Survey on the Benefits and Drawbacks of AUTOSAR

Silverio Martínez-Fernández, Claudia P. Ayala, Xavier Franch
Universitat Politècnica de Catalunya (UPC) – BarcelonaTech
Barcelona, Spain
{smartinez,cayala,franch}@essi.upc.edu

Elisa Y. Nakagawa
University of São Paulo (USP)
São Carlos, Brazil
elisa@icmc.usp.br

ABSTRACT

The use of software reference architectures plays a fundamental role in software development, as it could bring several benefits such as providing means to design applications' software architectures with higher productivity and quality. However, many organizations still find scarce the existing empirical evidence about the benefits and drawbacks of software reference architectures. Organizations need such evidence to make informed decisions whether or not to adopt a software reference architecture for the development and maintenance of software applications. In this context, this paper aims to gather evidence on AUTOSAR, a mature and accepted software reference architecture for automotive applications used worldwide by more than 180 organizations. We designed and executed a web-based survey addressed to practitioners with experience in using AUTOSAR. We obtained 51 valid responses. The survey results indicate that the most popular benefits of AUTOSAR are standardization (88%), reuse (80%) and interoperability (51%) whereas its most important drawbacks are complexity (65%), initial investment (59%) and learning curve (51%). The respondents of the survey also gave directions to handle the major drawbacks of AUTOSAR, such as the need of a tool environment to improve its usability and handle its complexity, and the need of more stable releases of AUTOSAR to decrease the cost of migrating among versions.

Categories and Subject Descriptors

D.2.11 [**Software Engineering**]: Software Architectures – *domain-specific architectures.*

General Terms

Documentation, Design, Standardization.

Keywords

AUTOSAR, automotive applications, automotive software development, software architecture, reference architecture, survey, empirical software engineering.

1. INTRODUCTION

Software development for automotive applications has steadily increased over the last decades. In the automotive domain, software is a key area for innovation and development costs. Electronics and software lead over 90% of all innovations and determine up to 40% of a vehicle's development costs, of which 50% to 70% are dedicated for the software of Electronic Control Units (ECU) [5].

Due to the importance of software development for automotive innovation and development costs, the standardization of a software architecture, methodology, software platform, and application interfaces may support to manage growing systems complexity and their integrations, as well as keeping the costs feasible.

Under this scenario, AUTOSAR (AUTomotive Open System ARchitecture) was founded in 2003, and first released in 2005. AUTOSAR is a worldwide development partnership to "establish an open industry standard for the automotive software architecture between suppliers and manufacturers" [12]. The partnership include different types of stakeholders: Original Equipment Manufacturers (OEM), suppliers, tool developers, and new market entrants.

AUTOSAR is a software reference architecture that has become mature and accepted [23]. A software reference architecture is a generic architecture for a class of systems that is used as a foundation for the design of concrete architectures from this class [2]. Due to the success of AUTOSAR in industry, being used by many organizations, we believe that understanding its benefits and drawbacks could help practitioners and researchers to better approach the expectation of adopting software reference architectures in an industrial setting. Our research goal is *to gather evidence of benefits and drawbacks of using AUTOSAR in the industrial practice from different stakeholders involved in its usage*. To get an in-depth understanding of the benefits and drawbacks of AUTOSAR usage for automotive software development, we designed and executed a web-based survey. We obtained 51 valid responses.

The results of this web-based survey could be of interest for researchers and practitioners. On the one hand, for researchers who would like to get insights about the real benefits/drawbacks of this type of software reference architectures in an industrial setting; in order to better shape their approaches for exploiting such potential benefits and mitigating potential drawbacks. On the other hand, results are relevant not only for AUTOSAR practitioners to get directions for improvement of current drawbacks and risks; but also for practitioners in general that can better understand and polish their expectations from a software reference architecture.

In particular, these results may be relevant for other business domains besides automotive software. For instance, this is the idea of the initiative "derive applications" of AUTOSAR, which aims to extend the scope to non-automotive areas [7].

This document is structured as follows. Section 2 provides a background on AUTOSAR. Section 3 shows the research methodology of this empirical study. Section 4 presents the results of this survey. Section 5 discusses limitations of the survey. Finally, Section 6 summarizes the conclusions and future work.

2. BACKGROUND

A car includes a number of ECUs or micro-controllers (μC) modules, most of them dedicated to drive sensors and actuators [9]. For instance, the software than run on an ECU can first read data from the car sensors (e.g., engine speed and the speed that is requested by the driver), and then process such data to control actuators (e.g., changing the amount of fuel or the timing or its ignition). This is only an example of application of the 80 to 100 ECUs that today's luxury-class cars include [13].

AUTOSAR provides a layered component-based software architecture to structure the software for an ECU. AUTOSAR is a software reference architecture with these characteristics [2]:

- It aims to *standardize* the ECU software architectures, aiming at components interoperability.

- It targets *multiple organizations* (e.g., OEMs, suppliers, tool developers and new market entrants) that share the automotive market domain. AUTOSAR is a global standard with 186 partners by March 2015 (91 in Europe, 67 in Asia, 27 in America and 1 in Africa) [14].

