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UNDERSTANDING AND ACCEPTANCE OF SYSTEMS ENGINEERING IN AUTOMOTIVE PRODUCT DEVELOPMENT

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Abstract: *Systems Engineering (SE) is a new engineering method for many firms in Automotive Product Development that expectedly advances their development processes to meet their stakeholder needs more effectively. Literature suggest that understanding and acceptance are key factors in the implementation, however comprehensive modes for their increase are barely discussed. In this paper, we propose a Participatory Action Research based on multiple research elements to find an effective technique for gaining understanding and acceptance on SE in a validated model environment of automotive industry called Formula SAE. We present practical outcomes at each steps of the implementation process and analyze the effect of improvements in the context of strategy, structure processes.*

Key words: *Systems Engineering, Organizational Understanding, Organizational Acceptance, New Method Implementation, Automotive Product Development*

1. Introduction

The Automotive Product Development (APD) segment has been facing with tremendous product-oriented changes, mainly triggered by the spread of technical innovations (e.g. autonomous systems), customer-driven new challenges as well as novel sustainability-oriented standards. (Talimian & Vychytil, 2021; Majláth & Ricordel, 2021; De & Giri, 2019) Systems Engineering (SE) is an approach to manage complexity, which interconnects technical mindset with organizational tools and deals with components and problems of a comprehensive system, regardless of whether they are technical or managerial in their nature. (Falk & Muller, 2019) It has proven its effectiveness in New Product Development projects, resulting in improved product quality, increased budgetary effectiveness, faster time to market values and further developments in other aspects. (Vanek et al., 2017) Despite the facts that

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automotive industry has been facing with an immense technical revolution as well as new organizational challenges arise aiming to better meet the stakeholder needs, firms have barely applied this methodology so far. Although, an amount of studies concern imagined or realized effects of SE within the field, they mostly touch production cases or discuss the implementation on a theoretical basis (Dumitrescu et al., 2013; Gál et al., 2013; Fischer et al., 2020; Gyenge et al., 2021; Rabe et al., 2022). Even though the unequivocal benefit of SE appears in other industrial sectors including development activities, little evidence has been published on its utilization in APD (Henderson & Salado, 2021). This finding has gained our motivation to set a pilot research project in a valid downscaled model environment of automotive industry that is Formula Society of Automotive Engineering (FSAE). This setting enables us to implement SE as a new engineering method at an FSAE organization that has been thoroughly analyzed and then has been assigned as the subject of our experiments. This approach leads to a participatory action research, which promises original validated findings, developed directly from the practice and relevant for automotive OEMs. Having the uniformity between FSAE and industrial automotive product development already proven as well as the fundaments of the SE-based new organizational model introduced, in this paper we intend to present our recent findings on the factors affecting understanding and acceptance levels when implementing a new engineering method in APD (Kolossváry et al., 2020; Kolossváry et al., 2021). Essentially, this research aims to reveal an effective strategy that gains understanding and acceptance of the new method and provide an assessment whether it exerts any perceptible effect at the level of strategy, structures, and processes. The structure of our study is based on the sections as they follow: Section 2 introduces the background literature available on SE, understanding, acceptance and implementation of new engineering methods; Section 3 reveals our main research objectives and focused research questions; Section 4 provides a detailed assessment on the research design in addition to workshop agendas and interview protocols; Section 5 includes the discussion of the collected qualitative data and Section 6 provides our conclusions on the research questions and the assessment of the possible contributions for the APD sector.

2. Theoretical framework and literature review

Essentially, our study aims to analyze and reveal circumstances in the engineering practice, which affect the success of a SE implementation project and determine whether an organization can deal and improve with using SE in their practice.

Inkermann (2021) proposes an overview on various SE methods that are deemed to be applicable in automotive engineering sector and highlights some first insights from workshops which aimed to sensitize employees and managers about the SE mindset. Despite the immaturity of their study, a number of relevant studies have been processed to derive SE principles and methodologies for organizational implementation in the automotive segment. That paper is also interesting in terms of methodology and fundamentally stands close to our approach, however the long-term in-practice implementation procedure in a scaled environment and the dedicated focus on understanding and acceptance are missing. Huldt & Stenius (2019) emphasize that the knowledge to integrate SE and Model Based Systems Engineering (MBSE) in particular with prevailing business processes as well as the understanding of the value of the new model need to be improved when pursuing the

realization of a flourishing SE-based operation. Madni & Sievers (2018) find that to fully exploit the advancements that MBSE can deliver, numerous organizational developments need to be fulfilled, e.g., enthusiastically determined management on the inherent cultural change, the implemented MBSE methods must cover the entire system life cycle and require developments on supporting processes and tools, convincing the organization using real-world problems as examples. Although MBSE is not synonymic with SE but an evolutionary approach of it, these observations coincide with our assumptions, but lack substantial findings on understanding or acceptance factors of a new SE-based model adaption. The acceptance of any engineering method, but SE method is a necessary condition for their fruitful application in segments like mechanical, electrical or software engineering, and this applies for automotive industry as well (Lohmeyer et al., 2014). In this latter paper, authors investigate aspects of acceptance of new methods and tools and provide recommendations i.e., SE methods should be established by a shared understanding of what SE means. Araujo (2001) analyze what factors could explain a low level of acceptancy of new engineering methods and tools and find 9 major causes as introduced over the following paragraphs.

