MANAGERS' UNDERSTANDING OF AGILE IN HARDWARE DEVELOPMENT

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ABSTRACT

The agile methodology is gaining attention among practitioners and researchers in hardware development. As a new methodology, it is a source of misunderstandings and misinterpretations. This is problematic at the managers' levels as they may hinder its adoption or lead to its impractical implementation and use. This study, therefore, aims to explore the manager's level of understanding of the agile methodology. The study identifies the similarities and differences between the fundamental elements of the agile methodology and the elements mentioned by managers in hardware development. The fundamental elements of the agile methodology are identified based on the elements presented in the Scrum method; the elements mentioned by managers are identified based on ten semi-structured interviews with managers in hardware development. The study shows that the understanding of the agile methodology varies largely among managers. The obtained detailed insights in the managers' level of understanding of the agile methodology could be used to develop appropriate support to facilitate its adoption and implementation.

Keywords: Agile hardware development, Scrum, New product development, Organisation of product development, Case study

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1 INTRODUCTION

The agile methodology has gained increasing attention among practitioners and researchers in hardware development[1] (Conforto *et al.*, 2014; Cooper and Sommer, 2018). Companies in the manufacturing industry have begun to adopt it to cope with the fast-paced environment in which they operate (Marzi *et al.*, 2021; Cooper and Sommer, 2018). The benefits and challenges of the agile methodology in hardware development have been reported in several works (Schmidt *et al.*, 2019; Cooper and Sommer, 2016; Sommer *et al.*, 2015). As a new methodology for hardware development, one of the challenges presented is lack of understanding of it (Schmidt *et al.*, 2019). While lack of understanding is problematic at all organizational levels, it is especially pregnant at the managers' level, who are responsible for the adoption, implementation and use of the agile methodology. In an industry survey of manufacturing companies, Schmidt *et al.* (2019) reported that the lack of understanding by middle and top management were ranked as the third and fourth most significant challenges out of twenty-two. As a consequence of this challenge, some managers tend to be sceptical of the benefits of the agile methodology (Cooper and Sommer, 2018; Zasa *et al.*, 2021), thus hindering its adoption; other managers instead tend to have very high expectations in terms of benefits (Schmidt *et al.*, 2019), which can lead to its impractical implementation and use, potentially resulting in frustration and loss of motivation. Some works have started to tackle this issue. For instance, Zasa *et al.* (2021) identify managerial workshops as a way to engage managers and increase awareness of the benefits of agile methodology; for managers used to the Stage-Gate model, Cooper and Sommer (2020) propose metrics to help measuring the progress of agile projects. However, these works are of an explorative nature and few in number.

Importantly, little is known about the details of the managers' level of understanding of the agile methodology. A better insight in that aspect could be used as a basis to develop in a more systematic manner adequate support for managers to alleviate the lack of understanding of the agile methodology. The present study seeks to explore the manager's level of understanding of the agile methodology, and therefore aims at answering the following research question: *What are the similarities and differences between the fundamental elements of the agile methodology and the elements mentioned by managers in hardware development?* To this end, a qualitative research methodology, based on semi-structured interviews of managers of a global manufacturing company, was adopted. The present study is limited to the Scrum method, by far the most employed method in hardware development (Atzberger *et al.*, 2020). The fundamental elements of Scrum are described in *The Scrum Guide*, a vade mecum written by Schwaber and Sutherland (2020), the founding fathers of the method. The guide is used in this study as basis for identifying the similarities and differences between the fundamental elements of the agile methodology and the elements mentioned by managers in hardware development.

The article is structured as follow. Section 2 presents the fundamental elements of the Scrum method and provides insights into the benefits and challenges of the adopting, implementing, and using the agile methodology in hardware development. Section 3 presents a description of the research methodology followed in the study. Section 4 presents the data analysis and the study findings. Section 5 presents the interpretations, implications, and limitations of the study findings.

