Transparency and Contracts: Continuous Integration and Delivery in the Automotive Value-Chain

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***Abstract*—The automotive industry is rapidly changing thanks to both new technological challenges, like autonomous vehicles, connected cars and electrification, and new players that are entering the market, like Tesla, Google, Apple, and Uber. Most of the innovation in automotive is nowadays coming from electronics and software. The pressure of reducing the time to market and increasing flexibility while keeping quality are leading motivations for these companies to embrace system-wide Continuous Integration and Delivery.**

In this paper, we investigate the challenges and impediments posed by Continuous Integration and Delivery 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 *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 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; contracts; information sharing; automotive; interview survey**

I. 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 [**?**].

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 [**?**]. Consequently, the overall development organization is split in different groups, both by abstraction and competency (e.g. top level requirements, architecture, design and software development, hardware, mechanical parts).This can cause a silo effect that hinders information sharing and synergy.

Due to an increasing market demand [**?**] and the success of agile methodologies [**?**], large-scale systems development organizations adopt agile practices [**?**] such as continuous integration and delivery (CI&D), which promise shorter time to market and improved quality [**?**]. OEMs especially 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 on 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. [**?**], 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 [**?**]. Hosseini et al. refer to this as *transparency* and note that the crucial aspects for decision making are information accessibility and availability [**?**], [**?**]. To our knowledge, this perspective has not been applied to system-wide CI&D.

In this paper we investigate challenges and impediments of system-wide CI&D in automotive system-development. Specifically, we focus on *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:

[1]https://www.google.com/selfdrivingcar/

[2]https://en.wikipedia.org/wiki/Apple_electric_car_project

[3]http://www.electronics-eetimes.com/news/innovation-car-90-comes-electronics-and-software

[4]Originally developed for defense applications by the German DoD - http://www.v-modell-xt.de/

- *RQ1: What are the risks and/or benefits of increasing inter-organisational transparency?*
- *RQ2: Is there a lack or overload of information that is exchanged across organizations?*
- *RQ3: Are contracts an impediment for scaling agility across company boundaries, and are industry-wide standards and processes shared among organizations an enabler?*

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. Therefore 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 around 30 different agile teams.

The main findings of the study are the following:

- *RQ1* - Inter-organisational transparency is not a necessary condition for inter-organizational CI&D but considered 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 information sharing among the members of the project that belong to different companies. However, transparency as such does not help provide a holistic project overview.
- *RQ3* - Contracts are an impediment for inter-organisational CI&D; however, contracts also help facilitating negotiations between different organizations. Industry-wide standards and processes and open source initiatives are seen as positive for promoting collaboration, knowledge sharing, and communication.

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

II. 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 (NGEAs)* projects, funded by Vinnova [**?**]. These projects are coordinated by Volvo Cars and involve the Chalmers University of Technology, some research centers in Sweden and many suppliers of the OEM, including Autoliv, Arccore, Combitech, Cybercom, Knowit, Prevas, ÅF-Technology, Semcom, and Qamcom. The projects aim to develop new software processes and proof of concepts to strengthen the competitiveness of the automotive industry in Sweden. The main objectives of the projects are to investigate (i) the transition of Volvo Cars towards continuous integration and delivery, (ii) new business models and innovative ways of working within the automotive value-chain, and (iii) vehicles as part of system of systems. In this paper we mostly focus on point (ii) and its impact on (i). Since OEMs are increasingly transforming into software companies, nowadays the automotive domain is attracting the attention of the software engineering community.

In this paper, we refer to software-related, inter-organizational collaborations between automotive suppliers and manufacturers (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 [**?**]. Yet, it relies on complex supplier networks and strong dependence on hardware and software development [**?**].

Nowadays, a vehicle is a *driving software package* as compared to the vehicles of not even ten years ago. Jörgen Mössinger, VP for automotive systems integration at Bosch, said: "Electronics and especially software are the main sources of automotive innovation today." [**?**]. The Boston Consulting Group estimates that the total costs of electronic parts will rise from 20% of the value in a typical car in 2004 to 40% in 2015. Software, instead of hardware, has become the differentiating factor [**?**], [**?**], [**?**], [**?**] between companies and their products. This evolution of the automotive industry, illustrated by the exponential increase of software, creates new challenges regarding software integration, development, deployment, and maintenance. Therefore, its development needs to support the related integration and evolution of time [**?**], [**?**], [**?**]. The increasing number of stakeholders involved in the software development projects imposes additional challenges to the architecture teams, as the development and design literally 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 its suppliers (Tier-1 and Tier-2). In general the OEM is the coordinator and platform owner in the automotive ecosystem [**?**]. Tier-1 suppliers are considered 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.