1. Lack of a reason or interest: Several organizations and their members believe that they do not need to use any new method or tools despite their availability and find existing processes sufficient. In general, designers show their interest in utilizing new methods for: facilitating communication, integrating knowledge and experience into methods and tools, and contributing with a structure in the product development process (Lindahl, 2005).
2. Lack of understanding of the nature of the methods: In many cases, practitioners are unsure how they can benefit from the new available tools and techniques. This is essentially important, just as the development of the specific mindset is, which is a key task in design methods usability (Andreasen, 2003; Daalhuizen & Cash, 2021).
3. Lack of resources: Organizations complain that they do not have sufficient resources to implement the new methods. This is likely to be affected by the level of motivation and the organizational commitment (Daalhuizen & Badke-Schaub, 2011) as it has found to be the subject of resource allocation rather than the availability of resources (Ernzer et al., 2003).
4. Lack of 'appeal': Majority of the methods and tools have been published in a raw format and presented in academic language, and therefore, they seem too complicated to introduce in practice and use them to cope with everyday tasks. Bligård et al. (2018) identifies "lack of appeal" as a usability issue of a method and categorizes usability barriers into three groups: barriers in the organization, user perceptions of the method, and the actual use of the method.
5. Poor design of tools: The application of some tools involves procedures that are too complicated and do not reflect on practice.
6. Poor promotion practices: Not enough effort has been taken to disseminate the available methods and tools. Empirical outcomes underlie that engineers may not prefer a method, in which they have not yet gained any experience, or which has not been recommended by a respected designer. (López-Mesa & Bylund, 2011)
7. Fear of change: Introduction of new tools is normally perceived as a change, and such processes are generally not welcomed by all members of the organization. This stands regardless the industry type or the object of change. The fear of change is attributed to uncertainty, which is often triggered by inappropriate or insufficient communication on the issue (Badke-Schaub et al., 2011).

8. Too many options: There is a lack of taxonomy and procedures for supporting the assessment and tools selection.

9. Negative attitude: Most practitioners are skeptical on new tools and approaches. The origin of this fear frequently leads back to previous bad experiences.

Even though these factors concern circumstances of acceptance, we propose that 4 out of the 9 causes rather relate to understanding, and this assumption is supported by the literature as well (Laing, et al., 2020; Lohmeyer et al., 2014). We consider "Lack of understanding", "Lack of appeal", "Fear of change" and "Too many options" aspects as a subject of understanding issue and believe that a focused and well-targeted training could increase the level of understanding and lead to a more effective new model implementation. This observation suggests that the two main factors, which seemingly take predominant roles in a new engineering model implementation process are understanding and acceptance. In such situation, we expect that the development of these two factors is key, therefore a profound systematic review is essential on literature discussing the role of understanding and acceptance in the event of a new engineering method implementation into the product development practice. In agreement with Araujo's (2001) findings, it is prioritized to have both understanding and acceptance terms mentioned in the setting of a new engineering method implementation and discussed within a single study. Based on our early findings developed from the literature, we address these parameters as understanding, acceptance, new engineering method implementation and search for studies discussing preferably all three, but at least one of them within one paper. We used Science Direct and Google Scholar databases and sought for review and research papers, manuscripts, theses and books. Following the analysis conducted on the selected papers, we provide our results in Table 1, which indicates the relevance of the three key aspects in each literature as a systematic comparison. Our purpose is to represent which paper touches what aspect of the analysis: understanding and/or acceptance and/or organizational implementation of new engineering methods.

Table 1. Literature and their theoretical contribution to one or more of the analyzed aspects (marked with "X")

Reference	Understanding	Acceptance	Implementation
Rasiel & Friga (2001)	X		
Dweck (2017)	X		
Curuksu (2018)	X		
Burge (2010)	X		
Tien & Berg (2003)	X		
Selart (2010)	X		X
Holloway (2015)	X		
Giacomin & Forcellini (2016)	X		X
Inkermann (2021)	X		X
Honoré-Livermore et al. (2022)	X		
Pozatti et al. (2021)		X	
Araujo (2001)		X	X
Reiß et al. (2017)	X	X	
Entwistle & Ramsden (2015)	X	X	
Birkhofer et al. (2005)		X	
Kasser (2010)		X	

Reference	Understanding	Acceptance	Implementation
Lohmeyer et al. (2014)		X	X
Wallace (2011)	X		X
Bhise (2017)			X
Fischer et al. (2020)			X
Kossiakoff et al. (2011)			X
Jackson (2016)			X
Laporte et al. (2017)			X
Tremblay et al. (2019)			X
Albers et al. (2018)	X		X
Lindahl (2005)		X	
Andreasen (2003)	X		
Daalhuizen & Cash (2021)	X		
Daalhuizen and Badke-Schaub (2011)	X	X	
Ernzer (2003)		X	
Bligård et al. (2018)	X		
López-Mesa & Bylund (2011)		X	
Badke-Schaub et al. (2011)	X		
Hedlund & Ingo (2018)	X		X
Akingbola et al. (2019)	X		X
Ackermann et al. (2021)			X
Lee et al. (2017)		X	
Laur & Danilovic (2020)			X
Gamble (2020)			X
McDermott et al. (2020)	X	X	