2 THE AGILE METHODOLOGY IN HARDWARE DEVELOPMENT

2.1 The agile methodology: The fundamental elements of Scrum

Agile methodology is an umbrella term to refer to several methods (e.g., Scrum, eXtreme Programming and Dynamic System Development Method) intended to improve software development (Beck *et al.*, 2001). One of the most well-known methods is Scrum (Schmidt *et al.*, 2019). It was developed in the early 1990s and is described in *The Scrum Guide*, a vade mecum written by the method's founders Schwaber and Sutherland (2020). Scrum is described in prescriptive terms. In *The Scrum Guide*, Schwaber and Sutherland (2020) point out that "changing the core design or ideas of

[1] As Schmidt et al. (2019), we use interchangeably the terms “hardware development” and “development of physical products” to refer to the development of products that bear a physical nature.

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Scrum, leaving out elements, or not following the rules of Scrum, covers up problems and limits the benefits of Scrum, potentially even rendering it useless" (p. 1). Scrum is described by four components: Values, Team, Events, and Artifacts, each of which is composed of several elements. A good understanding of Scrum fundamental components and elements is therefore important for its adoption, implementation and use.

Values: This component is based on five elements, namely commitment, focus, openness, respect and courage. Commitment means that the Scrum Team is committed to achieving the goals and supporting each other. In addition, the Scrum Team must be focused on the work and the goals of the Sprint. The Scrum Team members must respect each other as independent and capable people. Finally, the Scrum Team must have the courage to work on problems and do the right things.

Team: The elements of the Team component refer to the characteristics of the Scrum Team and its roles. The Scrum Team is a small group of people (usually less than ten people) who are responsible for all product-related activities. The Scrum Team has no subteams or hierarchies; it is cross-functional, meaning it has all the skills needed to develop a task; and it is self-managing, meaning the team decides who does what, when and how. The Scrum Team consists of the Developers, who are responsible for creating a useful increment in each Sprint; the Product Owner, who represents the needs of the project's stakeholders and is responsible for effectively managing the Product Backlog; and the Scrum Master, who helps the organization understand Scrum fundamental components and elements and improve Scrum practices.

Events: Scrum consists of a series of events: Sprint Planning, Daily Scrum, Sprint Review and Sprint Retrospective, which are all part of the Sprint. All events take place in the same place to reduce complexity and Sprints have a fixed length to create consistency. During Sprint Planning, the team decides on the work to be done during the Sprint by selecting items from the Product Backlog. The team also sets the Sprint Goal that must be achieved by the end of the Sprint. The Daily Scrum is a daily 15-minute meeting to review progress towards the Sprint Goal and adjust the work that needs to be done. Towards the end of the Sprint, the Sprint Review takes place. At this event, the team presents the Sprint deliverables to the key stakeholders, reviews them, and decides on adjustments based on changes in the environment; these changes are recorded as modifications in the Product Backlog. The fourth and final event is the Sprint Retrospective, where the team discusses its interactions, processes and tools to find ways to improve its quality and effectiveness.

Artifacts: They represent the work and are used to enhance the visibility of key information. Each of the artifacts is linked to a commitment to increase focus and measure progress. The first artifact is the Product Backlog. It is the source of the work that needs to be done by the Scrum Team and is presented as an ordered list of items needed for the product. Its associated commitment is the Product Goal, which represents the future state of the product. The second artifact is the Sprint Backlog. It is an actionable plan for the Developers and consists of a set of items from the Product Backlog for the Sprint. Its associated commitment is the Sprint Goal, which is the exact work that the Developers must have completed by the end of the Sprint. The third and final artifact is the Increment; it is described as the steppingstone towards the Product Goal. It must work together with the previous increments and create value. The commitment associated with the Increment is the Definition of Done, which is a description of the Increment once it has met all the quality criteria required for the product.

