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Implementation of Scrum in the Construction Industry

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Abstract

The way in which construction projects are managed has not changed significantly in the last decades; however, stakeholders, materials, competition, and user requirements are continuously changing. This creates a gap between the current managerial view on how construction projects are conducted and how they could be managed to increase efficiency.

The construction industry could use new frameworks for action in the project and product management, and learn from the experiences of other industries. With this background in mind, some construction companies are enhancing the performance of their project teams to improve their competitiveness and increase the added value to their clients and themselves.

This paper investigates the implementation of a framework from the IT sector into the construction industry: Scrum. Conducting a case study, the implementation and application of Scrum was analysed through the evaluation of its different artifacts. This research covers the following questions: Can Scrum be implemented in the design phase of the construction industry? What adaptations are needed to use Scrum to improve the design phase of construction projects? How and where could Scrum, or parts of it, be used by the design and planning departments of construction companies?

The results from this study show that Scrum has great potential in the design and planning departments of construction firms. From the analysis of the applications of Scrum in the case study, tangible benefits and weaknesses of the implementation, and its different artifacts, were identified. Finally, this paper gives recommendations about the use of Scrum in the design phase and proposes an outlook to implement Scrum in other phases of construction projects.

Keywords: Agile; Design Phase; Process Model; Project Management; Scrum

1. Introduction

In the construction industry, one of the biggest challenges when creating a building is to account for the unforeseeable [1]. In order to reduce the amount of unforeseeable events, project managers typically use templates, checklists and often models with phases, sub-phases and sub-sub-phases, as indicated for example in [2]. This so-called sequential project management approach aims to plan the project in detail and tries to carry it out without any deviation [3]. The creation of this plan often takes up significant resources before the actual construction has even started. In many cases, these processes are so long that by the time the execution phase has started, the plan needs to be revised because of modified project requirements [4]. Constant modifications of the project requirements coupled with occurring problems in defining the original product requirement causes cost overruns and schedule delay and lowers the product quality. As a countermeasure, agile project management was created [1], whereas agility is defined

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as “...the ability to both create and respond to change in order to profit in a turbulent business environment” [5]. Instead of trying to predict unforeseeable risks, one should approach them as opportunities to profit. Therefore, the agile approach is advantageous to the traditional one, as resource consuming detailed planning from the start of the project is avoided. At the same time, decisions are delayed as long as possible [3, 5].

Scrum is one of many agile project management methods. It was created by Sutherland and Schwaber between 1993 and 1995 [6] and their work strongly influenced the Agile Manifesto [7], which sets twelve principles and four key values for all agile project management methods. Similarly, the work by Sutherland and Schwaber was heavily influenced by Nonaka and Takeuchi [8]. In fact, [8] was one of the main foundations for the lean concept. Therefore, it is important to make the differentiation between lean and agile [9]: “*Lean manufacturing* [was developed as] *a response to competitive pressures with limited resources. Agile manufacturing, on the other hand, is a response to complexity brought about by constant change. Lean is a collection of operational techniques focused on productive use of resources. Agility is an overall strategy focused on thriving in an unpredictable environment. [...] Flexible manufacturing system* [offers] *reactive adaption, while* [agile system offers] *proactive adaption.*”

In this paper, section 2 explains the basics of Scrum before the case study is then presented in Section 3 and the implementation in Section 4. The results are presented in Section 5, and Section 6 concludes this paper and gives an outlook for the implementation of Scrum in the construction industry.

2. Scrum – An agile project management method

Scrum is a framework for product development where different processes and techniques can be applied to complex projects. A typical Scrum framework is shown in Figure 1. The Scrum framework consists of the Scrum Roles, the Scrum Artifacts and the Scrum Events [10], which are all explained in the following sections. The expression Scrum is a move from Rugby, where a detailed position, with a clear purpose is needed to achieve a common goal [6].

