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Transparency and Contracts: Continuous Integration and Delivery in the Automotive Ecosystem

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ABSTRACT

Most of the innovation in automotive is nowadays coming from electronics and software. The pressure of reducing time to market and increasing flexibility while keeping quality are leading motivations for these companies to embrace system-wide Continuous Integration and Delivery (CI&D), which in the scope of complex automotive value-chains, implies inter-organizational CI&D.

In this paper, we investigate the challenges and impediments posed by inter-organizational CI&D in the automotive domain, i.e. continuous software development that involves agile interaction between an OEM (the car manufacturer) and its software suppliers. In particular, we focus on *legal contracts* that regulate the agreements between these companies and *transparency* intended as the degree/level of information that is shared between the various companies in the value-chain. The main findings of this study show that (i) inter-organizational transparency is considered positive but not a necessary condition for inter-organizational CI&D, (ii) transparency has positive effects on information sharing among different companies, and (iii) legal contracts are an impediment for inter-organizational CI&D. The results of the study provide useful insights for practitioners that work in similar settings. In addition, the identified challenges and impediments define a research agenda for researchers.

KEYWORDS

Continuous integration and delivery, transparency, legal contracts, information sharing, automotive, interview survey

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1 INTRODUCTION

The automotive industry is rapidly changing, driven by needs of electric/hybrid cars, autonomous driving, and connected cars. At the same time, new major players are emerging in the field, like Google[1], Apple[2], Tesla, and Uber, while Original Equipment Manufacturers (OEMs) are increasingly turning into software companies. Historically, software was introduced in cars to optimize the control of the engine. Today, according to industry experts[3], 80% to 90% of the innovation in the automotive industry is based on electronics, a big part of which is software [22].

Traditionally, automotive system development is characterized by a complex supply-chain. The OEM relies on a large number of suppliers to produce parts of the vehicle, including electrical and software components. These components are integrated by the OEM with a growing amount of in-house development. This means that the knowledge and competence of building a car is spread across an ecosystem composed of several different companies, each with potentially different internal organizations, objectives, competences, constraints, cultures, languages, and geographical locations.

To manage this complexity, the V-model[4] is the de-facto development method in the automotive domain as also implicitly suggested by the ISO 26262 functional safety standard [17]. Consequently, the overall development organization is split in different groups, both by abstraction and competence (e.g. top level requirements, architecture, software development, mechanical parts). This can cause a silo effect that hinders information sharing and synergy.

Due to an increasing market demand [34] and the success of agile methodologies [27], large-scale system development organizations adopt agile practices [18] such as continuous integration and delivery (CI&D), which promise shorter time to market and improved quality [34]. OEMs in particular, do expect increased flexibility and shorter cycle times. However, in order to fully benefit from these approaches, OEMs need to apply them beyond the scope of individual teams, towards the scope of the complete automotive system, and to some extent even across organizational boundaries in their (software) value-chain. According to Hosseini et al. [15], it is crucial to understand the intended degree of information to be shared between partners in the value-chain, especially with respect to accountability, openness, and efficiency [3]. Hosseini et al. refer to this as *transparency* and note that the crucial aspects for decision

[1]https://www.google.com/selfdrivingcar/
[2]https://en.wikipedia.org/wiki/Apple_electric_car_project
[3]https://tinyurl.com/y9jnoupd
[4]Originally developed for the defense domain - www.v-modell-xt.de

making are information accessibility and availability [15, 47]. To our knowledge, this critical perspective of transparency and legal contracts has not been applied to inter-organizational CI&D.

In this paper we investigate challenges and impediments of inter-organizational CI&D in automotive system-development , i.e. the collaboration between an OEM and one or more suppliers, where contributions from more than one organization are continuously integrated and compiled into a potential delivery to end-users. Specifically, we focus on *legal contracts* that regulate the agreements between these companies and *inter-organisational transparency* intended as the degree/level of information that is shared between the various companies involved in the development and its associated value-chain. Our study addresses the following research questions:

- *RQ1: What are risks and/or benefits of increasing transparency in an inter-organizational CI&D setting?*
- *RQ2: (How) can sufficient information be provided in inter-organizational CI&D collaborations?*
- *RQ3: Are contracts an impediment for scaling CI&D across company boundaries?*
- *RQ4: Are industry-wide standards and processes shared among organizations an enabler for inter-organizational CI&D?*

To give an answer to these research questions we performed semi-structured interviews within Volvo Cars and one of their larger suppliers in the context of a pilot project within Volvo Cars. This pilot project is experimenting a more open and transparent way of working between these two companies. Thus, this pilot project is an ideal setting for investigating the effects of changing the way of collaborating between OEMs and suppliers. The pilot project is a large and complex project with over 200 engineers and developers. In an attempt to reduce the complexity, developers from both companies work in the same office space, and they are organized in about 30 different agile teams. The main findings of our study are:
RQ1 - Inter-organisational transparency is not a necessary condition for inter-organizational CI&D but considered as positive for various reasons. While strategies exist that facilitate information sharing across organizations, the automotive industry experiences difficulties to share information, manage responsibilities, and intellectual properties at the pace required for CI&D.
RQ2 - Transparency has positive effects on increasing information sharing among the members of the project that belong to different companies. However, transparency as such does not help providing a holistic project overview. Finally, overload of information is unlikely to be considered a problem.
RQ3 - In their current form, contracts are an impediment for inter-organisational CI&D; however, they also help facilitating negotiations between different organizations.
RQ4 - Industry-wide standards and processes and open source initiatives are seen as positive for promoting collaboration, knowledge sharing, and communication.