2.2 The agile methodology in hardware development

Led by the positive results in the software industry, the adoption, implementation and use of the agile methodology, especially Scrum, in hardware development is gaining interest among researchers and practitioners (Marzi *et al.*, 2021; Conforto *et al.*, 2014; Cooper and Sommer, 2016). Nevertheless, when adopting, implementing and using the agile methodology in hardware development conditions change and challenge the basic premises and foundations of the methodology. Hardware development still relies on Stage-Gate management models (Cooper and Sommer, 2018); therefore, several authors have studied the integration of the Stage-Gate model and agile methodology ,i.e., Edwards *et al.* (2019), Sommer *et al.* (2015), and Conforto and Amaral (2016). While the Stage-Gate model is used at the strategic level, the agile methods are applied at the execution level. On the one hand, Stage-Gate

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consists of phases, milestones, and macro-deliverables for the project (Edwards *et al.*, 2019); it is used to monitor project progress and coordinate the project portfolio (Sommer *et al.*, 2015). On the other hand, the agile methodology is adopted by the development team to structure the execution of the project (Sommer *et al.*, 2015; Cooper and Sommer, 2016). It is associated with iterative development and decomposition of macro-deliverables into tasks or small deliveries (Conforto and Amaral, 2016).

The results of previous studies conclude that the adoption, implementation and use of the agile methodology in hardware development is possible and beneficial, albeit with challenges (Schmidt *et al.*, 2019; Cooper and Sommer, 2016; Sommer *et al.*, 2015). Benefits include better communication and knowledge sharing within the team, flexibility and responsiveness to changing requirements, and team motivation (Sommer *et al.*, 2015; Schmidt *et al.*, 2019). Nevertheless, it is associated with some technical and organizational challenges. These include the necessary modifications of the methodology to be suitable for hardware development (e.g., constraints on physicality), allocation of full-time teams, changes in organizational culture, and the establishment of an 'agile' mindset (Cooper and Sommer, 2016; Conforto *et al.*, 2014).

Managers seem to be the most important stakeholders in the implementation and use of the agile methodology (Edwards *et al.*, 2019). They are the ones responsible for facilitating and implementing the required organisational and technical changes. Their understanding of the methodology is critical; a lack of it can lead to scepticism (Cooper and Sommer, 2018), poor methodology customization, micromanagement and frustration (Dikert *et al.*, 2016). All of these can hinder the adoption, implementation and use of the methodology. The reviewed studies that have highlighted this challenge (Cooper and Sommer, 2016; Cooper and Sommer, 2018; Dikert *et al.*, 2016; Schmidt *et al.*, 2019) have not, however, given a detailed account of the managers' level of understanding of the agile methodology, which would help developing appropriate support for managers to mitigate this issue. Further research is needed in that domain, which motivates the present issue.

3 RESEARCH METHODOLOGY

This study is based on a single case study, which allows for intensive exploration and in-depth description of the studied phenomenon (Yin, 2018). It helps to reduce extraneous variation (Eisenhardt, 1989) because it is ensured that all interviewees belong to the same organization, work with similar projects, and are trained on the same formalized development methodology. The case was selected based on a typical case rationale (Yin, 2018) because it illustrates the adoption, implementation, and use of the agile methodology in hardware development. The selected case is a large global manufacturing company that provides products and services to customers in various industry segments such as medical, oil, automotive, etc. The company is on an agile transformation journey which seeks to adopt, implement and use the methodology in the whole organization; this study focuses on the hardware development part of it. The company has decided to adopt, implement and use the methodology while maintaining its organizational structure and Stage-Gate model.

The data collection was based on semi-structured interviews and study of documents. A total of ten interviews were conducted with eleven interviewees. All the interviewees are hardware development managers (including project managers, line managers, senior managers, among others). They are involved in the company's initiative to adopt the agile methodology in hardware development. The interviews followed a predefined interview guide that included open-ended questions to gather information about the interviewees' experiences in adopting the agile methodology. The interviews were conducted digitally and in English; they lasted about 60 minutes. Two researchers and one interviewee were present at each interview, except for one interview where two interviewees were present. The interviews were audio/video recorded and transcribed. Documents were used as data sources to corroborate or supplement the data collected in the interviews. Documents included the company's digital material on organizational structure, representation of management models, and presentation of adoption initiatives.