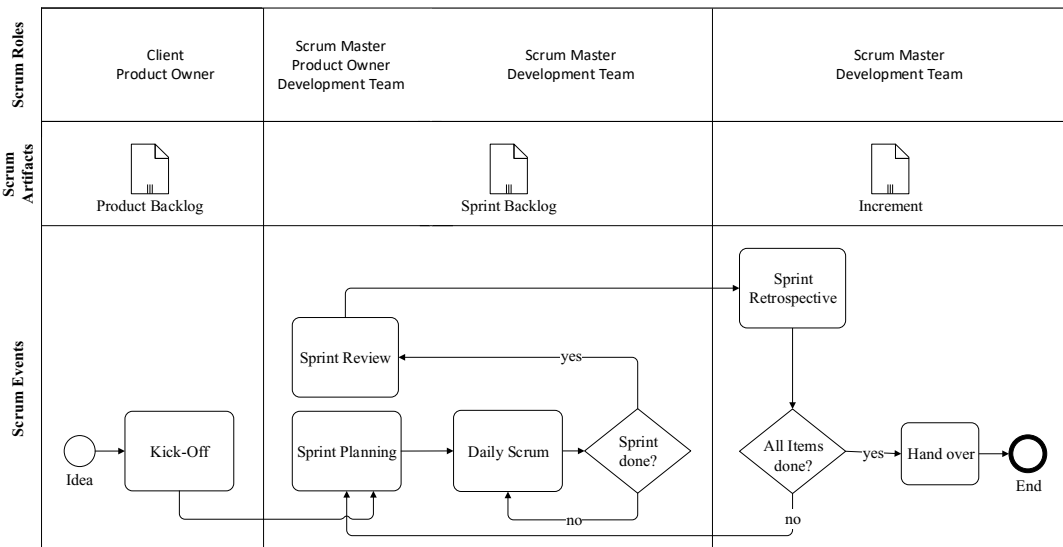


Figure 1: Typical Scrum Framework

2.1. Scrum Roles

The *Scrum Team* consists of the Product Owner, the Development Team and the Scrum Master. The team is self-organised and cross-functional. All decisions of the project are taken within this entity and they have all the competencies needed for the project – there are no advisors to the Scrum Team. The management’s sole purpose is to assist and support the Scrum Team to the best of their abilities so that the Scrum Team achieves their goal [10]. The size of the team varies depending on the area of operations, but a size of seven (\pm two) members has proven to be successful [6].

The *Product Owner* is responsible for maximizing the value of the project and is the sole representation of the client. He is in charge of creating, updating, and prioritizing the Product Backlog Items (PBIs; Section 2.2). In addition, other responsibilities include optimizing the work performance of the Development Team, to ensure that the PBIs are clear,

transparent and understood by everyone [10] The Product Owner also takes into account other stakeholders interests and is the only one who can make changes to the PBIs [10].

The individuals that do the actual work are in the *Development Team*. The members of this team are all equal (no project manager) and although each and everyone has their field of expertise, the team is hold accountable as a whole.

The *Scrum Master* ensures that everyone in the Scrum Team understands what is meant by Scrum. The Scrum Master simply enforces the framework given by Scrum and the changes made considering new information. Additionally, the Scrum Master sets all the Scrum Events (Section 2.3) and explains to individuals outside the Scrum Team how they can (or cannot) interact with the Scrum Team. One of the main task of the Scrum Master is to remove any obstacles brought to the Scrum Team so that the Development Team can focus on their work and are not slowed down by insignificant things [10].

2.2. Scrum Artifacts

The Scrum Artifacts can be described as elements with a certain definition in the Scrum framework [6, 10] and are explained below.

The *Product Backlog* is a prioritised list of different Items (e.g. creating floor plans, defining the fire protection concept, designing load bearing elements). Each Item is divided into Tasks and represents a simple and detailed description of what needs to be done by the Development Team. A task is a work package addressed by one or more members of the Development Team and ideally can be completed during one or two days.