Note, that it is quite usual in the automotive software development to share code from different partners (typically: encrypted binary code). We leave the challenges related to these aspects, such as product liability, for future work.

The paper is organized as follows. Section 2 defines the context of the study. Section 3 presents related works. Section 4 describes the research methodology we followed in order to give an answer to the research questions. Section 5 presents the results of the study. Section 7 discusses the main findings. The paper concludes in Section 8 with final remarks and directions for future work.

2 CONTEXT OF THE STUDY

This work is carried out in the context of the *Next-Generation Electrical Architecture (NGEA)* and *Next-Generation Electrical Architecture - step 2 (NGEA2)* projects [1], coordinated by Volvo Cars. The projects investigate (i) the transition of Volvo Cars towards CI&D, (ii) new business models and innovative ways of working within the automotive value-chain, and (iii) vehicles as part of a system of systems. In this paper we mostly focus on point (ii) and its impact on (i). With the increasing transformation of OEMs into software companies, software engineering competences become increasingly crucial.

In this paper, we refer to software-related, inter-organizational collaborations between automotive suppliers and manufacturers (the OEMs) as *automotive ecosystem*. Perceived as an ecosystem, the current automotive industry can be characterized as *closed*, with strict organizational boundaries, stiff processes, established business models, and a straightforward value creation [4]. Yet, it relies on complex supplier networks and strong dependence on hardware and software development [21].

Nowadays, a vehicle is a *driving software package* as compared to the vehicles of not even ten years ago. Software, instead of hardware, has become the differentiating factor [4, 6, 32, 45] between companies and their products. This evolution of the automotive industry creates new challenges regarding software integration, development, deployment, and maintenance. Thus, its development needs to support the related integration and evolution over time [6, 19, 35]. The increasing number of stakeholders involved in the software development projects imposes additional challenges to the architecture teams, since the software design cannot be controlled, or even understood, in detail by a single group any more.

Key stakeholders in the automotive value-chain are classified as OEMs (e.g. Volvo Cars) and their suppliers (Tier-1 and Tier-2). In general, an OEM is the coordinator and platform owner in the automotive ecosystem [23]. Tier-1 suppliers are considered as direct suppliers to OEM and Tier-2 companies are a second level of suppliers, indirect to the OEM and directly connected to Tier-1.

Therefore, OEMs experience heavy reliance on external developers and subcontractors; this complicates coordination throughout the entire development process. Expensive communication and coordination delays during integration are results of outsourcing significant parts of development to suppliers.

The software engineering process traditionally follows the V-model, where development at the level of components is parallelized among the different suppliers, and internal in-house development. The degree of parallelism can easily reach level 50 (i.e. 50 parallel developments). Once the collaboration between the OEM and its suppliers is regulated by contract, parallel developments start by signing a contract and after months the large amount of externally developed software comes back to the OEM to be integrated as black-box functionality [6]. This leads to a challenging, complex, and sometimes chaotic integration. At this stage many misunderstandings, conflicting interpretations, wrong assumptions, etc. are discovered. Consequently, contract relations between the OEM and the suppliers might slow down the inter-organizational CI&D.

In order to avoid such integration problems, automotive software development increasingly embraces continuous integration. Changes are implemented, locally tested, and then integrated into a main branch with the goal to obtain feedback from system level tests. This way of working is now widely used by in house software teams that are working on software components. Through submitting small changes early and often as well as fixing potential integration problems directly, quality and cycle time of changes can be improved. But in order to benefit from these aspects on a system level, continuous integration from many teams need to be considered in a hierarchy of sub-systems. In addition, software components that are developed in house often depend on other software components (e.g. basic software, runtime environments), developed by suppliers. Thus, it becomes increasingly important to understand how continuous integration can be supported when involving external organizations.

3 RELATED WORKS

Continuous Integration and Delivery: CI is a development practice that assumes that developers frequently commit their new code into a shared repository. While there is rich literature on how to implement and setup small-scale CI for a project (e.g. [13, 33]), there is lack of scientific support for how to scale such setups and how to deal with involved hardware and complexities in embedded software [10]. There are, however, works that report on challenges with scaling of continuous integration [37, 39] as well as with the applicability of agile approaches in the embedded domain [11].

Related to Continuous Integration are Continuous Delivery and Continuous Deployment. Continuous delivery is often referred to as "a software development practice in which the software is kept in a state that, in principle, it could be always released to its users" [16]. In contrast, Continuous Deployment would require to not only deliver the software, but also to deploy it into the user's runtime environment. Thus, Continuous Deployment becomes important when considering "over the air" updates to end-users. Differently, our work focuses on the continuous delivery between suppliers and OEM, since we argue that this is the natural consequence of an OEM embracing inter-organizational continuous integration.

Rissanen and Münch [36] addressed the challenges for companies in the B2B domain that are making the transition towards continuous delivery and identified key aspects in technical, procedural, and customer areas. While this study provides relevant insights, it does not take into account the challenges involved in embedded and autonomous systems.

Transparency between actors in software ecosystems: One important aspect in our interviews has been the contract between these parties and their requirements with respect to time and functionality. Not surprisingly, Requirements Engineering (RE) practice in traditional proprietary software projects (as e.g. described in [38, 40]) differs significantly from the way requirements are handled in open source projects, where requirements are post-hoc assertions of functional capabilities and included into the system feature-set after their implementation [44].