The data analysis followed the general Qualitative Data Analysis Process proposed by Miles et al. (2020). The data were analysed using an inductive approach in three steps. The first step was to assign

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codes to the transcripts. The assigned codes retained the interviewees' own terms, thus foregrounding their voices. The second step was to group the codes according to their word and content similarity. At the end of the second step, a total of twenty-one codes were assigned; they represent the elements of the agile methodology mentioned by the interviewees (managers). The resulting codes are shown in Figure 1. The identification of the codes is supported by the quotes from the interviewees shown in Table 1. In the third step, the codes identified in the previous step were compared with the fundamental elements of Scrum described in the literature. As a result, similarities and differences between these elements were identified. Figure 1 shows the steps followed in the data analysis. The steps were carried iteratively and involved several discussions within the research team to ensure their coherence and relevance to the study; that was supported by the use of a qualitative data analysis software.

4 DATA ANALYSIS AND FINDINGS

4.1 General findings

A total of twenty-one elements are mentioned by the interviewees. Most are connected to the Scrum elements, but some have no obvious connection, and some Scrum elements are never mentioned, see Figure 1. On average, each respondent mentions between five and six elements (with a range of one to fourteen elements per interviewee). Each element is mentioned by an average of two or three interviewees; only one element, Sprint-based planning meeting, is mentioned by ten interviewees. Most of the elements mentioned by the interviewees have a related fundamental element of Scrum or can be connected to a Scrum component. An exception is modularized design, which was mentioned by the interviewees but is not a fundamental element of Scrum. This element has to do with designing and working with products based on modules or subsystems. According to the interviewees, this element supports the shortening of learning loops by speeding up feedback between teams and early rejection of inappropriate solutions. Further similarities and differences are presented below.

4.2 Values: similarities and differences

In terms of values, the interviewees mention four elements: commitment, responsibility, proactivity, and trust. Regarding commitment, it was mentioned that the team members must be committed to carrying out all planned activities in order to achieve the Result Definition (see Section 4.5). According to the interviewees, in the agile methodology, each team member chooses activities to perform, which leads to strong individual commitment. This is related to the second element: responsibility. The interviewees emphasize the importance of having responsible team members in order to build teams with mandate to make decisions. They point out that the responsibilities of each team members need to be clarified. In addition, the interviewees claim that the agile methodology requires proactive individuals, i.e., members who propose ideas to improve or change situations. Finally, regarding trust, the interviewees say that the agile methodology requires a shift from trust in documentation to trust in the development project and its progress.

Two connections can be made between the elements mentioned by the managers and the fundamental elements of Scrum. Commitment is a fundamental element of Scrum and it is mentioned by the interviewees. Another connection can be made between proactivity and courage. Both elements put emphasis on people dealing with problems and trying to contribute ideas to solve them or improve situations. Apart from these similarities, the values of focus, openness and respect are not mentioned by the interviewees.

4.3 Team: similarities and differences

In relation to the Team component, the interviewees mention that agile teams must have all the competences, capabilities and resources needed to complete a task. In addition, teams must work in a collaborative way, so that feedback can be transferred more efficiently between the involved organizational units. These elements can be related to the cross-functional team, a fundamental element of Scrum. However, the interviewees go a step further by pointing out that not only skills but also fully dedicated resources, including personnel and machinery, are needed.