The *Sprint Backlog* contains a number of Items which are selected by the Product Owner and the Development Team from the Product Backlog. This list (i.e. Sprint Backlog) contains the Items that the Development Team believes can reach the *state of done* during a Sprint (Section 2.3).

The entity of the Scrum Team defines a *state of done*. When an Item from the Sprint Backlog is considered as done, it is removed from the Sprint Backlog and is then part of the *Increment*. Therefore, the Increment is the sum of all Items considered done.

To be able to estimate how many Items from the Product Backlog can be worked off within a Sprint, Scrum suggests the use of *Planning Poker*, by which each member of the Development Team receives several cards with the numbers zero, one, two, three, five, eight, thirteen, and so on (following the Fibonacci sequence) that will be used to estimate the amount of work needed for a certain Item to reach the state of done by the end of the upcoming sprint. That includes for example that an architect makes an assumption for the water sewage system even it is not his/her field of expertise. If the returned card have numbers further than three numbers apart in the Fibonacci sequence, the people with the highest and lowest number must explain why they picked their number and the game is repeated until all the cards are within a range of three numbers in the sequence. The average is then used as an estimation of the effort for a given Item [11]. Throughout Scrum the Development Team estimates the amount of needed work using points instead of time (e.g., man-hours). This is done because [6] suggests that Gantt-Charts are never accurate and therefore there is no point in trying to assume a number of hours for a task if it is not going to be met. For example, these points merely stipulate that an Item with an eight is more work than an Item with a three or five. However, this information could be used at a later time by the Product Owner to estimate project durations (i.e. completion dates).

2.3. Scrum Events

This Section describes the different events in which the Scrum Team can uphold to the key factors of Scrum: transparency, inspection, and adaption [10].

Like in any other project a *Kick-Off* meeting is held – based on the client's demands – and the Product Owner creates the Product Backlog to fulfil this demand.

The *Sprint Planning* has a maximum duration of eight hours for a Sprint of a month (proportionally smaller for a shorter Sprint) [10]. During this Sprint Planning, the Development Team guesses the amount of work for the most important Items of the Product Backlog with Planning Poker. After that, the Development Team chooses the Items they think can be done in the Sprint, starting with the most important one; this list is called the *Sprint Backlog* (see also Section 2.2). While considering all the Items from the Sprint Backlog, a bigger goal – the Sprint goal – must be defined. This enables the Development Team to always ask (inspect) themselves: Is this work I am currently doing really necessary for this Sprint (in order to reach the goal)?

When the Sprint Planning is done, the Development Team can start working on the Items during the Sprint. The *Sprint* is a fixed timeframe in which the Development Team aims to reach the state of done for each Item. During the Sprint no changes are permitted to the Items, unless the value or the scope of the Items – with consultation of the Product Owner – is increased. By the end of the Sprint, the Items that cannot be considered as done are moved back to the Product Backlog and will be re-evaluated in the next Sprint Planning.

During the Sprint, the Development Team and the Scrum Master meet daily for the *Daily Scrum*. The Daily Scrum is a 15 minutes meeting scheduled at the same time and same location every day during a Sprint. Every member of the Development Team should come prepared to this meeting and are expected to answer the following three questions:

- 1) What did I do since the last Daily Scrum to help the Development Team to reach the Sprint Goal?
- 2) What will I do until the next Daily Scrum to help the Development Team to reach the Sprint Goal?
- 3) What are my obstacles that prevents me or the Development Team to reach the Sprint Goal?

The Scrum Master is responsible that during these 15 minutes only these three questions are answered and that the entire Development Team is present. If needed, a follow-up meeting can be set between the involved members. This meeting is also used for inspection: The members of the Development Team are seeing their own progress and everyone knows what the others are working on. Further, through the constant interactions between experts of different areas everyone starts to gain new knowledge outside their expertise.