By applying a critical look on the literature encountered, we find that our preliminary assumption, that is a successful implementation cannot be realized without an endeavor to understand and accept the new engineering model gets confirmed. Despite this observation, none of the reviewed papers investigate understanding and acceptance thoroughly in the moment of the implementation of a new engineering model. Undoubtedly, the study from Lohmeyer et al. (2014) nearly fills this gap in by discussing acceptance factors and formulating recommendations to an SE implementation project, however, their research is based on a data gained from general engineering domain concealing multiple engineering sectors instead of specifying research focus on automotive product development. (Henderson & Salado, 2021) Also, they do not deal with determining factors of understanding and training practices on the improvement of understanding, which would be one of our main research objectives to facilitate the SE implementation at automotive product development departments.

In order to establish an even better grounded assumption, we endeavored to discover a study that might provide findings for all of our targeted attributes, by using keywords as “change management” and “support engagement” in searches focused in the automotive or product development domains. In other words, by this study, we do not aim to analyze the applicability of certain well-renowned change management models, however good practices on gaining understanding and acceptance in a transformation process are in our target. A number of traditional manufacturers in the automotive field seek implementation of agile product development approaches, which promote transformational type change processes

(Hedlund & Ingo, 2018). In such experiments, gaining the breakthrough in leader and employee mindset is key. Akingbola et al. (2019) present a nonprofit organization specific change model. It could be relevant in our research model environment, however FSAE does not necessarily incorporate what is generally understood by the term "nonprofit organizations". Nevertheless, in their model, stakeholders and stakeholder involvement appear as a highlighted factor, and these roles are frequently emphasized, similarly to SE literature. Ackermann et al. (2021) investigates the utilization and organizational effects of a self-management framework which has been developed to advance responses on digital transformation within the automotive sector, although their paper lacks findings concerning mindset change or redeeming acceptance.

Concluding the theoretical framework, we address the gap in knowledge identified in the intersection of all three sets: understanding, acceptance, and new engineering model implementation. An analysis concealing all three aspects discussed in a single study in their complexity is missing.

3. Research objective and research questions

By this study we intend to present findings which are not only filling this void in but are also meaningful for those practitioners in the automotive product development segment, who are deliberating or dealing with SE implementation. We believe that former studies underlie the relevance of our research for such findings. Expectedly, Araujo's (2001) factors of acceptance as well as the recommendations of Lohmeyer et al. (2014) are likely to be expanded by this very study. Therefore, our main objectives for this research are: (i) provide an assessment on the factors affecting understanding and acceptance of new methods in product development; (ii) Provide good practices of gaining understanding and acceptance in the moment of implementation of the new methodology specifically for automotive product development segment; (iii) reveal the effects of a presumed gain of understanding and acceptance in terms of strategy, structure and processes. In order to focus more our research objectives, we propose research questions as they follow:

- RQ1: How can the understanding and acceptance of SE be improved in FSAE, when it comes to the implementation of a new SE-based engineering method?
- RQ2a: What is the effect of the applied techniques (e.g. employee involvement) in the education of the new engineering method in terms of frontal versus a learning by doing way?
- RQ2b: Is any break-through moment observable in the process of implementation?

4. Research design

As presented in a previous study, we assigned a validated model environment in order to conduct further investigations in a scaled setting of automotive industry. (Kolossváry et al., 2020) This is called FSAE. Such self-operating teams are based in a university environment and maintain well-established connections with numerous industrial actors. Thus, they portray an integrated form of ecosystems, in which universities and businesses cooperate in a well-organized manner. These collaborations facilitate the establishment of incubational programs (Lesáková, 2012), research and development projects and the foundation of high performing

student teams competing in FSAE (or other programs) (Davies, 2014). A good example on this is the student innovation teams (e.g. FSAE) at Széchenyi István University in Győr, which have over 10 years of history. From the several teams present at the university, as many as 3 are associated with automotive focus. This is due to the exceptionally strong links to the local automotive industry. This has led to the establishment of the several unique academic departments focusing on the areas of automotive production, development and management. These have been formed in a separate faculty of automotive engineering, which flagship project based educational forms are the FSAE teams, one focusing on drivetrain development and the other one on vehicle development. The cumulative number of students reaches 100. The operation and challenges of these are very similar to the ones observed in vehicle industry. Thus, it lends itself as an excellent model environment for examining the implementation of SE in a scaled agile setting. Building upon the fact that FSAE is a relevant setting of industrial product development departments, we have started an SE implementation project that is demanded by multiple automotive firms, commonly traditional automotive OEMs as the presence of their product integrity efforts hit an unprecedented magnitude (Hage et al., 2020).