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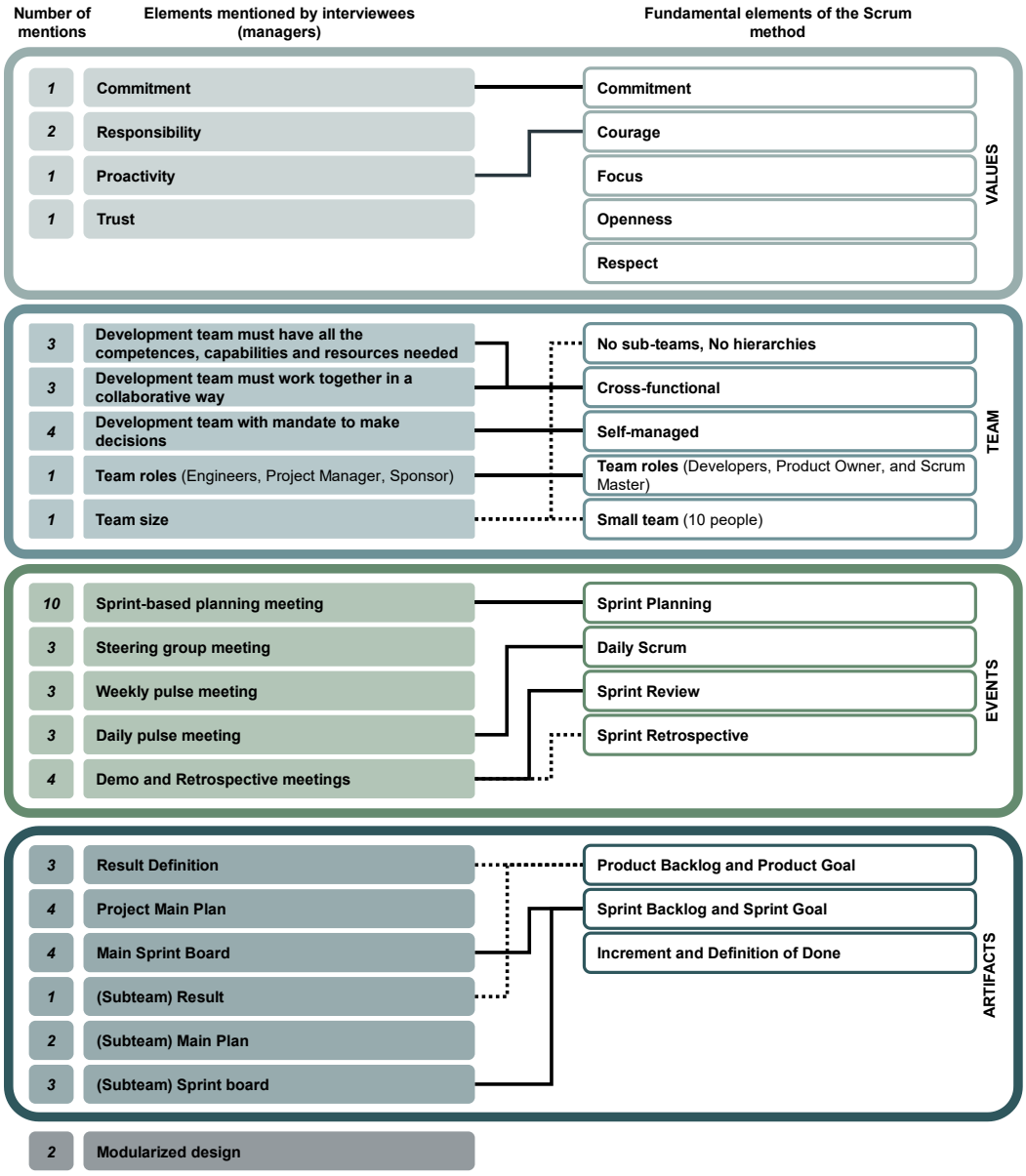

Figure 1. Comparison between elements mentioned by the interviewees and fundamental elements of the Scrum method. The solid links represent a strong connection between the elements, while the dashed links represent weak connections.