- It is a *classical* software reference architecture that was defined when technology, software, and algorithms required for the software architecture of automotive applications had already been tested in practice.

Figure 1 shows that AUTOSAR distinguishes between three main software layers [14]:

- *Application layer:* it consists of AUTOSAR software components that are mapped on the ECU. AUTOSAR software components are atomic software components of type application software components or sensor/actuator software components. All interactions between AUTOSAR software components are routed through the AUTOSAR runtime environment. The AUTOSAR interface assures the connectivity of software elements surrounding the AUTOSAR runtime environment.

- *Runtime environment (RTE):* it provides a communication abstraction by providing the same interface and services whether inter-ECU communication channels are used (e.g., CAN, LIN, FlexRay and MOST) or communication stays intra-ECU.

- *Basic software (BSW):* basic software is the standardized software layer, which provides services to the AUTOSAR software components and is necessary to run the functional part of the software. It does not fulfill any functional job itself and is situated below the AUTOSAR runtime environment. For instance, it is responsible for handling the communication between different ECUs on the electronic buses and the diagnostic services which are read when a car is taken to a repair shop.

Application layer
Runtime environment (RTE)
Basic software (BSW)
ECU-Hardware

Figure 1. AUTOSAR layered ECU component-based software architecture.

At the bottom of Figure 1, we can see the ECU-hardware resources, and how AUTOSAR offer mechanisms for software and hardware independence.

2.1 Related Work

Recent research have addressed several problems while migrating to AUTOSAR by assisting automotive software designers in planning long term development projects based on multiple AUTOSAR meta-model versions [8], and by migrating a partner's specific, legacy models to their AUTOSAR equivalents [22].

Besides AUTOSAR, other automotive software architectures exist. For instance, JasPar (Japan Automotive Software Platform and Architecture) is an industry partnership with the objective to promote automotive software technology and to cut development costs by encouraging Japanese companies to collaboratively develop non-competitive technologies [15]. Another software architecture for smaller systems is presented in [16]. Concerning standards, several complementary and partly overlapping standards with AUTOSAR (e.g., IP-XACT) are reviewed in [10].

Finally, with respect to the benefits and drawbacks of software reference architectures, Angelov et al. conducted a global web-based survey on using software reference architectures [3]. Also, some authors of this paper executed a case study on the benefits and drawbacks of using software reference architectures conducted in an IT consulting company [17]. Despite such research, more evidence should be gathered to be able to aggregate and generalize these results. Since AUTOSAR is a software reference architecture widely used in industry, we believe that understanding its benefits and drawbacks can help in such aggregation goal.

3. RESEARCH METHOD

To capture a snapshot of the current benefits and drawbacks of using AUTOSAR, we performed a web-based survey [24].

We followed the six-step process for surveys defined in [6]. These six steps are survey definition, design, implementation, execution, analysis and packaging.

To ensure rigor and repeatability of our study, and to reduce researcher bias while conducting the survey, we designed a survey protocol. Next subsections briefly present details of such protocol: the research questions of the survey, the target population and sampling, the questionnaire that was devised for data collection, and techniques for data analysis of the survey.

3.1 Research Questions

Based on the aforementioned goal of the study in Section 1, we devised two Research Questions (RQ):

- RQ1: Which are the benefits of using AUTOSAR?

- RQ2: Which are the drawbacks and risks of using AUTOSAR?

3.2 Research Design and Sampling

Our population is the global community of practitioners that use AUTOSAR.

To recruit participants, we advertised the survey at professional meetings, specifically the 6th AUTOSAR Open Conference celebrated in Munich. At this conference we collected some responses in situ and also got some contacts to whom we sent an

invitation to participate by e-mail. Furthermore, we advertised it in two LinkedIn groups ("Autosar" that has around 5,000 members, and "AUTOSAR" that has more than 1,000 members). Finally, we spread the survey over other social networks (e.g., Twitter) indexed by the hashtag #AUTOSAR. We did not advertise it through academic communities, blogs, conferences or workshops, because we targeted practitioners with experience in AUTOSAR.

3.3 Data Collection and Instruments

To devise the instrument to collect the data, we based the questions about benefits and drawbacks and their responses on previous research on software reference architectures [3, 17].

As instrument to collect the data, we decided that an on-line questionnaire was the most convenient, because it allows the collection of data from a large, remotely-located population, which could be used to contact AUTOSAR practitioners.

The questionnaire of this survey was based on two groups of questions.

The first group of questions consisted of two questions about the benefits and drawbacks of AUTOSAR (see Table 1). This group was mandatory to fill. We prioritized its simplicity so that it could be filled out in less than 10 minutes. We believe that the simplicity of these questions was key to get a sufficient number of responses.

Table 1. Group 1 of questions (mandatory).