Participatory Action Research (PAR) is an emerging methodology applied predominantly in qualitative research projects and also an evidence-based learning and facilitation process in organizational and community development. (Chevalier & Buckles, 2019; Walter 2009) Even though it has evolved originally in the field of social sciences, Johnsson (2016) applies and introduces the Participatory Action Research (PAR) approach in their engineering-focused paper and proposes the involvement of the researcher in the method implementation processes. They vary data collection methodologies – e.g., observation, workshops, questionnaires, and semi-structured interviews – upon the actual focus and research purpose. We find this approach to be an effective and insightful technique to discover the circumstances affecting understanding and acceptance. In order to facilitate further understanding, we decided to apply a methodological tool from the study of Abrell et al. (2017): researchers presented early interview results to the group of respondents in order to capture their immediate responses to further sophisticate and expand data samples. Additionally, the chances to succeed with this research project and fast develop validated findings raised significantly by attaining the local FSAE team as a model environment. SE is high on complexity and requires a comprehensive mindset. (Honour, 2008) When setting up a platform for our experiments, it is key to consider the available human resources and competences, to be capable of realizing such mindset change. We suspect that the industrially relevant, fresh-minded, university-backed setting results in rapid mindset development among the engineering students when it comes to SE just as Jackson et al. (2023) revealed the outstanding impact factor of university ecosystem in Entrepreneurial Mindset Development.

As initiating a fundamental organizational change, it is essential to consider the role of stakeholders, and identify which one of them will influence this transformation the most profoundly. (Laur & Danilovic, 2020; Gamble, 2020) FSAE is an environment where team identity plays a prominent role and definitely counts as an internal stakeholder. (Tjandra et al., 2021; Kolossváry et al., 2021) Therefore, we decided to involve team representatives as promptly as possible, as in the early stages success relies mainly on building support for the vision and gaining leaders' dedication to foster the change (Young et al., 2020).

The board of Team A (the FSAE team with which we cooperate and set up the SE implementation) was approached first. Fischer et al. (2020) analyze various options on how to implement a SE expert unit into an existing organization structure. As our

preliminary efforts, we presented materials introducing (i) the SE methods and tools, (ii) best practices from other industries, (iii) early-stage applications of RFLP (Requirements, Functional, Logical, Physical) model in front of the board members over 3 consecutive meetings. Once they understood the provisional benefits of using SE and got committed to the transformation, from that point on they also functioned as drivers of the change. Thus, the authors of this article teamed up with the board members and formed an Innovation Team (Johnsson, 2016). Although this part proved to be essential to set up the PAR, it was never considered as a core action to realize organizational understanding and acceptance. We decided to apply a top-down approach with the new engineering method implementation, however, as intended, applying a pull instead of push strategy. Therefore, the provisioned challenge within the implementation concerns the conviction of the 5 department leaders (heads of Chassis, Aerodynamics, Vehicle dynamics, Powertrain, and Electronics subsidiaries) and department members. The Innovation Team agreed on a milestone placed 6 months on from the moment of the kick-off meeting, that is for having a SE in use status at a semi-maturity level. The understanding and acceptance of the new methodology should be gained to a level that the targeted maturity of implementation is reached within this timeframe. Throughout the next sections we present the milestones of the implementation in a chronological order. Due to the participatory nature of our study, these steps not only consist of methods and tools, but also describe the relevant data collection circumstances including observations, questionnaires, and semi-structured interviews.

4.1. Initial implementation efforts

The Innovation Team had agreed to invite an expert to present the elementary toolset of SE and its applications within the automotive product development domain. This expert was affiliated with an automotive OEM firm, named Company A (for reasons of privacy) and works at the SE responsible branch of their whole vehicle development unit. A webinar was held in front of an audience of the Innovation team, department leaders and senior team members. The presentation brought only a few practical examples on the use of SE in a daily business. It was rather based on theories and models developed for the application of SE in the automotive product development segment. By the end of the session, 2 questions were asked, both from the members of the Innovation Team. Based on our general impressions and informal feedbacks from the audience, we assume that the SE knowledge that the presentation intended to deliver, did not make sense properly for the target audience. The importance of SE was highlighted, and thoughts were arisen, but the context and usability of the introduced SE models and techniques remained unclear. Following up this lecture, the Innovation Team agreed to organize workshops, in which all department leaders and other senior team members participate and advance with understanding and acceptance of SE methodology through the next subordinate level. Prior to the first workshop session, an online questionnaire was distributed among the participants, who were department leaders, and senior team members of Team A. We present elementary survey parameters as follows:

- Number of responses: 18 (all workshop participants)
- Filling out privacy: anonymous
- Platform: online survey, Google Forms
- Target group: workshop participants

The structure of the questionnaire was built upon our two key research aspects: understanding and acceptance. In the first part, 4 open-ended questions were added

aiming to reveal the prevailing evolution level of SE mindset in the moment of filling out the survey. These queries were based on Araujo's (2001) findings that we discussed in Section 2.1. The second part of the survey included 9 different aspects of acceptance and 9 questions were raised accordingly. These queries requested the respondent to give a score on a simple 10-point scale and indicate whether they would answer the specific question with yes (=10) or no (=1) or prefer another value in between. In other words, we aimed to express how much do the respondents agree with a specific statement that was embedded in the question. We had pre-analyzed the data before the first workshop session was organized to react on any critical attributes that might occur and address it with the workshop program if necessary. The structure of the survey is introduced by Table 2. We present the Aggregate Responses (AR), Match Rate (MR) values, and notes (if relevant) to each question points. Over the first section that addresses understanding, ARs should be considered as the most common answer given to a specific question. ARs consecutively provide extracts, which are generated through a systematic analysis of the meaning of answers and facilitate the understanding of the data. AR also serves as a reference to further analyses. In the second part, average values are added replacing the ARs. Where relevant, MR indicates the deviation of each answer from the AR and classified as "match" (MR=1), "minor disparity" (MR=0,5), and "contradictory" (MR=0).