Transparency and an emergent collaboration among stakeholders play a major role in driving requirements discussion and decision-making. To the best of our knowledge, however, research has so far mainly investigated emergent developers [14, 31, 42] and emergent knowledge [46], while only few and more recent works exist that start to investigate the effect of emergent contributors on requirements [26], across organizations [24, 28], and its implications with respect to transparency [8, 15]. We consider this an important research direction, since stakeholders with in-depth domain knowledge, the implicit knowledge about customer needs, their business domain and the system's environment [9], must participate even when they span team- or geographic boundaries [5]. In line with our findings, open communication channels have shown their value for building communities around *healthy* ecosystems [20]. However, our results indicate that this transparency and information sharing needs to be carefully balanced: when planning transparency, one should specifically understand stakeholders of information, as well as its usefulness, quality, and meaningfulness [15].

4 RESEARCH METHOD

This section describes the research method used to address our research questions. Our data collection is based on semi-structured interviews. The interview protocol follows the seven-stages approach by Kvale & Brinkmann [25], which covers preparation, execution, and reporting. The seven stages are: Thematising, Designing, Interviewing, Transcribing, Analysing, Verifying, and Reporting.
Thematising: This phase decides on the purpose and subject matter, as well as the methods to be applied. In our case, the purpose of the interview survey is to require in-depth information on the topics of CI&D and Transparency in the automotive industry.
Designing: This phase takes care of designing the seven stages of the approach specifically for the study. The structure of the interview survey, transcribing details, analysis protocol [43], verification, and reporting are discussed with each interviewee in detail, along with the request for permission to record and transcribe.
Interviewing: The interview has been structured as a semi-structured interview where open questions guide the interview process towards a list of goals that need to be achieved in the interview. Semi-structured interviews are very suitable for exploratory research [41] like ours. We prepared an interview guide[5] that organizes the interview in three categories of questions: introduction, main part, and cool-off. The *introduction* is meant to create context/background, and to provide and maintain an informal and interactive atmosphere. The *main part* of the interview is aimed at the actual research. The questions aim to guide the interview, but be dynamic and interactive at the same time. This dynamic and interactive nature of interviewing is useful for exploration and development of interesting and unexpected ideas brought up by the interviewees, which are less possible with other (more structured) methodologies, such as questionnaire surveys. At the end of the interview, or *cool-off*, we give time to each interviewee to ask some questions about the topics: these could be topics or themes that are not mentioned in the interview or could be important for the research. We selected the candidates to be interviewed within the pilot project by trying to cover different expertise and by selecting

[5]https://www.dropbox.com/s/esnehg0iz7ekksa/InterviewGuide.pdf?dl=0

people that are knowledgeable about the topic. An overview of the selected interviewees' information can be found in Table 1; the last column reports the years of industry experience in the current role and, if applicable, the total number of years of experience.

No.	Company	Role within company	Exp. in years
1	Volvo Cars	Project Manager RFQ project	4+ (20+)
2	Volvo Cars	Software Developer	2 (3)
3	Volvo Cars	Director of Strategy and Concepts	2+ (26)
4	Tier-1 supplier	Chief Engineer	2.5 (17)
5	Tier-1 supplier	System Lead	10+ (18)
6	Tier-1 supplier	Software Configuration Manager	4
7	Tier-1 supplier	Open Source and Community Manager	<1 (28)
8	Tier-1 supplier	Chief Executive Officer	10+
9	Tier-1 supplier	Product Manager	3 (13)
10	Volvo Cars	Electrical System Architect	2.5 (19)

Table 1: Overview of interviewees

Transcribing: Analyzing the interview results requires to transcribe the interview in a clear and precise manner. Interviews, transcripts, analysis, and coding are in English.
Analysing: For the analysis of the interview results, a protocol is applied to code the interview transcripts, retrieve useful information and analyze it for the research. This is done by using the method explained by Saldana [43]. The transcript is divided into parts that are smaller and easier to code. This could be words, phrases, paragraphs or sections. The goal of this analysis is to find keywords or uncover themes that can be of value for the research. The findings are managed in the coding section of a qualitative research tool, Atlas.ti[6]. This tool is used to manage quotations and codes of transcripts. The quotations and codes describe the train of thoughts of the interviewees. This is used to organize each interview into datasets and to help supporting or negating propositions and research questions. All information that was relevant for the research was submitted as a quotation and connected to a code, including information that was not a direct answer to a research question or proposition. In order to group the codes, we have formulated a set of propositions that are then confirmed or negated by analysing the data collected through the semi-structured interviews we performed. The propositions aim at helping eliciting the different facets of transparency and contract-based collaboration, and are based on knowledge acquired in numerous meetings with Volvo Cars, with many suppliers within the NGEA and NGEA2 projects, and in our multi-annual and established collaboration with these companies. This entire process made it easy to group all relevant quotations in an overview and to create a selective dataset. This dataset was then further analysed to retrieve the answers on the questions of every interviewee. In addition, the dataset provides extra information that could benefit the findings for the specific question. This could be extra background information, another perspective on the question or maybe start a new discussion.