As shown in Figure **??** the software engineering process follows the V-model, with the development on the left-hand side and verification on the right-hand side. The development at the level of components is parallelized among the different suppliers, and internal in-house development. The degree of

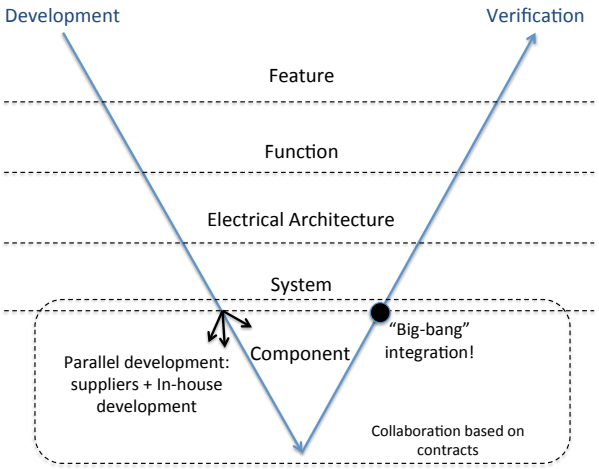

Fig. 1. Collaboration based on contracts

parallelism can easily reach level 50 (i.e. 50 parallel developments). Once the collaboration between the OEM and its suppliers is regulated by contract, the parallel developments represented in Figure **??** start by signing a contract and then after months the large amount of externally developed software comes back to the OEM to be integrated as black-box functionality [**?**]. This leads to the above mentioned "big bang" 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 system-wide CI&D.

III. 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 [**?**], 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 [**?**], 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 [**?**] 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 interviewee, which are less possible with other (more structured) methodologies, such as questionnaire surveys. At the end of the interview, or *cool-off*, the interviewee is given time 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 people that are knowledgeable about the topic. An overview of the selected interviewees' information can be found in Table **??**; the years in brackets refer to industry experience, without brackets refer to experience in that specific role.

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 I
Overview of interviewees

Also an appointment is made with the interviewee to verify and validate the transcript.

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 [**?**]. The transcript is divided into smaller and easier to code parts. 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 in order to process them into feasible datasets and to help supporting or negating propositions and research questions. All information that was relevant for the research was submitted as

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

[6]Qualitative Research tool Atlas.ti; https://atlasti.com

a quotation and connected to a code, including information that was not a direct answer to a research question or proposition. The codes were grouped into code groups to give an answer to one specific question, i.e. codes relevant to proposition 1 were submitted in code group "Proposition 1". This is done to simplify the writing process of the findings for each individual research questions and propositions. 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.

The results of this process are captures 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 [**?**]. 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 [**?**], we safeguard the *reliability* of conducting, analyzing and reporting the interview process. Accordingly, the results are considered reliable too. As for *generalizability*, the results of the research can be applied to other domains than the automotive industry.

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 suppliers that work with Volvo Cars collaborate 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 shared with many other domains, like for instance aviation. We then expect that the our results will be valuable also outside of the automotive domain.

IV. Results

To guide the research and operationalize the interview survey we carefully formulated a set of propositions that are then confirmed or negated by analysing the data collected through the semi-structured interviews we performed. Specifically, the first four propositions are defined for RQ1, propositions 5 and 6 are defined for RQ2, and the remaining two are defined for RQ3. 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.

In Sections **??** through **??** we present the findings related to RQ1 through RQ3, respectively, along with some illustrative quotes from the transcripts. Finally, in Section **??** we answer the RQs by summarizing the findings and highlighting the main challenges.

A. Research Question 1

The propositions we defined for RQ1 (i.e. *What are the risks and/or benefits of increasing inter-organisational transparency?*) focus on these aspects:

- *Transparency is a necessary condition for inter-organisational CI&D* - Proposition 1
- *Transparency is perceived positively/negatively within the companies* - Proposition 2
- *It is easy to improve transparency* - Proposition 3
- *There is a connection between transparency and quality of results of the project* - Proposition 4

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

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)

In any case interviewees highlight the importance of transparency, see for instance:

> *"I think it [transparency] is very important, very important in general to increase efficiency. Very much for CI&D."* (Software developer, Volvo Cars)

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

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 between companies. The complexity of the project is experienced as an impediment working against full transparency of information. However, it is not always easy to understand how to manage the new information:

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

The interview results **support the proposition**: the increase of information transparency is generally considered positive. This answer to proposition 2 is deduced 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. However, it is important to identify which kind of information should be shared. As we can see 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)

This aspect is important also for the suppliers:

> *"When we are doing our estimation or calculations of our prices, this is internally done. That is the setup today. It is a fixed price project, due to that. So we are still in a traditional OEM and supplier role."*
>
> (System Lead, Tier-1 supplier)

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: Create an understanding. In some cases, 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)

3) Proposition 3: Inter-organisational sharing of information is considered simple between members of the projects: 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 are investigating (collaboration between Volvo Cars and a supplier) is perceived as a complex project by both companies.