Table 2. Example for analysis on the pre-workshop survey data

Question	AR/average	MR/-	Notes
1. Who are the key stakeholders of your team?	Sponsors, University, Competitions, Rules	0,61	Some also say: team management, and those respondents have a totally different approach to what is meant by the term stakeholders.

In the "understanding part", we experience a general lack of consensus over the responses with MR values ranging 0,44-0,75 which fact implies that the SE mindset had not evolved yet for the time of surveying. Considering the "acceptance part", we encounter low or moderate signs of affirmative responses. Respondents appear to be skeptical especially with aspects concerning sufficient resources, information received, and the implementation of SE specific tools and techniques. After data analysis we find the diversity of answers high, excepting questions subjecting need for change or learning about a new engineering model (SE). This finding suggests that team members feel the call for a model change which is induced by the fact that nowadays FSAE is facing with analogous challenges to automotive industry, in terms of the appearance of electrification, hybrid powertrains and autonomous driving,

4.2. Workshops

As agreed with the Innovation Team, we organized workshops aiming primarily the engagement of the department leaders towards the change. The workshops took part in two parts within 10 days of time. Further parameters of the workshop sessions are indicated as they follow:

- Number of participants (WS1; WS2): 20 (including 2 instructors); 19 (including 1 instructor)

- Duration (WS1; WS2): 7h 45m; 2h 0m
- Format: on-site, teamwork based
- Target group: department leaders and senior team members

Our first attempt with a frontal presentation format appeared to be barely effective. Therefore, we decided to gain the involvement of team members and transform the actual educational content to better meet the mindset of an FSAE team. The main goal of the workshop sessions was to boost understanding and achieve acceptance of SE through various exercises consisting of system and requirement architectures development as well as the formation of an SE-based organization structure including the assignment of potential positions and responsibilities. Essentially, our aim was to increase the engagement of department leaders and senior team members by involving them more into the implementation strategy creation. We assumed that feeling the involvement might make positive effects on acceptance and placing the whole workshop activity in their FSAE context might gain understanding of the SE model.

Baughey (2011) propose an essential model within the domain of SE that is called the RFLP architectures. This framework proposes a totally new viewpoint on what traditional automotive development applies. They believe developing and implementing RFLP structures will provide more capability to understand and improve the systems that manufacturers can develop and deliver. In order to facilitate the understanding and the identification of the possible benefits of the RFLP structures, an elementary "systems architecture" ought to be developed first. Second, as Aguilar et al. (2016) highlight, applying a Requirements Engineering approach should be an initial step of software development to satisfy the users' needs. As discussed, these findings should be considered as relevant due to the software-oriented composition of automobiles, and therefore, we intended to include them in our training sessions and posted such activities on the workshop agenda. We organized an on-site workshop in the office of Team A and proposed FSAE-specific exercises for the training. The most highlighted activities of the agenda were as they follow:

- Benefits of SE (part 1) – duration:15 min.: This session was scheduled to fill in multiple functions. It was an icebreaker block, in which we conducted free discussions on actual issues and frequently discussed topics of the team. By the end of the session, the conversation was diverted towards the potential benefits of SE which was approached through their actual problems. Keywords about SE benefits were noted after common deliberation and marked on a whiteboard (e.g. quality control, car and powertrain integration, task management, changing functional organizational structure, meet stakeholder demands).
- SE introduction and architecture benchmarks – duration: 45 + 30 min.: The toolset of SE as well as the philosophy of system thinking were presented using examples and best practices from or touching the automotive domain. RFLP architectures are essential elements of SE techniques, and we introduced examples based on models presented by Friedenthal et al. (2014).
- Elementary systems architecture creation and assembly – duration: 25 + 20 min.: We asked participants to form teams of 3s in which at least 1 Innovation Team member is assigned to each team. Then, teams were about to develop draft systems architectures for the whole FSAE car. Following a 15-minute brainstorming section, all groups presented their solution. Then, we evaluated the sample structures and assembled a whole aggregated structure utilizing all groups' solutions.