Id	Question	Options
1	Which are the benefits of using AUTOSAR?*	List of benefits: standardization, facilitation, increased productivity, reuse, reduced development costs, reduced maintenance costs, reduced time-to-market, risk reduction, enhanced quality, interoperability, knowledge repository, improved communication, elaboration of mission, vision and strategy, best practices, novel design solutions, reputation, none, other.
2	Which are the drawbacks and risks of using AUTOSAR?*	List of drawbacks: initial investment, inefficient instantiation, too abstract, term confusion, bad documentation, bad quality, too specific or limiting, learning curve, dependency in AUTOSAR, complexity, none, other.

* Note: These questions were multiple choice, so that the respondent could choose several options. Also, for each choice, the respondent could add a comment.

The second group of questions consisted of personal data about the respondent, such as contact information, his/her company, experience, and so on (see Table 2). This group of questions was optional. We made it optional because some practitioners are reluctant to provide personal data, and we did not want to discourage them.

It is important to note that we provided room to add any comment or observation in both groups of questions to partially mitigate the rigidness of the on-line questionnaire.

The survey was available at http://www.essi.upc.edu/~e-survey/index.php?sid=13916&lang=en. For the survey implementation, execution and analysis, we used an open source tool: LimeSurvey[1]. In order to get more responses, the survey is

---

[1] https://www.limesurvey.org/en/

still open. We encourage the interested reader with experience in AUTOSAR to refer to the previous link.

Table 2. Group 2 of questions (optional).

Id	Question	Options
3	First name and surname	Free text.
4	E-mail	A valid e-mail.
5	Your education area	A list of education areas: automotive, informatics, telecommunications, administration and management, industrial, mathematics, physics, economy, chemistry, statistics, electronics, biology, other.
6	Name of your company	Free text.
7	The role of your company with respect to AUTOSAR	A list of roles: OEM, supplier, tool developer, new entrant market, other.
8	Briefly describe the project in which you have used AUTOSAR	Free text.
9	What was your role in the project? What was your responsibility?	Free text.
10	How many years of experience do you have with AUTOSAR	A valid positive number.
11	Before sending the survey, would you add a comment to help understanding the context of your answers?	Free text.

3.4 Data Analysis

We analyzed the data gathered in each of the categories given as options of the survey. In addition, we gathered several comments as a result of the open questions added. To analyze such comments, we created new categories for refining/polishing the ones given by the survey. These categories were then further discussed and analyzed by the research team to better interpret and describe evidence. Section 4 shows this analysis.

4. RESULTS

We got a total of 51 valid responses[2]. Out of these 51 valid responses, 36 respondents (71%) filled both groups of questions whereas 15 respondents (29%) preferred not to give personal data in the second group of questions.

For the respondents that filled the second group of questions, we had data about their education area, the role of their company with respect to AUTOSAR, and their years of experience with AUTOSAR.

Figure 2 shows the education area of the survey respondents: 13 respondents had an automotive background, 11 respondents studied software engineering or related courses, 9 respondents had academic training in electronic, and 3 respondents had other background. 15 respondents did not reply to this question (i.e., n/a). We can see that respondents had higher education, what

---

[2] The valid responses, of which we removed name, email and company of the participants due to confidentiality issues, are available at http://www.essi.upc.edu/~smartinez/public/responses-WASA15.xls

contribute to a better understanding of AUTOSAR benefits and drawbacks. Also, we can see that AUTOSAR partners look for recruiting professionals with automotive, software and electronic academic training.
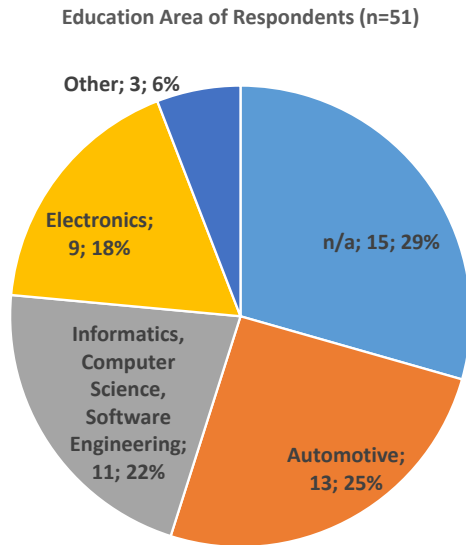

Figure 2. Pie chart with the education area of respondents.

Figure 3 shows a pie chart with the role of the company of respondents with respect to AUTOSAR: 12 respondents worked for an OEM, 10 practitioners for a supplier, 8 respondents are tool developers, 4 participants are consultants, and 2 practitioners belonged to a new market entrant. In this survey, we got representatives for all the types of stakeholders in AUTOSAR.
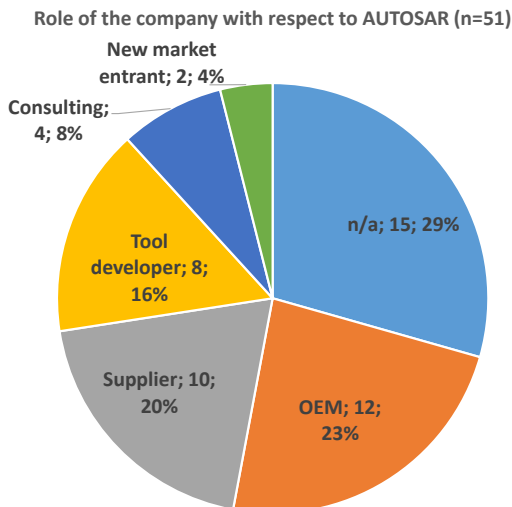

Figure 3. Pie chart with the role of the company of respondents with respect to AUTOSAR.