After each Sprint, the Increment is inspected by the Scrum Team during the *Sprint Review* and, if needed, adaptations are made to the Product Backlog based on new information. The Sprint Review has a maximum duration of four hours for a one-month Sprint [10]. The following actions occur during the Sprint Review:

- The Scrum Master has a first-hand contact with all the members of the Scrum Team and checks that all are present.
- The Product Owner explains what Items reached the state of done and which did not.
- The Development Team discusses what went well during the Sprint, what did not, and how the problems were resolved.
- The Development Team presents the Increment and answers questions if needed.
- The Product Owner discusses the Product Backlog and guesses a completion date.
- Considering the newly updated Increment, the Scrum Team decides what is important for the next Sprint and therefore sets a preliminary Sprint goal.

After the Sprint Review, the *Sprint Retrospective* meeting is usually held. The goal of this meeting is to critically evaluate involved parties, the processes and techniques used, as well as their relations and interactions. Therefore, “what was done?” is not inspected, but “how was it done?”. In doing so, the Scrum Team can suggest improvements to the process and gradually improve their performance.

The framework displayed in Figure 1 uses incremental steps on a daily basis (Daily Scrum), as well as on a weekly/monthly basis to complete the Sprint and corresponding Product Backlog. The crucial benefit of this incremental approach is that by focusing on one Task, less distractions arise, leading to expedited completion of work: No matter how good one person may be, multi-tasking is always slower [6]. In general, the use of Scrum has proven to be very valuable in complex projects, especially those where the requirements and/or the vital technology are not yet very mature [12], and it is, amongst all the different agile methods (e.g., Extreme Programming, Adaptive Project Management, Dynamic Project Management), the one most frequently used [4].

3. Case Study

Scrum was implemented in the design phase of an ongoing project consisting of three four-story multi-family buildings for the Swiss market with a total floor area of about 2'100 m² divided into eleven flats and 200 m² of commercial space. Design, engineering and production are done in Tallinn (Estonia) and the prefabricated timber-modules will be transported from Estonia to Switzerland.

The project was planned in accordance to the Swiss Standard SIA 112 [2]. That standard includes six phases to construct a building using the traditional sequential approach shown in Figure 2.

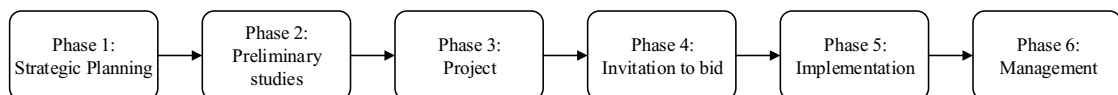


Figure 2: Building phases according to [2]

Phase 1 had already been completed; thus, this case study focused on the implementation of Scrum in Phase 2 and Phase 3. According to [2], Phase 2 starts with the project definition, includes a feasibility study and ends with the

selection of the best project to meet the defined requirements. For Phase 3, the first goal is to perform a concept and profitability optimisation, followed by a project and cost optimisation. At the end of Phase 3, everything should be ready for the application of the building permit. Phase 4 to Phase 6 were excluded from this study.

Since there was not a reference for the time it would take to apply for a building permit, an optimistic initial target for this was set to four weeks from the start of Phase 2. After two weeks using Scrum, it was realized that the original goal was not feasible so the timeframe to apply for the building permit was extended to 15 weeks. This would ensure that the application would be accepted with the minimum number of imposed building restraints or objections from the building officials. The use of Scrum in the project was followed for a period of eight weeks in 2015, and during that time the authors participated in all Scrum Events. In addition, an interview was conducted with the Development Team and the Scrum Master at the end of the eight weeks to get their feedback about the entire process.

4. Implementation of Scrum

As Scrum is empirical, it is based on transparency, inspection and adaptation [10]. The general Scrum framework with the multiple events, artifacts and roles (Figure 1) can be adapted to fit the requirements of a specific project. Although it is recommended to use the framework as a whole – not only parts of it – one may modify Scrum to achieve specific goals. In this case however, almost no initial modification was done as can be seen in Table 1.