[6]https://atlasti.com

The results of this process are captured in the findings, the answers to the research questions and the propositions.
Verifying: Verification activities include ascertaining the validity, reliability and generalizability of the findings. *Validity* refers to the question if the study investigates what was originally intended to [25]. The purpose of the interviews is to gather from the interviewees insights and knowledge on the topics. The interview is semi-structured and the questions are intended as guidelines throughout the interview, so to safeguard validity. By applying the systematic and structured approach by Kvale and Brinkmann [25], we aim to safeguard the *reliability* of conducting, analyzing and reporting the interview process. Further threats to validity, and how we mitigate them, are discussed in Section 6.
Reporting: In this paper we report the results of the analysis and we answer our research questions. Even though the study is performed within a single OEM, the supplier company collaborates with many other OEMs in a very similar way. This makes the results of our study useful, and potentially generalizable to the automotive domain. Moreover, the way automotive OEMs work with suppliers is common to many other domains, e.g. aviation. We expect that our results will be valuable also outside the automotive domain. Further studies, however, are needed, as discussed in Section 6.

5 RESULTS

In Sections 5.1 through 5.4 we present the findings related to RQ1 through RQ4, respectively, along with some illustrative quotes from the transcripts. Figure 1 shows an overview of the results and findings. The reason of having boxes of different colours, i.e., the distinction among software-dependent (direct), software-driven (indirect), and software-agnostic, will be explained in the discussion section (Section 7). Finally, in Section 5.5 we answer the RQs by summarizing the findings and highlighting the related challenges.

5.1 Research Question 1

The propositions we defined for RQ1 (i.e. *What are risks and/or benefits of increasing transparency in an inter-organizational CI&D setting?*) are:

- *Proposition 1:* Increasing inter-organisational transparency of information is a necessary condition for inter-organisational CI&D
- *Proposition 2:* Increased inter-organisational transparency of information is considered positive
- *Proposition 3:* Typical risks of inter-organisational transparency (e.g. distance, tooling, IP) can be managed in practice.
- *Proposition 4:* A more open transparency policy improves the quality of the project and its results.

5.1.1 Proposition 1: Increasing inter-organisational transparency of information is a necessary condition for inter-organisational CI&D. The interviewees were asked how important inter-organisational transparency is for CI&D and whether it is a necessity to pursue. The interview results **reject the proposition**. Inter-organisational transparency has been identified as very important to pursue in

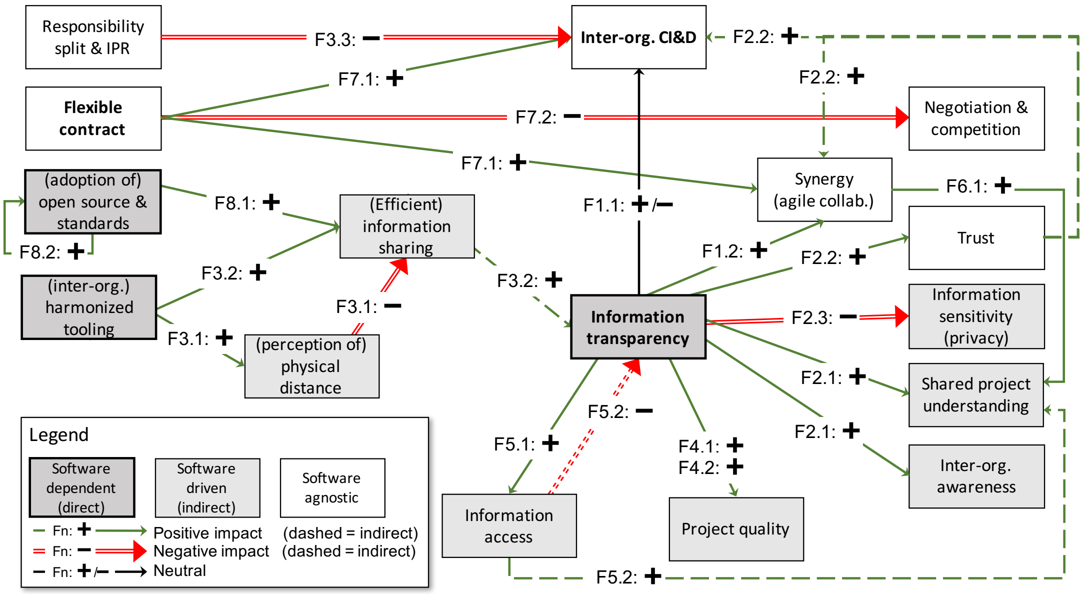

Figure 1: Illustration of results and findings

general, but not a necessity for inter-organisational CI&D. This answer to proposition 1 derives from the following findings[7].

F1.1: Important, but not necessary. The interviewees agree that information transparency and inter-organisational CI&D are related, but also independent and successful as such, e.g. inter-organisational CI&D without full transparency:

> *"Transparency is super important, but not deeply related to CI&D. [...] I don't find the logic relationship between the topics [...]"* (Project manager RFQ project, Volvo Cars)

F1.2: Beneficial for synergy. The interviewees agree that the combination of inter-organisational transparency and CI&D produces synergy effects such as efficiency, trust, and mutual understanding.

5.1.2 Proposition 2: Increased inter-organisational transparency of information is considered positive. Increasing inter-organisational transparency can be perceived differently by different stakeholders. The interviewees were asked how they considered the increase of transparency across companies, and how they perceived business and personal relationships among companies.

The interview results **support the proposition**: the increase of information transparency is generally considered positive. This answer to proposition 2 derives from the following findings.

F2.1: Increased transparency is positive. All the interviewees experience positively the increase of inter-organisational transparency between companies and employees, for both business and personal relationships:

> *"Transparency and CI&D really give a benefit to Volvo Cars in the future reuse of assets, knowledge and experience."* (Software developer, Volvo Cars)

The interviewees experience positive effects in terms of more awareness of the project status and increased mutual understanding. In particular, Volvo Cars employees found sharing a workplace with developers of the supplier especially effective for creating a shared mental model.