Figure 4 shows a box plot with the years of experience of the 36 respondents that replied to the second group of questions of the on-line questionnaire. It has six boxes: the first box has all respondents together; the rest of boxes are subsets by the role of the respondents' company with respect to AUTOSAR. In the first box, we can see that there are two respondents with more than 10.5 years of experience in AUTOSAR (extreme cases). The upper quartile is 5 years of experience. The median is 4 years of

experience. The lower quartile is 2.15 years of experience. Finally, the minimum is 0.9 years of experience. We can see that respondents had experience in AUTOSAR by the moment of participating in the survey. Finally, tool developers were the respondents with more experience.
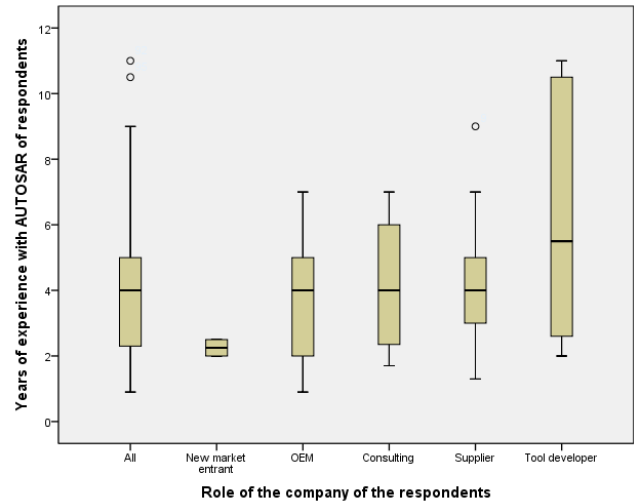

Figure 4. Box plot of the years of experience of respondents.

Next subsections respectively present the results of the survey about the benefits and drawbacks of AUTOSAR (see Figure 5 and Figure 6).

4.1 RQ1: Results on AUTOSAR Benefits

Figure 5 shows the responses about the benefits of AUTOSAR. The X-axis contains the frequency in which respondents mentioned each benefit. The Y-axis represent the options that were given in the on-line questionnaire as benefits.

Next, we explain AUTOSAR benefits and provide some of the comments provided by the respondents in the on-line questionnaire between quotation marks. The benefits are shown in order from the most to the least mentioned one, indicating among brackets the percentage of respondents that mentioned it.

The most mentioned benefit of AUTOSAR was *standardization (88%)*. This is not surprising. Indeed, in its website AUTOSAR is defined as "a de-facto open industry standard for automotive E/E architecture which will serve as a basic infrastructure for the management of functions within both future applications and standard software modules" [14]. This is a relevant benefit, since if a car is compliant with AUTOSAR, the software developed by different stakeholders (e.g., OEM) could be used in many cars, no matter its automotive manufacturer.

Some of the respondents commented that standardization is a benefit "if it does not affect competition". A respondent argued that AUTOSAR stakeholders should "cooperate on standards, and compete on implementation". Finally, s/he explicitly stated that complexity is a "trade-off with novel design solutions". This trade-off refers to the "too specific or limiting" drawback.