- Benefits of SE (part 2) – duration 15 min.: After performing introduction sections to all participants, including those, who had no background knowledge on SE, the potential benefits of SE were asked again. Keywords were promoted to complete the collection developed in the first part of "Benefits of SE": improve team members' involvement, decision supports, top-down approach, more effective organizational processes.
- Elementary requirements architecture creation and assembly – duration: 25 + 20 min.: We followed the same approach to the "Elementary systems architecture creation and assembly" section.
- Systems and requirements architecture creation and assembly – duration: 60 min.: In this section, we attempted to create real architectures submerging 2 sub-systems level below the system of systems level. Departments formed groups and worked out their own structures to systems and requirements architectures. Then, we discussed and assembled together to finally develop simplified systems and requirements architectures for their whole product, the FSAE racecar. This section proved to be especially instructive as it revealed some elements and cases of requirements that need to be linked with more than one system unit. These examples lead to deliberations and decisions in which SE can prove its values and bring new techniques and tools (e.g., SysML language, application of RFLP structures) into use. The first workshop session concluded with a round of feedback (duration: 15 min.) in which everyone posted their thoughts on the session, the approach, SE, opportunities of the new method in their domain, and suggestions for further actions. Some of the feedbacks were: "Benchmarks from the automotive field were instructive"; "It was fantastic to be able to work with our structures applying some SE principles"; "It would be useful to learn SysML language and use it in the upcoming project phase"; "Specifying the SE-based team roles would be necessary as soon as possible". The workshop agenda was appropriately complemented with short and lunch breaks as well as with a team building leisure event as a closing activity of the day.

All participants unanimously agreed on a next session that is scheduled within 10 days. The agenda for workshop session 2 consisted of the following activities: Briefing and discussion (15 min.); Requirement architecture overview, discussion on further proposals and development directions (30 min.); SE-based organization presentation (15 min.); SE roles and positions – discussion and description in groups of 3 (15 min.); SE roles and positions – summary (45 min.); Feedback and evaluation (15 min.). In this second workshop session, we overviewed the tree-structures of the recently developed sample system and requirement architectures. The process on understanding the new design philosophy was apparent. Discussions on technical aspects of the new engineering method was deep and progressive. The second part also highlighted the organizational aspects of SE implementation. SE managerial roles were designed and filled up with tasks that fits with the primary activities of the team, but still carry the SE characteristics. As a closing of all workshop activities, we saved some time for sharing overall impressions, thoughts, and proposals about the sessions. All opinions popped up throughout the workshop were noted. Our records include thoughts as they follow: "we need to use a software that facilitates the development of our structures"; "The organizational transformation should be started with the assignment of a Verifications Manager"; "We also need a Systems Engineer from the team who can coordinate the entire transformation process internally".

As a follow-up activity after the workshops, we proposed a post-workshop survey, in which the respondents were asked with the very same questions as in the

pre-workshop form. Thus, we could conduct a comparison analysis between two phases of the implementation, before and after workshop. Results facilitate to reveal the impact of the workshop sessions on the assessment of the gain on understanding and acceptance. Survey results have been analyzed with the same methods used in section 4.1. Hereby we present some elemental details about the questionnaire as follows:

- Number of responses: 16 (all except 2 workshop participants)
- Filling out privacy: anonymous
- Platform: online survey, Google Forms
- Target group: workshop participants

The online form was filled out on the week following the second workshop session. In the briefing section, respondents were informed that they should consider questions according to the plans and processes which determines the current operation of the team and its short-term plans. Overall, AMR values increased and evaluation patterns appear to be less variable than at the pre-workshop survey. A certain extent of systems thinking is already traceable, especially in goals and requirements setting. In general, respondents suggest deriving goals from previous year performance and express in the average amount of scores achieved in the season. Some already mention the “importance of top-down approach in goal setting” as an approach that is urged to be applied. In terms of stakeholders, a new item was identified: team identity. This term already appeared in our discussions during the workshop sessions, as team members agreed that this phenomenon is something the team of all time should work for and satisfy some special requirements e.g., evolution-based design, high quality manufacturing, smart solutions, etc. Among the answers the “5 sub-systems" and the “structural approach” terms were more frequently used. Respondents still found that they lack resources to implement the new engineering method. In sum, data suggest that the implementation activities gained a positive impact on both understanding and acceptance domains, but further clarifications and more detailed information are needed to thoroughly analyze influencing factors and practices that contributed on the seeming improvement

4.3. Interviews

The pre- and post-workshop surveys were designed to reveal elementary information on the circumstances of understanding and acceptance, plus, indicate the direction of the presumed development on these aspects. However, we assume that a profound knowledge could only be gained if not only clean information but also, emotions, vibrancies and biases are captured. In-depth interviewing is a tool that enables us to analyze these factors thoroughly. Therefore, we conducted semi-structured interviews involving all department leaders and a board member (6 senior team members in sum) to verify the data collected in the pre-and post-workshop surveys and try to capture additional insights. Prior to the interview sessions, respondents were faced with the aggregated results of the surveys. The aim of the data collection applying the semi-structured interview technique is to reveal detailed information on the determinants that are behind each aggregated answer, and gain confirmation or rejection on our intermediate findings at each query. Interview outcomes are presented by Table 3