F2.2: Trust is increased. The increase of transparency of information increases trust, too, on two levels. Firstly, increased trust between stakeholders improves collaboration and communication. Secondly, the trust gained in past projects is inherited in future projects as well. However, it is hard to understand whether trust is increased because of working in the same office or because of transparency. This should be further investigated.

F2.3: Some information is sensitive. It is important to identify which kind of information should be shared.

> *"[...] when you are completely transparent you also have to treat that information in a sensitive way."* (Product Owner, Tier-1 supplier)

Some interviewees argue that there will be always some information that should not be shared:

> *"[...] they [Volvo Cars] still keep 5% information for themselves such as business-critical information (future plans for example). But they are getting more and more open on that as well."* (Chief Engineer, Tier-1 supplier)

Despite this tendency to more openness, the customer does not want or need to know everything, because this might create unnecessary stress:

> *"There is a lot of information and there is a risk with this amount of information. People will jump to conclusions when they see some bad numbers somewhere or something that is not happening."* (System Lead, Tier-1 supplier)

5.1.3 Proposition 3: Typical risks of inter-organisational transparency (e.g. distance, tooling, IP) can be managed in practice. This proposition challenges the interviewees to critically evaluate the level of difficulty to share information across companies. In particular, the interviewees were asked about the difficulty to share information and the role of physical distance. The pilot project we

[7] We use the notation F$x.y$ to refer to y-th finding of proposition x.

are investigating (collaboration between Volvo Cars and a supplier) is perceived as a complex project by both companies.

The findings **partially support the proposition**. Tooling and inter-organisational transparency (i.e. reducing physical distance, inter-organisational information sharing) reduce the complexity of a project. However, the automotive industry experiences difficulties to share information, and manage responsibilities and IPR. This answer to proposition 3 derives from the following findings.

F3.1: Reducing physical distance is beneficial for efficiency. The interviewees agreed that reducing the physical distance among project members is the ideal situation for information sharing, thanks to shorter feedback loops. The new way of working introduced in the pilot project further enables both developers and management staff to share information more efficiently.

However, alternative solutions to sharing the same physical working environments might be also conceived:

> *"It is always better that you can sit alongside each other. But it is a bit of generation question also. There are a lot of useful tools today, for example, Skype or Lync [...] the younger people [...] are used to, thanks to online gaming and such [...] It will be feasible and possible to work even though you are placed in different companies or countries. I don't think that will be a big issue in the future."*
>
> (Electrical System Architect, Volvo Cars)

Moreover, it remains difficult to merge different organisations and cultures:

> *"The change in culture or workplace can be either positive or negative for current or new team members. This is important to keep in mind when you merge organisations."*
>
> (Chief Engineer, Tier-1 supplier)

F3.2: Tooling can support information sharing. The tooling used for sharing information between developers or management staff is also a crucial factor for efficient information sharing across, but also within, companies. The interviewees are positive about the tools and their supportive role in the project and agree that it reduces its complexity. However, there is still room for improvements and open source seems to be an attractive direction.

> *"Unfortunately, we are not there yet, because globally they have chosen other tools which don't support CI&D in my opinion. So they have chosen proprietary or other tools that are restricted, so definitive the company should embrace the open source tools that are available."*
>
> (System Lead, Tier-1 supplier)

F3.3: Managing responsibilities and IPR. The automotive ecosystem (i.e. the cross-organizational collaboration to develop software) has to deal with safety-, legal-, and responsibility issues. Therefore, it is extremely difficult to manage responsibilities (responsibility split) and IPR, for hardware and software. This is seen as an impediment and/or challenge for inter-organisational CI&D.

5.1.4 Proposition 4: A more open transparency policy improves the quality of the project and its results. This proposition is developed to investigate whether the quality of the project results benefit from a more open transparency policy across companies. In particular, the interviewees were asked about the effects of this policy on the project and its results.

The findings **support this proposition**: the quality of the project and its results improve thanks to a more open transparency policy across companies. This answer to proposition 4 is deduced from the following findings.

F4.1: Overall project quality is increased. The interviewees were unanimous on the positive effects of increased transparency on the quality of the project and its results. The quality improvements are already visible in the early stage of the project and they are confident on the improvements in the long term. An open transparency policy is positive for quality control because of mutual understanding of the project status and for gain in efficiency. Thanks to customer involvement, supplier employees also experience a healthy pressure that leads them to a higher quality level.

F4.2: Short feedback loops benefit project quality. More open transparency policies allow project members to have shorter feedback loops and consequently to work more efficiently.

5.2 Research Question 2

The propositions we defined for RQ2 (i.e. *(How) can sufficient information be provided in inter-organizational CI&D collaborations?*) focus on these aspects:

- *Proposition 5:* Project members have sufficient information to perform their activities
- *Proposition 6:* Information overload (in terms of frequent exchange) is unlikely to be considered a problem, if the exchanged information is precise.

5.2.1 Proposition 5: Project members have sufficient information to perform their activities. This proposition challenges the interviewees to critically evaluate information, sent and received, among project members. They were asked what kind of information is (not) shared, if they have sufficient information available to perform their activities, and how this compares to other projects.