The second most popular benefit was *reuse (80%)*. As one practitioner stated, "standardized interfaces allows us to reuse components in different projects". Besides the BSW layer (see Figure 1), reuse in application software can reach up to 80% [19].
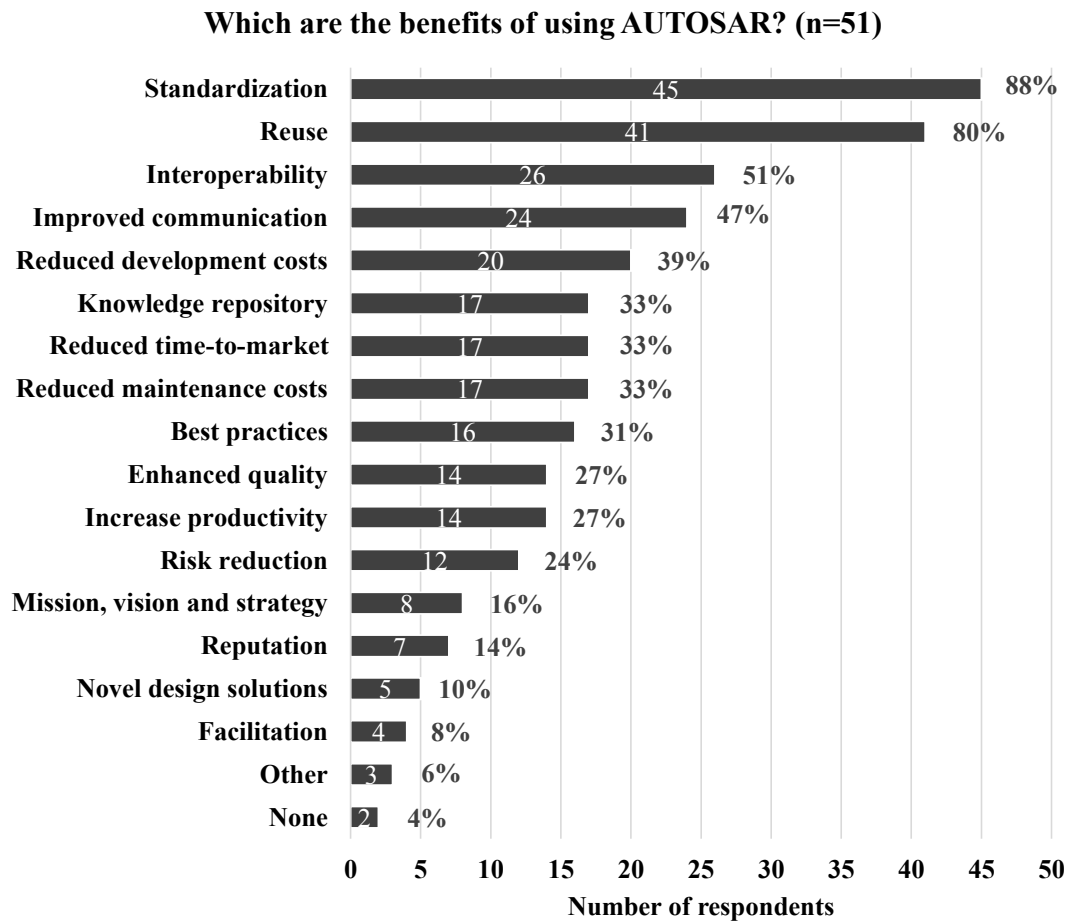
Which are the benefits of using AUTOSAR? (n=51)

Figure 5. Results of the question "Which are the benefits of using AUTOSAR?"

Another practitioner warned that in spite of such reuse, "efforts are often needed, not 100% reuse".

Interoperability (51%) was mentioned as a benefit by half of the respondents. One respondent indicated that it is one of the "goals" of AUTOSAR. Interoperability in AUTOSAR refers to the RTE that acts as a communication center for inter- and intra-ECU information exchange.

The fact that AUTOSAR stakeholders share the same architectural mindset, fosters an *improved communication (47%)*. As one respondent indicated, "people talk the same language".

As one respondent claimed, reuse could lead to "cost and time saving". The results of this survey indicated that *reduced development costs (39%)* is the fifth most popular benefit of AUTOSAR. One practitioner noted that such cost reduction happen "in BSW but also in application software".

AUTOSAR has a lively community that maintains a *knowledge repository (33%)*. Such repository consists of "documents, releases (SVN), and discussions (change management)".

Other benefit related to reuse is the *reduced time-to-market (33%)*. Automotive software can reach the market faster because "component reuse lowers the development time of new products". One practitioner warned that the reuse of a component "reduce time-to-market only if it is already in the standard, otherwise not".

Establishing a standard software architecture helps to *reduce maintenance costs (33%)*.

In a lower extent, respondents supported the following benefits: *best practices (31%)*; *enhanced quality (27%)*; *increase productivity (27%)*; *risk reduction (24%)*; *mission, vision, strategy (16%)*; *reputation (14%)*; *novel design solutions (10%)*; *facilitation (8%)*; *other benefits (6%)*; and *none (4%)*.

Three benefits were written down in the "other" option: "*electronic exchange*", "*scalability* because AUTOSAR was designed from the beginning to handle growing complexity", and "*design flexibility*".

4.2 RQ2: Results on AUTOSAR Drawbacks

Figure 6 shows the responses about the drawbacks and risks of AUTOSAR in the same way as Figure 5.

Below, we explain in descendent order these drawbacks and provide some of the comments given by the respondents in the on-line questionnaire.