Table 1: Events, artifacts and roles used (✓)

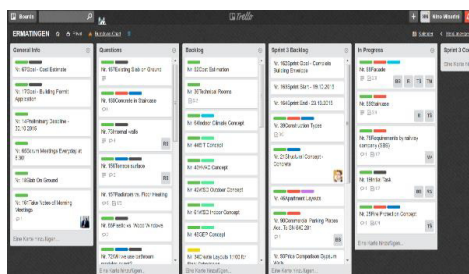
Scrum Team			Scrum Events					Scrum Artifact			
Product Owner	Development Team	Scrum Master	Sprint	Sprint Planning	Daily Scrum	Sprint Review	Sprint Retrospective	Product Backlog	Sprint Backlog	Planning Poker	Increment
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	*	✓

*Added after implementation of Scrum (from Sprint number five)

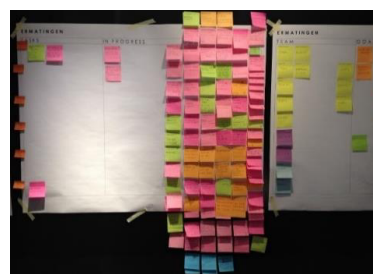
The Development Team consisted of a total of seven individuals. The area of expertise covered by the Development Team was Architecture (three representative), Building Physics (one representative), Civil Engineering (one representative), Cost Estimation (one representative) and Interior Design (one representative). Instead of the Product Owner creating the Product Backlog, the architects from the Development Team and the Scrum Master were the ones doing it; although this was not the ideal case, it was necessary due to other commitments by the Product Owner that would delay the creation of the PBIs. Every member of the Development Team, as well as the Scrum Master, were required to attend all Scrum Events. They were also required to participate in the Scrum Review and Planning with the Product Owner. Before Sprint number five, the number of Items that could be done in a Sprint was entirely based on the experience from the Development Team, without any systematic way to do that. After Sprint number five, the use of Planning Poker was implemented to determine the effort for each Item, hence how many to use from the Product Backlog.

At first, the Sprint duration was fixed to five working days. This meant that on Monday the Sprint Planning was held, from Tuesday to Thursday work took place and information was exchanged during the Daily Scrum. On Friday, the Sprint Review and Retrospective was conducted. After four weeks, it was found that it was not enough time to address all the Scrum Events and do the required work during the duration of the Sprint. Therefore, the Scrum Team decided to adjust the Sprint duration to two weeks, which allowed for a more realistic timeframe.

The Development Team used a Kanban board to keep track on what was important during the Sprint, as well as during the entire project. Since the Product Owner as well as the authors were not in the same location as the Development Team, a virtual and a physical Kanban board were used. The virtual one was done using Trello (Figure 3 (a)), a free online organization tool. A view of the physical Kanban is depicted in Figure 3 (b).



(a)



(b)

Figure 3: Screenshot of virtual Kanban board (a) and physical Kanban board (b). Source: the authors.

5. Results

The results from the implementation of Scrum were evaluated by grading the Daily Scrums, interviewing the Scrum Team, and conducting a critical analysis of the Product Backlog Items.

All Daily Scrums were recorded and systematically analysed using a template with eight questions developed for this study. All questions were graded with marks in the range of 1.0 (not measurable) to 6.0 (excellent). The questions answered at the end of each Daily Scrum, along with their absolute weight for the final evaluation, are summarized in Table 2.

Table 2: Weight of Daily Scrum questions

Question	Absolute weight [%]
Q1 - How many participants completed a Task?	33.3
Q2 - How many participants answered the three core questions?	33.3
Q3 - How long was the Daily Scrum?	6.6
Q4 - Took the Daily Scrum place at the same location and time as always?	6.6
Q5 - Was someone absent, late or left early?	6.6
Q6 - How many participants talked longer than three minutes?	3.3
Q7 - How many participants talked less than a minute?	3.3
Q8 - How many extern participants talked?	6.6

The questions in Table 2 were organized in three parts: Q1, Q2, and Q3 through Q8. The weight was set to reflect 1) the importance of the Items and their associated Tasks, 2) the three core questions of the Daily Scrum (What did I do? What will I do? What are the obstacles?) and 3) general information (How long? Where? When? Who?).