Table 1. Interviewees quotes

Component	Interviewee quote
Values	"So, this is important to change from a culture where people complain about things going wrong to actually act and do something, actively do something to change and try to make sure that it does not happen again." Interviewee 08
Team	"I mean, and then the team has all the mandate to take decisions to reach the goal regardless how they do it, right? So that is a bit agile for me." Interviewee 11
Events	"So, we're still dependent on a regular set deadline but in that time period of the project timeline, we have divided into Sprints and would like to deliver results all the time, small things. And in that Sprint, we have this normal process of agility, sort to say, or Sprint Planning, working in the Sprint, Demo, Retrospective." Interviewee 09
Artifacts	"It should be a result that makes sense that you can be proud of telling your colleagues about, that could be important for them, but the main thing is also that we get empowered and are proud by ourselves to tell someone that we have done this." Interviewee 09

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In addition, the interviewees mention that the team must have the mandate to make decisions. In their opinion, this is a departure from other product development methodologies or models where the project manager is responsible for planning the work of the whole team. This element is related to self-managed teams, the fundamental element of Scrum, which states that team members are responsible for planning, defining and describing the tasks to be done. Nevertheless, the interviewees mention that the self-management of the team is limited: the team can make decisions as long as they do not interfere with the requirements of the project or take up more resources than those allocated for it.

In terms of team roles, the interviewees mention the Project Manager, who is the responsible of driving the project from start to finish, and the Sponsor, who is responsible for the project's cost budget. They also mention the Steering Group, which approves the projects' decisions passages. However, the Steering Group is not part of the team. Although not explicitly mentioned, there are similarities between the fundamental roles of Scrum and those mentioned by the interviewees. For example, the responsibilities of Project Manager and Sponsor could be related to those of the Product Owner. The Scrum Master is not mentioned by the interviewees. However, in the studied case, it is the Change Leaders who explain the agile methodology in the organization.

Although small teams without subteams or hierarchies are presented as fundamental elements of Scrum, according to the interviewees, development teams consist of about 40 to 60 people. These teams are divided into subteams of about 15 people.

4.4 Events: similarities and differences

The third component is Events. First of all, the Sprint-based planning meeting is the most frequently mentioned element by the interviewees. This is a planning meeting in which the team determines the activities to be performed in each of the Sprints according to the main project plan (see Section 4.5). In addition, the interviewees mention the use of Daily pulse meetings. Similar to fundamental element of Scrum, Daily Scrum, this meeting is used to monitor progress on project deliverables and to ensure that the project is on track. Finally, Demo and Retrospective meetings are often mentioned together without distinguishing between them. They are described as information-sharing and learning meetings in which the development team presents the results of the Sprint to other stakeholders. Although these meetings are similar to the fundamental element of Scrum Sprint Review, they do not count with the presence of customers.

The interviewees mention other meetings that are not presented as fundamental elements of Scrum. First, the Steering Group meetings: these meetings are focused on decision points and prioritization of projects. Several managers attend these meetings. Second, the Weekly pulse meetings: during such a meeting, managers define the requirements of the customers and the technical performance demands of the product and raise issues that can jeopardize the projects from a functional, time or cost perspective.

4.5 Artifacts: similarities and differences

The artifacts mentioned by the interviewees are presented and articulated in Figure 2. First, the interviewees mention the use of a Result Definition, i.e., a description of the project result, in other words, what they want to achieve at the end of the project. The Result Definition is then broken down into several results. These results are presented in the Project Main Plan. It shows the overall long-term plan of the project, which is divided into several Sprints of four to eight weeks duration, with a result assigned to each Sprint. Based on the Project Main Plan, each subteam has its own Main Plan, the (Subteam) Main Plan. It is also divided into Sprints and shows the activities and results that the subteam needs to do for the project. If one relates the above elements to the fundamental elements of Scrum, one can see a connection between Result Definition and the Product Goal, because both are a description of the end result that needs to be achieved during the project, the product. Although the Product Goal is the commitment of the Product Backlog, the interviewees do not mention any element that reflects the latter, they use the Project Main Plan instead.