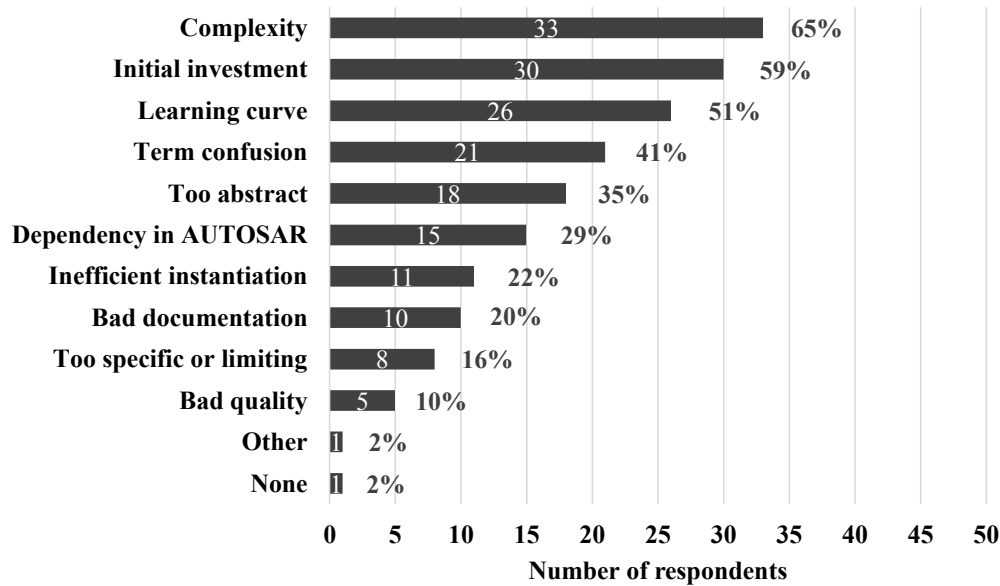**Which are the drawbacks and risks of using AUTOSAR? (n=51)**

Category	Number of respondents	Percentage
Complexity	33	65%
Initial investment	30	59%
Learning curve	26	51%
Term confusion	21	41%
Too abstract	18	35%
Dependency in AUTOSAR	15	29%
Inefficient instantiation	11	22%
Bad documentation	10	20%
Too specific or limiting	8	16%
Bad quality	5	10%
Other	1	2%
None	1	2%

Number of respondents

Figure 6. Results of the question "Which are the drawbacks and risks of using AUTOSAR?"

The most mentioned drawback of AUTOSAR in this survey was *complexity (65%)*. Respondents gave several comments about the consequences of complexity, such as that it "is a tradeoff with increased productivity". They also gave indications where this complexity gets bigger: "large projects with many developers and highly interconnected functionality is where using AUTOSAR becomes very tough".

In the direction of giving suggestions about how to handle complexity, two respondents agreed on the importance of tools to ease automotive software development, e.g., "expertise is needed but tool environment helps. Tools are a must"; "AUTOSAR should be more tool oriented so as to overcome this complexity".

The second most mentioned drawback was *initial investment (59%)*. Due to the characteristics of AUTOSAR, we should not only consider the investment on training personnel on AUTOSAR, but also the "membership fee" to become a partner as organization.

The *learning curve (51%)* to master in AUTOSAR was mentioned by half of the respondents. As one respondent stated: "many engineers have difficulty learning the standard".

Practitioners also face problems with *term confusion (41%)*.

Some respondents found AUTOSAR *too abstract (35%)*. As a solution to overcome abstraction, a practitioner proposed a "tool environment" (as to overcome with complexity).

All the developments based on the standard have *dependency in AUTOSAR (29%)*. Automotive software systems based on AUTOSAR are "statically defined systems". Therefore, new releases of AUTOSAR should consider "looking for backward compatibility".

In a lower extent, respondents indicated the drawbacks below: *inefficient instantiation (22%)*; *bad documentation (20%)*,

however a practitioner indicated that there is "no bad documentation (100,000 pages of documentation), and that such documents are available for the community", hence they may refer to a more digestive or lightweight documentation; *too specific or limiting (16%)*, e.g., "as a design philosophy AUTOSAR is a desirable standard. However AUTOSAR specifies too many things and leaves little latitude for custom components in all layers beneath the application software. This is not a model that all OEMs can work with effectively"; *bad quality (10%)*; *other drawbacks (2%)*, and *none (2%)*.

The drawback that was mentioned in the "other" option was "*repetitive investment*" because "it is hard and costly to migrate to a new AUTOSAR version". This extra cost while migrating was also mentioned by another practitioner: "we just started migrating towards AUTOSAR, and found that even after 10 years, it makes delays and confusion and instead of increasing the quality it reduces it. Also the cost of the tools is high".

5. VALIDITY
This section discusses possible threats to validity in terms of construct, internal and external validity. It also emphasizes the mitigation actions used.

5.1 Construct Validity
Construct validity refers to issues that affect our ability to reflect the constructs under study using adequate instruments [20]. To strengthen this aspect we made sure to perform a rigorous planning of the study and establishing a rigorous protocol. We paid special attention to design our data collection instrument (i.e., the on-line questionnaire) in such a way that it was fully understood by the respondents. We made sure of polishing the instruments with suitable vocabulary that the participants were familiar with. Furthermore, we included specific mitigation actions for evaluation apprehension by ensuring the confidentiality and aggregation of the answers, so the

respondents could freely share their real perceptions. In the on-line questionnaire, we added open questions to let respondents to express the response that better reflected their opinion.