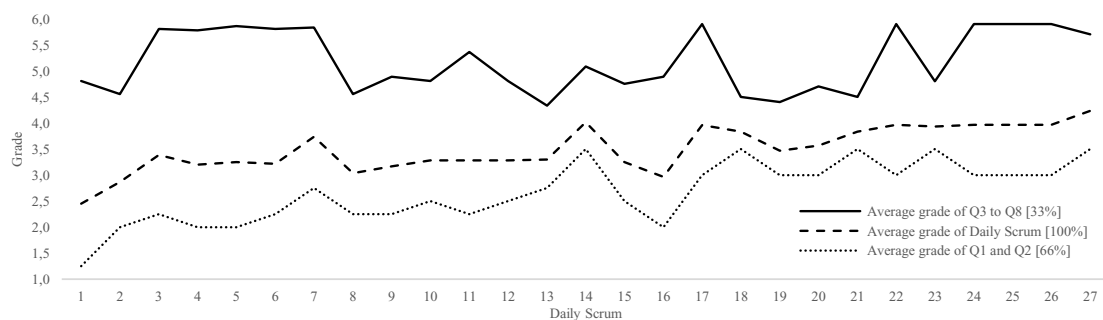


Figure 4: Weighted evaluation of Daily Scrums

The evaluation of the Daily Scrums is summarized in Figure 4. The performance of the Daily Scrum (dashed line in Figure 5), as represented by the average grade, increased from a 2.5 (very poor) to a 4.3 (satisfactory-good) over the 27 observed Daily Scrums. This was attributed mainly to the improvements related to question Q2, as with time the Development Team got much better in getting a clear understanding of the whole process. They could report on what was done since the last meeting, as well as efficiently planning upcoming work while identifying and articulating the main obstacles in their tasks. The average grades for Q1 deteriorated mostly due to the fact that the Items did not consist of Tasks which could be completed in one or two days of work, making it hard to make improvements in this area. The fluctuation of the dashed line is based on the average grade for Q1 and Q2 (dotted line). The average grade for Q3 to Q8 (solid line) varied strongly from day to day, but it was generally on the upper end of the scale (overall average of 5.2); however, no general improvements were observed.

At the end of week eight, an interview was conducted with the Development Team and the Scrum Master (with a total of eight participants) and questions were graded from 1.0 (low) to five (high). The main purpose of the interview was to get feedback from the Scrum Team regarding their general perception about the Scrum framework and its implementation. The results from those interviews showed that the duration of the Daily Scrum was appropriate; however, the Sprint Planning and Retrospective were slightly too long, and the Sprint Review was slightly short. In addition, the efficiency (i.e. the added value for the design process) of the different Scrum Events was rated by the interview participants. The Daily Scrum received a 3.9, the Sprint Planning and Review each a 3.5 and the Sprint Retrospective a 3.0, all from a scale from 1.0 (does not add any value) to 5.0 (does provide a lot of value).

As the Scrum Framework (Figure 1) states who must attend the Scrum Events, the attendance necessity was rated by the Development Team and the Scrum Master as well. The grades ranged from 4.0 (Daily Scrum) to a 4.4 (Sprint Review). In addition, the different team members were asked about their view of Scrum regarding the following criteria:

- Introduction: How was the introduction to Scrum?
- Knowledge: What is your personal state of knowledge about Scrum?
- Necessity: Do you understand why did you use Scrum in this Project?
- Continuity: Do you know who you can ask if you have questions about Scrum?
- Relevance: Do you like the application of Scrum for the Design Process?