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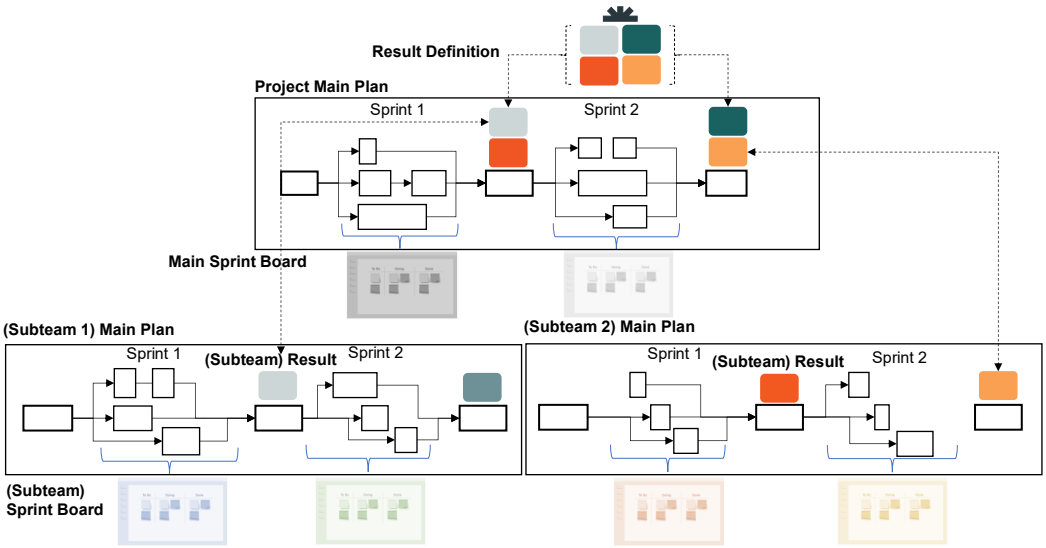

Figure 2. Artifacts mentioned by the interviewees.

A Main Sprint Board is used for each Sprint in the Project Main Plan. This is a white board that contains the work that needs to be done during the Sprint to achieve the result of the Sprint. The Main Sprint Board is used by line and project managers to discuss the dependencies of the results. Based on the Main Sprint Board, each subteam has a (Subteam) Sprint Board. It is also a white board and contains the tasks that each member of the subteam must perform to achieve the Sprint result. At the end of each Sprint, each team member presents their results. These can take various forms, such as diagrams, quality measurements, live demos, videos, design modules, etc. The most important feature of the results is that they are something that the team members can be proud of and that can be useful for other subteam members. In relation to the fundamental elements of Scrum, both the Main Sprint Board and the (Subteam) Sprint Board can be connected to the Sprint Backlog as they are actionable plans for the team. Since everything is planned via the Project Main Plan, there is no notion of Increment, nor Definition of Done, in their original sense.

5 DISCUSSION AND CONCLUSION

5.1 Interpretation of the findings

Regarding the general findings, one striking result is the disparity observed between the interviewees. One mentioned only one element, while another mentioned fourteen elements. In the reviewed literature, "management" is considered a homogeneous group, but this study shows differences in the understanding of the Scrum method. The number of mentions is also unevenly distributed among the Scrum components: Very few interviewees talked about Values, mentioning instead Teams, Events, and Artifacts. Sprint-based planning meeting seems to be the only element shared among most of the interviewees, which seems to imply a limited common understanding of the method.
From the study of the similarities and differences between the fundamental elements of the Scrum method and the elements mentioned by the managers, two interpretations seem to emerge. Most of the values are omitted by the interviewees, some elements such as the Sprint Backlog seem to have been modified (burn-charts or cumulative flows are not used), and some seem to be remnants of the control paradigm of the Stage-Gate model (e.g., the managers set certain limits to the teams' decision-making scope). This interpretation goes in the direction of supporting earlier results regarding a certain lack of understanding, at least of familiarity, with the Scrum method (Cooper and Sommer, 2016; Cooper and Sommer, 2018; Dikert et al., 2016; Schmidt et al., 2019).