5.2 Internal Validity

Internal validity refers to issues that affect our ability to conclude causal effects between independent and dependent variables [20]. Regarding individuals that participated in the study, there is always the possibility that they forget something or do not explicitly state it when they are asked about. To reduce this risk, we designed the on-line questionnaire in such a way that the respondent must answer all the corresponding questions while s/he could complete the questionnaire at any time, so it gives them the possibility of consulting registries and documentation in case s/he needs to remember something.

Another limitation regarding the participants is that they might not have answered truthfully to the questions. To address this problem, we made participation voluntary and ensured that personal data would be treated confidentially. Furthermore, participants spent personal time on answering the on-line questionnaire. We can therefore assume that those who volunteered to spend time have no reason to be dishonest [9]. Still, there were couple of responses that were removed because it was clear that they were invalid (e.g., just indicating none benefits and none drawbacks, or introducing fake personal data). One reason may be that they just entered to see the questions of the survey.

Furthermore, when using surveys like this, there exists always the threat that respondents tend to be strong supporters or strong opponents of the analyzed technology; thus biasing the results. To reduce this threat, we tried hard to foster most people to participate by attending to an AUTOSAR related conference and explaining them the importance of having the opinion of all of them. In addition, we added in the on-line questionnaire the group of questions about personal data (see Table 2) in order to further contact them in cases where we detect suspicious situations. Most of the respondents replied to these questions.

Also, to reduce the potential researcher bias, several meetings were held among the researchers to discuss the course of the data analysis and the preliminary results.

5.3 External Validity

External validity is concerned with to what extent it is possible to generalize the findings, and to what extent the findings are of interest to other people outside the investigated case [20]. We had a limited number of participants. However, this is due to the fact that our survey targeted a very specific population and required participants with experience with AUTOSAR. The participation of this study (51 participants) compared to other empirical studies in software architecture is similar [1]. In [1], the authors analyze the sampling of four studies with the following participation: 56 participants, 11 software companies, 53 industrial software architects, and 22 students.

We recognize that our results cannot be generalized to other software reference architectures without further work. However, we remark that there exist organizations with similar contexts to AUTOSAR that could benefit from the results of this survey [18]. As Seddon et al. suggests: "if the forces within an organization that drove observed behavior are likely to exist in other organizations, it is likely that those other organizations, too, will exhibit similar behavior" [21]. Thus, we made available our instrument (see Section 3.3) to foster other researchers and practitioners to use them and compare results. We expect that our results strengthen the evidence regarding software reference architectures and encourage others to provide similar evidences that help to mature software reference architecture research and practice.

6. CONCLUSIONS AND FUTURE WORK

As a software reference architecture, AUTOSAR provides a blueprint for developing software architectures for automotive applications. Academics perspective of software reference architecture and its benefits and drawbacks are not always in line with the industry's practice. Therefore, there is a vital need for gathering and disseminating empirical evidence to help practitioners to choose appropriate methods and techniques for supporting the software architecture process [11].

With the goal of supporting organizations that plan to adopt or have adopted a software reference architecture, this paper has addressed the benefits and drawbacks of AUTOSAR. A web-based survey was conducted to analyze how AUTOSAR is perceived by industrial practitioners. We obtained 51 valid responses. This results help to increase the empirical evidence about software reference architecture as follows.

First, this survey uncovered AUTOSAR benefits, being the most popular ones standardization (88%), reuse (80%) and interoperability (51%). With respect to the drawbacks of AUTOSAR, the study revealed mainly complexity (65%), initial investment (59%) and learning curve (51%).

Second, survey respondents gave directions to handle the major drawbacks. Results about the drawbacks of AUTOSAR show that experience reports about negative experiences are also needed.

With respect to complexity, they remarked that AUTOSAR should be more tool oriented to improve its usability. Several initiatives are already working on making AUTOSAR less complex and improving the tool environment, e.g., the AUTOSAR Tool Platform (Artop) [4].

Furthermore, the repetitive investment while migrating to a new release of AUTOSAR was uncovered as a drawback of software reference architectures. This drawback was not reported in previous studies of software reference architectures [3, 17]. It becomes necessary to balance between stability and updates of AUTOSAR, since some practitioners find that there are too many releases. This leads to a costly migration to new AUTOSAR versions. Recent research have addressed this issue by assisting automotive software designers in planning long term development projects based on multiple AUTOSAR meta-model versions [8], and by migrating a partner's specific, legacy models to their AUTOSAR equivalents [22].

Third, the results of this survey can be used as a first step to analyze how other software reference architectures with the aim of standardization could affect organizations in different business domains, i.e., non-automotive.

As future work, we aim to obtain more responses. Besides, we plan to analyze the responses from the perspective of different stakeholders (e.g., OEMs and suppliers) as well as different tiers

(e.g., Tier 1 and Tier 2). This would indicate which problems and drawbacks should be tackled first in which step of the AUTOSAR methodology.

Finally, we plan to represent and aggregate the empirical evidence of this survey with the benefits and drawbacks reported in other studies about software reference architectures [3, 17].