The findings **partially support this proposition**. On one side project members have sufficient information available for their activities, on the other side they are missing a holistic project overview. This answer to proposition 5 is deduced from the following findings:

F5.1: Project members have sufficient information. Both Volvo Cars and the supplier state that they have sufficient information available from both companies to perform their activities:

> *"Yes, I believe we have access to all information that is available."* (Chief Engineer, Tier-1 supplier)

Information shared between project members includes source code, project information, and time planning. Commercial information is not shared among project members. This information contains strategic decisions, estimations, and third-party agreements. The increased transparency across companies results in much more information than traditional projects, but equal or a bit more than agile projects.

F5.2: A holistic project overview is needed. The interviewees expressed that they miss an overview of their contribution in the product and in the overall project:

> *"We have close to 30 different SCRUM / AGILE teams. To get status from one of those in some kind of report, it would take you the whole day just to get the information you need. Then it will take you the whole next day to put it together*

> *in some kind of report if you try to do it in any traditional way."* (System Lead, Tier-1 supplier)

They further agree that understanding their contribution in a holistic picture could benefit all stakeholders, because the involvement can increase project efficiency and quality.

5.2.2 Proposition 6: Information overload (in terms of frequent exchange) is unlikely to be considered a problem, if the exchanged information is precise. We assumed that information overload could occur because of increased transparency between companies. This proposition was developed to challenge project members on how they experience information sharing. Interviewees were asked what kind of information is (not) shared, if it is more or less information than other projects, and if they experienced information overload.

The interview results **partly reject the proposition**: information overload is a risk that can be mitigated through precise information. This answer to proposition 6 is deduced from F5.2 and the following finding F6.1:

F6.1: Understanding thanks to collaboration. *Information precision* is information sharing where supply and demand of information correspond. *Information overload* is information sharing where the receiving organisation receives more information than absolutely necessary. All the interviewees argued that information overload was not seen as a problem or risk.

Thanks to clear collaboration, there is a shared understanding of the information, which should be supplied or demanded by a stakeholder. This naturally contributes to information precision.

5.3 Research Question 3

We defined the following proposition for RQ3 (i.e. *Are contracts an impediment for scaling CI&D across company boundaries?*):

- *Proposition 7:* Strict contract-based collaboration can be seen as an impediment for inter-organisational CI&D.

During the interview survey, the interviewees were asked about the role of the contract when looking at information sharing and inter-organisational CI&D. During our study it became clear that information sharing is seen as a crucial factor for inter-organisational collaboration. A contract regulates traditional project setups where the customer defines a list of requirements and the supplier has to fulfil it within a given time frame and budget. The automotive industry is traditional and relatively closed. It however emerges that it is changing towards more open collaborations, participation in open-source projects, and becoming a software-intensive sector.

The interview results **support the proposition**: a strict contract-based collaboration is an impediment for inter-organisational CI&D. This answer to proposition 7 is deduced from the following findings.

F7.1: Flexible contracts favour inter-organisational collaboration. The interviewees share the opinion that a more open (or flexible) contract would be healthier for the project and benefit inter-organisational collaboration:

> *"I would say that in this case Volvo Cars wants to work in an agile manner. That requires also basically agile contract. This is not really the case. This is in many sense stopping some of the activities..."* (Chief Engineer, Tier-1 supplier)

Although some of the project members from both customer and supplier companies are not fully aware of the contract details, they do share the feeling of being restricted. They believe that strict contracts conflict with an agile way of working instead of supporting it, and suggest to adopt more flexible contracts, instead, also referred to as Time and Materials (T&M) contracts[8]. The interviewees agree that a T&M contract allows for a better adaptation to project changes, distribution of resources, and it creates shared ownership otherwise hindered by traditional contracts:

> *"[...] it is possible in an agile world to do this differently, but the preferred way would be not to buy content [...] It would be better if they buy a certain number of engineering hours."* (System Lead, Tier-1 supplier)

They also argue in favour of a combination of a fixed price and T&M contract, where stakeholders would agree on the product and cost estimation, but maintain high-flexibility on how to produce it. This combination fulfils the need for flexibility and agility, but also better quality for the customer.

All interviewees made it clear that good collaboration among the companies is important from a legal and contractual perspective to support inter-organisational CI&D:

> *"A looser contract would be better and healthier for the project. I know Volvo Cars has its time schedule, you can fix the time, but then costs and functionalities float and lead into more agile contract."*
> (Open Source and Community manager, Tier-1 supplier)

F7.2: (Traditional) contracts ease negotiation. For a customer it is (still) more comfortable to work with contracts because one has more leverage and binds the supplier to pre-defined deliverables and deadlines. A Volvo Cars manager further states that it is hard for suppliers to negotiate with a T&M or other flexible contracts, and that traditional contracts make it easier competing with other suppliers.

5.4 Research Question 4

The proposition we defined for RQ4 (i.e. *Are industry-wide standards and processes shared among organizations an enabler for inter-organizational CI&D?*) focuses on this aspect:

- *Proposition 8:* Effects of adopting industry-wide standards and processes in a inter-organisational setting.

The interviewees were asked if they use industry-wide standards (such as AUTOSAR) or open source (e.g. GENIVI), and whether they find them beneficial for information sharing, which is important for inter-organisational CI&D.

The interview results **support the Proposition 8**: Depending on their maturity, industry standards or open-source frameworks allow a common language and shared knowledge, therefore, benefit information sharing, which is important for inter-organizational CI&D. This answer is deduced from the following findings.