Table 3. Interview protocol and aggregated results with MR values

	Question	AR	MR
	Understanding		
1	What do you think about the importance of identifying stakeholders? Is it an easy task?	Important, but their requirements are not always straightforward. We should focus more on this as stakeholders establish success.	0.67
2	Why is the comparison of a current project with the previous year experiences so dominant when setting new goals for the season? What are the predominant aspects that you consider in goals setting for the next period?	To secure our evolutionary design strategy, we need to consider previous years as a benchmark. When setting goals, apart from strategy, FS rules and recent trends are equally important. We should follow a top-down approach.	0.92
3	What do you mean by component architecture? Why could the responses on this be so diverse in the survey? Do you think that you should use component or system architectures?	It was not properly understood what is meant by them. Component architectures are visual maps of car parts, breaking down all sub-systems to lower levels and indicating the "horizontal" links.	0.83
4	Do all team members including managers agree that the application of a well-designed verification system is a must?	Needed ASAP. A well-designed verification system is a must. Also important in terms of quality assurance and reliability.	1.00
	Acceptance		
5	Do you find necessary to use Systems Engineering?	Yes, it should be used, but first be fitted to the team's structure and strategy. SE team roles and tasks could improve work effectiveness and lead to better products.	0.83
6	What were the root causes of the initial skepticism against SE and how could we dispel the doubts?	Team members had not been properly informed about SE before the workshop and the available info was too abstract to understand and accept SE.	0.75
7	Reportedly, the team does not have enough resources to their plans, and it sets back the implementation of SE. Do you agree with it?	Quantity-wise there are enough team members, however they struggle with the lack of management competences.	0.58
8	Expectations on usability of SE raised after the workshop,	An FSAE specified SE model could be applied properly. Different	0.75

	Question	AR	MR
		Understanding	
	this aspect is still divisive. Why? What is your point on the in-practice applicability of SE?	opinions arise, personalities differ and people tend to insist on doing tasks they are used to.	
9	Do you agree that SE tools and methods are easy to use in your work?	An SE model (tools and methods) which corresponds the elementary circumstances and goals of an FSAE team should work.	1.00
10	The general level of SE understanding raised from 4,89 to 8,8. What caused the increase in this magnitude?	Workshop was effective due to its learning-by-doing approach and the numerous examples on how-to-use SE.	1.00
11	It seems you had had a demand for changes before the SE implementation started. What is your motivation on that?	Positions and team roles should be better defined. Project management should improve. The team had demanded such improvements.	0.83
12	More people know in practice applicable SE techniques after the workshop than before. Do you agree with it?	Yes, first and foremost the architectures.	0.83
13	Do you prefer to learn about new Systems Engineering based tools and methods and apply them in your work?	Yes, sure. Focus should be put on the effectiveness improvement in process and resource management, and architecture development.	0.92

As the aggregated interview results indicate, the majority of MR values range from 0.75 to 1, except the two outliers, 0.58 (Question 7) and 0.67 (Question 1). At Question 1, answers do not contradict with each other, but many of them suggest that respondent applied different approaches with their answers. Unlike Question 1, the responses at Question 7 show contradictory records. A department leader claims: "I agree that we struggle with the lack of resources for transforming the organization according to SE principles. This is due to the scarcity of project management competences." On the other hand, another department leader finds that "we do have the resources, declaring the lack of resources is just an excuse". At other measurement points we experience high MR values in general, which fact implies that these records incorporate heterogeneous answers, in other words, reliable data. This particularly applies to questions 4, 9, 10, at which each response appears to conform with the others.

5. Results

5.1. Initial attempts: presentation and pre-workshop survey

Once we have processed multiple actions of the implementation, collected data should be placed in a perspective and reviewed in a context of the improvement

gained on understanding and acceptance. Research 'Question 1' proposes to reveal what the establishment of understanding and acceptance depend on when it comes to the implementation of a new engineering model in automotive product development practice. The effectiveness of a lecture type presentation appeared to be low, despite the presentation of an expert highly qualified in SE, and the overall thoroughness of the material. The presentation topic and examples were set in an automotive product development setting, however differed from the actual FSAE environment. After discussions conducted with Team A members, who listened to the presentation, we learned that the content was too abstract and hard to interpret in an FSAE setting. Looking at the pre-workshop results, it appears that the answers revealing the actual status of understanding were diverse, ending up in low MR values. This fact suggests that a decent share of respondents did not have a common understanding on what SE is. In terms of acceptance, we find similar patterns, implying to moderate results on accepting the new SE model. Apart from the learning willingness (Question 13) and the need for SE (Question 5) subjects, records show that respondents are somewhat skeptical, which condition is not adequate for a successful implementation. In sum, the first attempts have not delivered traces of willingness to conduct the organizational transformation in the required extent.

5.2. The way to adoption: the role of employee involvement

The workshop sessions proved to bring the expected outcomes by applying a learning by doing approach and involving participants into exercises and eventually, into the development of their own potential SE model. Simultaneous working on system and requirements architectures and creating them involving all department leaders already revealed hidden interconnections between certain sub-systems (e.g., cooling system: drivetrain and aerodynamics). At this point we observed an attitude change among the team members. Playing with their own architectures, especially during the sections in which they designed system trees for their own department, raised their interest and enlightened their view on SE. At the end of the first session, participants asked for follow-ups and future workshop sessions. They also expressed their interest in learning about other techniques, for instance about those, which facilitate effective stakeholder identification and requirements recognition. These phenomena have been validated by both the post-workshop survey results and the in-depth interview outcomes. The post-workshop survey results suggest two major findings: (a) aggregated results show an apparent improvement on general understanding and MR values indicate that the homogeneity of the answers has also increased; (b) judgement of acceptance has improved in a similar rate. The evolvement of the SE mindset already appears in the understanding section of the post-workshop survey records: "components are managed in architectures"; "5 sub-systems"; "role of the requirements manager, and the architect". In the in-depth interviews, department leaders provided a detailed explanation on their view of the pre- and post-workshop survey results. Additionally, they added their thoughts meticulously to each point of the query. Importantly, they highlighted the role of architecture design activities at the workshops, in which they could work on structures processes that is applied for their very project. This fact led to a significant raise in both understanding and acceptance levels (Questions 9 and 10). The workshop sessions influenced their goal setting strategy, however they still insist on their benchmarks with the previous seasons. The key role of verification activities in reaching their goals has been recognized and fully supported. Team A had not applied any comprehensive verifications strategy before, nor assigned a person in charge for it. These observations suggest that there is a great improvement in