The findings **partially support the proposition**. The tooling and inter-organisational transparency, i.e. reducing physical distance, benefit inter-organisational information sharing, and hence 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 is deduced 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 this, due 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 is important to highlight that it is always 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 from the pilot project are positive about the tools and their supportive role in the project and agree that it reduces the complexity of the project. However, the selection of the tools to be used is also extremely important:

> *"Let's say for example we are using a proprietary technology and the Supplier or Volvo Cars is the owner. That means that one of the parties have to adjust to this technology. The other part [the part that does not own the technology] is always going to be behind and will have difficulty to understand how everything should work."*
>
> (System Lead, Tier-1 supplier)

For what concerns tools, 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 system-wide CI&D.

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 about 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 about the improvements in the long term. An open transparency policy is positive for quality control because of mutual understanding of the project status and as a consequence 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.

B. Research Question 2

The propositions we defined for RQ2 (i.e. *Is there a lack or overload of information that is exchanged across organizations?*) focus on these aspects:

- *There is lack of information vs the amount of information is sufficient* - Proposition 5
- *Overload of information is/is not problematic* - Proposition 6

1) Proposition 5: Project members have sufficient information to perform their activities: This proposition challenges the interviewees to critically evaluate information, sent and received, between 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. All technical information is shared between project members, this includes source code, project information, and time planning. Commercial information is not shared between 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. Third-party agreements are an impediment for full transparency, because of licensing and responsibility issues.

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 companies, 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)

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.

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. The interviewees were asked what kind of information is (not) shared, if it is much more or less information than other projects, and if they experienced information overload. *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.

The interview results **support the proposition**: information overload is unlikely to be considered a problem. This answer to proposition 6 is deduced from the following findings:

F6.1: Understanding thanks to collaboration. 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.

C. Research Question 3

The propositions we defined for RQ3 (i.e. *Are contracts an impediment for scaling agility across company boundaries, and are industry-wide standards and processes shared among organizations an enabler?*) focus on these aspects:

- *Strict contract-based collaboration can be seen as an impediment for inter-organisational CI&D* - Prop. 7
- *Effects of adopting industry-wide standards and processes in a inter-organisational setting* - Proposition 8

1) Proposition 7: Strict contract-based collaboration is an impediment for inter-organisational Continuous Integration and Deployment: 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 the research 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. While still ongoing, this transition is confirmed by all interviewed stakeholders, and could lead to a cultural change toward adopting more open or flexible contracts for inter-organisational CI&D.

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 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[7]. 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)

[7]According to a T&M contract, the contractor is being billed per hour regardless of the software project duration. If any 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.

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:

> *"I think there are so many unknowns in this project, but [the supplier company] is building a platform out of this project as well. So they are taking part of the risk here. The risk is on both side, but I think an agile project, a full agile project would be better. Then we could get to a situation earlier with quality."*
>
> (Open Source and Community manager, Tier-1 supplier)

All interviewees made it clear that good collaboration between their 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 it is the costs and functionalities that float and lead into more agile contract."*
>
> (Open Source and Community manager, Tier-1 supplier)

F7.2: 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.

2) Proposition 8: Standards and processes, based on industry-wide data and process standards benefit inter-organisational CI&D: The interviewees were asked if they use industry-wise standards, and whether they find them beneficial for information sharing, which is important for inter-organisational CI&D. The automotive industry is participating in various open source projects (e.g. AUTOSAR and GENIVI) and attempts to be good open-source citizens:

> *"We are trying to be a good open-source member by also upstreaming strategies, especially around GENIVI and Yocto. Here we find issues or improvements in the tools and we try to pass them back what we can. That is one of the strategies of [the company] to work more open towards the open-source community..."*
>
> (Open Source and Community manager, Tier-1 supplier)

And also:

> *"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 an 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 development also enables companies to hire new employees easier, because open-source knowledge is more common than knowledge of proprietary technology.

The interview results **support the proposition**: industry standards and open-source projects allow a common language and shared knowledge, therefore, benefits information sharing, which is important for inter-organisational CI&D. This answer to proposition 8 is deduced from the following findings.

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.

F8.2: Maturity and management. It is important for the success and adoption of open-source projects and standards by stakeholder in the automotive industry, that these are highly controlled by one person, group or organisation. The maturity is also a crucial factor for the success or failure of an industry standard or open-source project.

D. 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 the risks and/or benefits of increasing inter-organisational transparency?: Transparency is not a necessary condition for inter-organizational CI&D. However, transparency is considered as positive as 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: Is there a lack or overload of information that is exchanged across organizations?: Increased transparency among organizations leads to much more information available to project members. In our pilot project participants feel that they have the information they need. However, they are missing a holistic project overview. This "big picture" could be beneficial for all stakeholders and can 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 agility across company boundaries, and are industry-wide standards and processes shared among organizations an enabler?: 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. 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. However, open-source projects should be mature enough and the management of the project should be clearly controlled by a person, team, or organization.