Figure 5 shows that the Introduction and Knowledge about Scrum were low when the project had started. It is worth to mention that all eight interviewed participants would like to continue using Scrum in the Design Process instead of the traditional approach they had used over years of practice. In fact, after only five weeks of experience, the Development Team was convinced that Scrum was more efficient than their previous approaches and methods. Mentioned benefits of Scrum were a higher transparency, better communication and collaboration, better flow of information and faster project development.

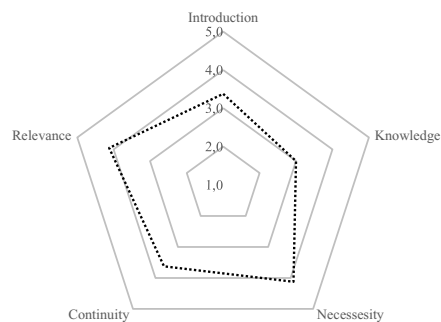


Figure 5: Perception from the Development Team and the Scrum Master about the implementation of Scrum for different criteria (1: poor; 5: high)

Another important advantage of using Scrum was that the many meetings enabled the single member to see the point of view of other team members and starts to understand why something was done in a certain way. Thereby, team members improved their knowledge in a field where they were not experts, helping to support the concept of cross-functional teams. The participants also indicated some difficulties when using Scrum, e.g. the missing knowledge at the beginning, no clear project leadership and that a lot of time was needed for voting in the Development Team as the team was hold accountable. Finally, the Kanban board has proven itself to a useful tool for the Development Team to keep track on the development.

Overall, the disadvantages can be addressed to the low knowledge about Scrum at the beginning of the process; the duties and responsibilities of each member were not clear or well defined. Therefore, it is important to not only implement the events, artifacts and roles shown in Table 1, but also to entirely understand them. Due to this reason, more time was needed for the meetings and the voting, as well as the creation of the Product Backlog. The knowledge gained from this process was very valuable and can be reused for future projects as the description of the Items remains the same and only the scope and some Tasks need to be adjusted. Over time, a pre-defined Product Backlog can be created to significantly expedite the time to complete Phase 2 and Phase 3.

6. Conclusion and Outlook

As shown in Section 4 and 5, the successful application of Scrum in the construction industry is possible. The paper shows that no significant adjustments are needed to the original Scrum framework given by [9]. The following points should be considered when Scrum is applied in the construction industry:

- Get a good understanding of how Scrum works and get all parties (Development Team, Scrum Master, Product Owner, Stakeholder, Management) involved from the beginning.
- Take enough time to create a clear and comprehensive Product Backlog with Items and Tasks.

- Inspect, update and adapt the Product Backlog Items before every Sprint Planning.
- Use Planning Poker for all Items and do it again if changes are made to the Items.
- Attend all the Scrum Events (even members of the Development Team working part-time on the project).
- Make decisions (the Product Owner) on a timely manner in every Sprint Review to avoid putting the Development Team on hold.

Constant inspection and adaption of a new Scrum process will evolve with time and further support and fasten the Design process. Our recommendation is not to try to plan every detail of Scrum as you are used to do, but to *just do and adapt* as needed.

Scrum, as described in this paper, can easily be applied in companies which have almost all the in-house expertise needed for the construction of a building. With the proper framework Scrum may also work with some external experts. However, this results in a higher effort for communication and therefore slowing down the process and defeating its purpose.

In addition, we believe that Scrum could also be applied in the construction phase with Daily Scrums on-site as a means of communication between the different companies to reduce waste of time. For example, Daily Scrum could be beneficial to inform construction companies about the work progress and the daily goal (Sprint) of other construction companies also working on site. In this case, no relocation of workers would be needed and the downtime could be reduced. We see great potential of the use of Scrum especially in refurbishment projects, where a daily update about new information of the existing construction could significantly improve the way projects are managed. Similar to the lean approach of the last planner concept [13].

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