Nevertheless, many of the deviations from the fundamental elements of the agile methodology seem to find their origin in the hardware development context presented in Section 2.2. Managers mention the use of large teams divided into several subteams, each specialised in a particular competence. This large team size is due to the highly multidisciplinary nature of hardware development. The different forms that the Results can take makes the challenge of presenting a prototype at the end of each Sprint tractable. The additional Steering Group meeting finds its justification in the fact that the company

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under study still partly relies on the Stage-Gate model as practiced in the manufacturing industry (Schmidt *et al.*, 2019; Edwards *et al.*, 2019). The added modular design element, which is not presented as a fundamental element of the Scrum method, reflects a commonly identified key challenge in the adoption, implementation and use of the agile methodology in hardware development: the difficulty of designing a modular product within the Sprint setups (Zasa *et al.*, 2021; Atzberger and Paetzold, 2019; Cooper and Sommer, 2016). Manufacturing companies deliver products that consist of modules that require the sharing of knowledge and physical resources between teams and suppliers that do not necessarily use an agile methodology. These conditions add an additional challenge to the adoption and use of agile methodology in manufacturing companies and might justify why managers add modularized design as an element of the agile methodology. Although it can be said that the similarities and differences identified indicate lack of understanding of the agile methodology on the part of managers, it can also be said that they reflect the need to adapt the methodology to the hardware development context.

In summary, managers' understanding and focus on components of the Scrum method vary. On the one hand, the claimed managers' lack of understanding with the Scrum method could be evidenced, for example, by the omission of Scrum values or the modification of Scrum Artifacts. On the other hand, it can be argued that the omission, modification, and addition of elements is not at all due to a lack of understanding, but to the adaptation of the agile methodology to the nature of hardware development.

5.2 Implications of the findings

The study shows a large discrepancy between the interviewees. Moreover, most of the values presented in the agile methodology are not mentioned by managers. According to Dikert *et al.* (2016), the understanding of agile values is a success factor in the adoption, implementation and use of the agile methodology in organizations because it promotes motivation and understanding of why changes are done. Furthermore, the authors point out that a lack of understanding of agile values leads to practises being carried out without understanding their purpose, thus creating false expectations of the methodology. One possible course of action is to use the identified differences as focal points for training material or discussions, which may not lead to a significantly improved understanding, but at least create a shared reality of a methodology in which managers recognise their own understanding, thus facilitating the formulation of procedures for decision-making and the clarification of roles and responsibilities.

As mentioned earlier, the company has adapted some elements of the Scrum method, while the literature emphasizes that altering them may reduce its benefits (see Section 2.1). At the same time, companies need a development methodology that is adapted to their product offering and cannot afford to wait for research-based evidence to guide their decision in adopting and modifying appropriately elements of the agile methodology. However, there is a potential danger when elements of the Scrum method are changed or adapted with the Stage-Gate model in mind: the expected benefits of these elements can no longer be guaranteed. This can be illustrated by the following three fundamental elements of Scrum: self-managed team, Sprint Review, the Definition of Done. Putting boundaries to the team's mandate for decision making can counteract the benefits derived from the self-managed team element: sense of responsibility, fast decision-making, motivation, etc. Having Sprint Reviews without external stakeholders can significantly affect the quality of feedback on the results. If there is no clear and shared Definition of Done, it is not possible to ensure that the results presented are valuable and useful to the other team members. Therefore, companies need to be aware of and reflect on the potentially detrimental effects of modifying the fundamental elements of Scrum.

5.3 Limitations and future work

This work presents limitations, some of these are related to the data collection techniques. The interviewees' answers may have been limited, for example, due to the use of recording devices, language barriers, etc. Other limitations arise from the data analysis, which depends on the researchers' interpretation of the interviewees' responses. An important limitation has to do with the reliance on a single case which limits the generalisation of the findings to other organizations. Moreover, based on the reviewed literature, managers have been studied as a homogeneous group. However different understandings might arise from several influencing factors, i.e., roles and responsibilities, organizational unit, or personalities. Different understanding due to those factors requires further

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research. A natural progression of this study is to analyse more cases of manufacturing companies that are engaged in the adoption, implementation, and use of the agile methodology in their hardware development. Furthermore, only the Scrum method was considered as agile methodology; further research could investigate the comparison with elements of other methods such as SAFe, LeSS or Scrum@Scale, that are now used in hardware development (Atzberger *et al.*, 2020).

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