7. ACKNOWLEDGMENTS

8. REFERENCES

[1] Ameller, D., Galster, M., Avgeriou, P. and Franch, X. 2015. A survey on quality attributes in service-based systems. *Software Quality Journal*. (Feb. 2015), 1–29.

[2] Angelov, S., Grefen, P. and Greefhorst, D. 2012. A framework for analysis and design of software reference architectures. *Information and Software Technology*. 54, 4 (2012), 417–431.

[3] Angelov, S., Trienekens, J. and Kusters, R. 2013. Software reference architectures-exploring their usage and design in practice. *Software Architecture* (2013), 17–24.

[4] Artop - AUTOSAR Tool Platform User Group: *http://www.artop.org/*. Accessed: 2015-03-11.

[5] AUTOSAR 2013. AUTOSAR — The Worldwide Automotive Standard for E/E Systems. *ATZextra worldwide*. 18, 9 (Oct. 2013), 5–12.

[6] Ciolkowski, M., Laitenberger, O., Vegas, S. and Biffl, S. 2003. Practical experiences in the design and conduct of surveys in empirical software engineering. *Empirical Methods and Studies in Software Engineering*. (2003), 104–128.

[7] Development Partnership AUTOSAR to extend scope of applications to non-automotive areas: 2011. *http://www.autosar.org/fileadmin/files/media_release/Development_Partnership_AUTOSAR_to_extend_scope_of_applications_to_non-automotive_areas_EN.pdf*. Accessed: 2015-03-11.

[8] Durisic, D., Staron, M., Tichy, M. and Hansson, J. 2014. Evolution of Long-Term Industrial Meta-Models -- An Automotive Case Study of AUTOSAR. *2014 40th EUROMICRO Conference on Software Engineering and Advanced Applications* (Aug. 2014), 141–148.

[9] Eklund, U. and Bosch, J. 2014. Architecture for Embedded Open Software Ecosystems. *Journal of Systems and Software*. (2014).

[10] Engineering Standards beyond AUTOSAR: *http://www.autosar.org/fileadmin/files/events/2013-11-13-6th-autosar-open/AUTOSAR_Engineering_Standards_Uni_Paderborn_Mueller.pdf*. Accessed: 2015-03-11.

[11] Falessi, D., Babar, M.A.M., Cantone, G. and Kruchten, P. 2010. Applying empirical software engineering to software architecture: challenges and lessons learned. *Empirical Software Engineering*. 15, 3 (2010), 250–276.

[12] Fürst, S. 2009. AUTOSAR – A Worldwide Standard is on the Road. *14th International VDI Congress Electronic Systems for Vehicles* (2009).

[13] Future Vehicle Software Architectures - Fraunhofer ESK: *http://www.esk.fraunhofer.de/en/projects/adaptives_bordnetz.html*. Accessed: 2015-03-09.

[14] Home : AUTOSAR: *http://www.autosar.org/*. Accessed: 2015-03-09.

[15] Jaspar WebSite - Jaspar HOME english: *https://www.jaspar.jp/english/index_e.php*. Accessed: 2015-03-09.

[16] Krdzalic, G. and Driss, A. 2014. Software Architecture Without Autosar. *Auto Tech Review*. 3, 4 (Apr. 2014), 28–31.

[17] Martínez-Fernández, S., Ayala, C.P., Franch, X. and Marques, H. 2013. Benefits and drawbacks of reference architectures. *Software Architecture. 7th European Conference, ECSA 2013, Montpellier, France, July 1-5, 2013. Proceedings* (2013), 307–310.

[18] Martínez-Fernández, S., Ayala, C.P., Franch, X., Marques, H. and Ameller, D. 2014. Towards Guidelines for Building a Business Case and Gathering Evidence of Software Reference Architectures in Industry. *Journal of Software Engineering Research and Development (JSERD)*. 2, 7 (2014).

[19] Overview on AUTOSAR Development: 2013. *http://www.autosar.org/fileadmin/files/events/2013-11-13-6th-autosar-open/AUTOSAR_Keynote_PSA_Salessy.pdf*. Accessed: 2015-03-11.

[20] Runeson, P. and Höst, M. 2009. Guidelines for conducting and reporting case study research in software engineering. *Empirical software engineering*. 14, 2 (2009), 131–164.

[21] Seddon, P.B. and Scheepers, R. 2011. Towards the improved treatment of generalization of knowledge claims in IS research: drawing general conclusions from samples. *European Journal of Information Systems*. 21, 1 (Apr. 2011), 6–21.

[22] Selim, G.M.K., Wang, S., Cordy, J.R. and Dingel, J. 2013. Model transformations for migrating legacy deployment models in the automotive industry. *Software & Systems Modeling*. 14, 1 (Jul. 2013), 365–381.

[23] Wiesbaden, S.A.M. "AUTOSAR has Become Mature and Accepted." *ATZextra worldwide*. 18, 9, 13–15.

[24] Wohlin, C., Höst, M. and Henningsson, K. 2003. Empirical research methods in software engineering. *Empirical Methods and Studies in Software Engineering*. (2003), 7–23.