The biggest challenges identified in our study are:

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

b) 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, and, from the supplier point of view, to compete transparently with other suppliers.

c) 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.

V. Discussion

A. Industry Perspective

This paper presented a pilot project of Volvo Cars and one of its suppliers to investigate innovative ways of working and innovative collaboration models of the two organizations. Industries interested in opening their platforms towards an ecosystem perspective, might benefit from our findings on adopting more agile and open collaborations.

It is important to highlight that system-wide CI&D could have an impact on both organizational and functional levels. The *impact on organisational level* is perceived differently by the two participating companies. For Volvo Cars, it is perceived as one of the many projects and since they do not have the integration and end-responsibility for the product, it has less of an 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 on functional level* of system-wide CI&D can be quantified in gain-in-efficiency, quality, and time-to-market. Also, CI&D has less side effects than intermittent integration, in case of big-bang integration.

Finally, the interviewees state that, to date, system-wide CI&D is not mature enough to see or foresee a big impact on business model strategies.

B. 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.

Researchers working on 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 degree of closeness to the OEM and the level of trust, and according to the purpose of the collaboration.

For what concerns contracts, our findings suggest that traditional contracts are an impediment to system-wide CI&D. However these types of contracts work well for what concerns negotiation and IPR. Innovative contracts and/or ways of working are needed.

VI. Related Works

A. Continuous Integration and Delivery

CI is a development practice that assumes each developer to frequently commit their new code into a shared repository. While there is rich literature on how to implement and setup a small scale continuous integration for a project (e.g. [**?**], [**?**]), there is lack of scientific support for how to scale such setups and also how to deal with involved hardware and complexities in embedded software [**?**]. There are, however, works that report on challenges with scaling of continuous integration [**?**], [**?**] as well as with the applicability of agile approaches in the embedded domain [**?**].

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" [**?**]. In contrast, Continuous Deployment would require to not only deliver the software, but also to deploy it into the user's runtime. Thus, Continuous Deployment becomes important when considering over the air updates to end-users. Our paper, however, focuses on the continuous delivery between supplier and OEM, since we argue that this is the natural consequence of an OEM embracing system-wide continuous integration.

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

B. Transparency between Actors in Software Ecosystems

Open source [**?**], modelling and architecture (e.g. software evolution, architecture, and product lines [**?**]), and managerial perspectives (e.g. business aspects and co-innovation [**?**]) are key topics of software ecosystems, and we consider openness and transparency as key properties. Different degrees exist, from widely proprietary ecosystems to pure open source ecosystems [**?**], [**?**]. Jansen et al. [**?**], Bosch et al. [**?**], and Manikas et al. [**?**] discuss how to analyze software ecosystems and relationships among the actors of ecosystems. We consider the notion of a software ecosystem as a useful perspective on development work in the automotive software value-chain [**?**] and by considering these related works, our study focuses on the specific interaction between automotive OEM and supplier.

One important aspect in our interviews has been the contract between both parties and the requirements defined there with respect to time and functionality. Not surprisingly, Requirements Engineering (RE) practice in traditional proprietary software projects (as e.g. described in [**?**], [**?**]) 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 [**?**].

Transparency and emergent collaboration of stakeholders play a major role in driving requirements discussion and decision-making. To our knowledge however, research has so far mainly investigated emergent developers [**?**], [**?**], [**?**] and emergent knowledge [**?**], while only few and more recent works exist that start to investigate the effect of emergent contributors on requirements [**?**], across organizations [**?**], [**?**], and its implications with respect to transparency [**?**], [**?**]. 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 systems environment [**?**], must participate even when they span team or geographic boundaries [**?**]. In line with our findings, open communication channels have shown their value for building communities around healthy ecosystems [**?**]. 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 [**?**].

VII. Conclusion and Future Works

In this paper we investigated challenges and impediments of CI&D that involves an OEM and its software suppliers. This is a relevant topic since automotive OEMs have strong motivations to embrace CI&D because of pressures of reducing the time to market and improving flexibility while keeping quality. Automotive OEMs are increasingly becoming software companies and most of the software is often produced by external companies, i.e. Tier-1 and Tier-2 suppliers, that populate the automotive ecosystem. For that reason, CI&D in the automotive industry has to take into account also other actors of the ecosystem. The increasing focus on software brings new challenges and opportunities for the software engineering field.

More specifically, in this paper we investigated whether the way of working with suppliers should change while moving towards CI&D; then we focused on *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 large project that is trying to reformulate the way 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 system-wide 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 business models within automotive domain, thus shifting towards a clearer and accepted win-win relationships between the actors of the ecosystem.