[8]According to a T&M contract, the contractor is being billed per hour regardless of the software project duration. If additional features have to be developed the supplier charges just for the time spent by its employees working on a certain set of tasks [en.wikipedia.org]. This brings high flexibility to accommodate projects with evolving requirements, but also high uncertainty about the related costs.

F8.1: Beneficial for information sharing. The industry standards and open-source projects allow a common language (i.e. AUTOSAR) and shared knowledge between project members; this improves communication and information sharing.

> *"Open source is a very strong area related to CI&D [...]. The tools are open source and the automotive industry is trying to keep this as open-source as possible. There are some weak areas, like code coverage tools. They are very weak, unfortunately, so we have to use commercial tools for that."*
>
> (Open Source and Community manager, Tier-1 supplier)

This makes hiring new employees easier, since open-source knowledge is more common than proprietary knowledge.

F8.2: Maturity and management. It is important for the success and adoption of open-source projects (tools or software components) and standards by stakeholders in the automotive industry, that they are sufficiently mature and that management is defined (i.e. controlled by one person, group or organisation).

5.5 Summary of the findings and challenges

The following summarizes the findings and highlights the main challenges while giving an answer to the research questions.

RQ1: What are risks and/or benefits of increasing transparency in an inter-organizational CI&D setting? Transparency is not a necessary condition for inter-organizational CI&D. However, transparency is considered as positive since it creates positive synergistic effects in terms of efficiency, trust, and mutual understanding, while avoiding unnecessary stressful situations. Transparency is also considered as positive in terms of increasing the overall project quality. There exist strategies to facilitate sharing among organizations. However, the automotive industry experiences difficulties in sharing information and managing responsibilities and IPR.

RQ2: (How) can sufficient information be provided in inter-organizational CI&D collaborations? Increased transparency among organizations leads to much more information available to project members. Participants of the pilot project feel that they generally have the information they need, but lacking a holistic project overview. This "big picture" could benefit all stakeholders and increase project efficiency and quality. Information overload in terms of frequency of updates is not considered a problem if the information exchanged is precise, i.e. supply and demand of information correspond.

RQ3: Are contracts an impediment for scaling CI&D across company boundaries? Strict contract-based collaboration is an impediment for inter-organisational CI&D. More flexible contracts will bring benefits to inter-organizational collaborations. However, contracts facilitate negotiations between different organizations.

RQ4: Are industry-wide standards and processes shared among organizations an enabler for inter-organizational CI&D?. Industry-wide standards and processes that are shared among organizations promote collaboration, knowledge sharing, and communication. Open-source initiatives help in the same direction and facilitate also the hiring process since people are already skilled. This holds both for open source tools and open source standards and frameworks, such as Genivi. However, open-source projects should be mature enough and the management of the project should be clearly defined.

AUTOSAR is one example of an industry standard, which defines software architecture for electronic control units (ECU) [12]. AUTOSAR defines certain components, such as application software components and basic software components as well as a runtime environment. These parts need to be integrated on specific hardware into a functional ECU, which requires that all software components are compiled in a single binary. This is typically done by a Tier-1 supplier and can cause delays in continuous integration.

The AUTOSAR consortium is currently working on a new flavour of AUTOSAR (Adaptive AUTOSAR) that removes the need of a single binary and allows software components to be exchanged individually. Thus, an OEM could order a first version of ECU hardware and basic software, then iteratively integrate several versions of their application software, learn limitations of the suppliers' first delivery and use this knowledge for ordering future versions of hardware and basic software. This scenario is made complicated by the fact that no upfront knowledge about the functionality of an integrated version is available. Thus, integration tests need to be more dynamic as well, and functionality that is distributed over several ECUs does either not fully benefit from continuous integration (since all expected functionality needs to be implemented by all ECUs) or needs to rely on automated service discovery.

Despite these exciting developments with respect to standards, we foresee that system level CI&D will have to rely on improved communication between OEM and supplier. As a first step, we investigate in this paper transparency in the context of system level, cross-organizational, continuous integration.

The biggest challenges identified in our study are:

Challenge 1 - The automotive industry experiences difficulties to share information in the ecosystem, as well as to manage responsibilities and IPRs.

Challenge 2 - When the collaboration between different organizations is regulated through more "open-contracts", it is not obvious how to manage negotiations and responsibility-sharing. It is also difficult to evaluate offers from different suppliers.

Challenge 3 - Means and strategies to share a "big picture" of the project among the different stakeholders should be identified. A holistic view of the project could be beneficial for all stakeholders, and increase project efficiency and quality.

6 THREATS TO VALIDITY

Lincoln and Guba [29] argue that qualitative research should be, objective, reliable, and internally and externally valid, all discussed in the following.

Objectivity ensures that the conclusions depend on the "subjects and the conditions of the case" rather than on the researcher [30]. The emphasis here is on the replicability of a study by other researchers. A possible threat to objectivity relates to the biases stemming from researcher effects on the case. To mitigate this threat, we carefully designed the study guide and strictly followed it in its execution, as explained in Section 4.

To ensure the **reliability** of our study, the study design (explained in Section 4) was reviewed by an expert in the field of empirical software engineering. In addition, the results of coding, conducted by the first author, were and peer-reviewed by a second author, and supported by a dedicated tool. These tactics helped us ensure that the study is executed with reasonable quality.

Internal validity aims at ensuring that the collected data enables researchers to draw valid conclusions [7]. This validity relates to "how" the research is carried out, and whether the used methods are credible. In this study, the interviews were mainly conducted by a single researcher and hence subjective interpretations might exist. To mitigate this threat, the interview guide was checked and validated by senior researchers experienced in software engineering, empirical studies and agile methods in automotive.