understanding, however recognizing stakeholder demands and effectively managing them still appears to be a challenge. Acceptance seems to improve significantly as well, primarily due to the specific setting of the implementation to FSAE context and the experimental design activities with their own architectures. Despite the seeming success, at the point discovering "sufficient resources", we find contradictory responses. However, from the individual answers, it turns out that this is more traceable to the generic fluctuation that is specific to FSAE: "experienced senior team members tend to leave their position for a career move into the industry". We find that the workshop (considering the two sessions as one event in the implementation process), has given a break-through moment in terms of the evolution of the SE mindset. As it turns out from our records, the effect of the improved understanding and acceptance of SE is perceptible on strategic, structure and processes levels as well. Table 4 indicates the summary of proof of improvements gained by the raise of understanding and acceptance in the context of these essential organizational aspects.

Table 4. Realization of understanding and acceptance improvements on strategy, structure, and processes

Level	Understanding	Acceptance
Strategy	Increased activity in collecting buzzwords on SE benefits during the workshop; Identification of new stakeholders; Identifying the need for more efficient quality management	Openness to learn more about SE; Asking for SE trainings involving all team members
Structure	Realizing the need for applying a top-down approach in requirements management; Facilitation of the development of horizontal links in the organizational structure	Introduction of new roles: Verifications manager; Reviewing the tasks of Chief Engineer and Project Manager; Considering the introduction of Architect and Requirements manager
Processes	Development of a new verifications protocol for all system-levels throughout the whole concept	Intention to apply RFLP architectures in their everyday practice; Asking for methodological support in RFLP architectures development

6. Conclusion

The implementation process has not been concluded yet, however we believe that the involvement of team members in key positions has made a positive impact to the leap that we realized in the evolution of the SE mindset and in the acceptance of the new SE engineering model. We find that in the implementation of a SE-based new engineering model, the understanding and the acceptance of the new framework can be improved by: (a) involving employees into the phase of specializing and shaping the new model; (b) applying a learning by doing approach; (c) playing with architectures of their own product; (d) facilitating the discovery of hidden connections and synergies between various sub-systems. Ideally, all these proposals should be applied, however having any of these actions is likely to lead to positive effects. Therefore, we propose an additional item to Araujo's (2001) factors on low level of acceptancy of new engineering methods, that is "Lack of involvement". This appears when members of the actual target organization, which is subjected to the

change are not involved in the model development and shaping process. General grade of acceptance raised to a level that team members asked for further actions with the implementation. As the result of our early implementation efforts, the interest of Team A on applying SE has been raised. Team members in key positions unanimously understood the fundaments of SE and an elementary level mindset has been developed. As a part of this implementation journey, the architecture design activities, including systems and requirements architectures, gained a break-through moment considering the entire implementation process. We suggest that an automotive product development unit, seeking SE methods, should approach an organizational implementation process by focusing on the fast improvement of understanding and acceptance factors, on which we found tested and presented techniques that worked in a relevant model environment of automotive product development.

These findings might provide a significant theoretical contribution to Fischer et al. (2020), and complement their proposals on implementation processes and structures by practical outcomes and good practices developed in the specific target environment. Also, employee involvement might facilitate the elimination of cognitice bias with some new techniques gaining understanding at an early stage of implementation. (McDermott et al., 2020)

Considering the impact for practitioners, these findings can contribute to automotive firms to re-examine their product development approach to recover or further improve their competitiveness in the new era, driven by altered stakeholder requirements. In an extended perspective, the outcomes of this study on gaining understanding and acceptance might support any model changes and organizational transformations proceeding in other industrial segments, including university ecosystems, which have been increasingly concerned with their entrepreneurial third mission over the traditional research and educational roles.

7. Limitations and future research

Beyond the theoretical and practical contributions, this study has some limitations, which should be considered at a future research of this field. First, the number of interviewees could be extended to all participants of sessions held to support the understanding and acceptance of SE. Second, the involvement of industry in order to sophisticate results and re-confirm their validity would raise the reliability of our findings presented in this paper.

In a future research, we recommend a thorough assessment on the entire implementation process with a particular regard to its maturity level. Such research could also raise the validity and recognition of our current results and the presented techniques on gaining understanding and acceptance, plus, it would indicate the actual status of the implementation process, which could specifically aid practitioners identifying their progress status and assess their own results in conducting a SE implementation.

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