External validity defines to what extent findings from the study can be generalized [7]. A threat to generalizability of results is that the study was conducted at two companies in the automotive industry, which means the findings are specific to this study and this domain. We however consider this study as a first in a series, and make available the replication package so that other researchers can replicate the study in other companies and in other domains.

7 DISCUSSION

In this section we rely on Figure 1 to discuss our findings. Where applicable, the discussion is organized from the perspective of industry (Section 7.1) and academic research (Section 7.2).

Overall, we found a correlation between transparency and CI&D, in the sense that transparency has a positive impact on CI&D, however, it is not a necessary condition, and in fact Proposition 1 has been rejected. Moreover, in the specific of *inter-organizational* CI&D, we found that increased information transparency can have negative effects on privacy: by increasing transparency, organizations should be more aware of which information is sensitive and hence should or shouldn't share. At the same time, transparency positively influences project quality, trust, inter-organizational awareness and shared project understanding. This creates a good environment for inter-organizational CI&D.

Further, we found that when information transparency and inter-organizational CI&D coexist, synergy (agile collaboration) increases, too. This confirms the potential benefits of applying agile development methodologies in ecosystems (like the automotive one) that target safety-critical systems and that are traditionally heavily controlled. In doing so, however, agile methodologies should remain conform to standards like the ISO 26262 [17] - a future challenge for both research and practice.

7.1 Industry Perspective

Industries interested in opening their platforms towards an ecosystem perspective, might benefit from our findings on adopting more agile and open collaborations. As discussed above, there is the need of **more mature ecosystems** based on innovative typology of contracts, negotiation and competition rules, and ways of splitting responsibilities and IPR. Traditional contracts are an impediment to inter-organizational CI&D, but they facilitate negotiation and IPR. An increase of information transparency has many positive effects, as can be seen in Figure 1, however it doesn't come for free.

Moreover, it is important to highlight that inter-organizational CI&D could have an impact at both organizational and functional levels. The **impact at an organisational level** is perceived differently by the two participating companies. For Volvo Cars, it is perceived as one of many projects and since they do not have the integration and end-responsibility for the product, it has not a big impact. However, for the supplier company, it is a high-risk experiment due to the complexity of the project. The employees of the supplier confirm that it has the highest complexity level the company accepted in its history.

The interviewees of both companies agree that the **impact at a functional level** of inter-organizational CI&D can be quantified in gain-in-efficiency, quality, and time-to-market. Also, CI&D has less side effects than intermittent integration.

Finally, the interviewees state that, to date, inter-organizational CI&D is not mature enough to predict the impact on **collaboration models**. More experience and experimentation are needed in order to understand whether they will require and/or promote new collaboration models.

7.2 Academic Perspective

Researchers that are interested in scaling agile methodologies to the entire organization or to inter-organizational collaborations might find in this paper interesting findings coming from an industrial project in a challenging domain that is witnessing a profound transformation in the last years.

Figure 1 emphasizes (in dark-grey color) three aspects that we identified as the most relevant for software engineering researchers, along with the related indirect effects (in light-grey). In particular, (1) to achieve the promised inter-organizational synergy, ecosystems need **harmonized tooling** that can flexibility inter-operate to a.o. mitigate the (perception of) physical distance and implement (efficient) information sharing. Advances in service-oriented technologies, cloud integration and seamless software adaptation can provide the building blocks for such tooling. (2) As mentioned in the beginning of this section, further research is needed to create effective **information transparency**. Researchers working in software ecosystems can find in this paper an interesting example of ecosystem in the challenging automotive domain. Innovative ways to share information and knowledge within the ecosystem are needed. We also expect that different levels of sharing will be required within the same ecosystem, according to the degree of closeness of the OEM, to the level of trust, and to the purpose of the collaboration. Platforms are already being developed mostly addressing different levels of data sharing (e.g. KAVE [9]). Software engineering approaches are needed to define the sharing models and how to translate them into e.g. information generalization for controlled sharing. Further, approaches for information access should offer techniques to trace the individual contribution within the project shared in the ecosystem, and generate holistic project views for shared understanding. If present, these two techniques would help increasing project quality. Finally, our study highlighted how (3) the inter-organizational **adoption of open-source software and standards** helps create a shared knowledge base and common language, which in turn further facilitate information sharing. Research in knowledge management applied to e.g. software architecture [2] barely touched upon this topic.

[9] http://kave.io

8 CONCLUSION AND FUTURE WORKS

In this paper we report on a semi-structured interview study in the automotive industry. In particular, we investigated whether the way of working in automotive ecosystems should change while moving towards inter-organizational CI&D; then we focused on *legal contracts* that regulate the agreements between OEMs and suppliers, and on *transparency* that is intended as the degree/level of information that is shared among the organisations collaborating in the same value-chain. The study has been performed within Volvo Cars in the context of a pilot and a large project that is researching new ways of working within the ecosystem. Employees of the supplier company seat within Volvo Cars together with employees of the OEM and in some sense they work as a unique company, thus having more access to information. The results of the study show that more flexible contracts are needed, and that more transparency between OEM and suppliers is considered as an enabler for inter-organizational CI&D. As future work we plan to investigate the challenges found in this paper within other companies and possibly in domains that are different from the automotive one. Another future research direction is investigating whether the new way of working will trigger new collaboration models within automotive domain, thus shifting towards a clearer and accepted win-win relationships between the actors of the ecosystem.

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