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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 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 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].

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Scrum is one of many agile project management methods. It was created by Sutherland and Schwaber between 1993 and 1995 [6]. They were heavily influenced by Nonaka's and Takeuschi's (1986) work [7], and strongly influenced the Agile Manifesto [8], which sets twelve principles and four key values for all agile project management methods.

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 shown in Section 5 and Section 6 concludes this paper and gives an outlook for additional 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 process is shown in Figure 16. The Scrum framework consists of the Scrum Roles, the Scrum Artifacts and the Scrum Events [9], which are all explained in the following sections.

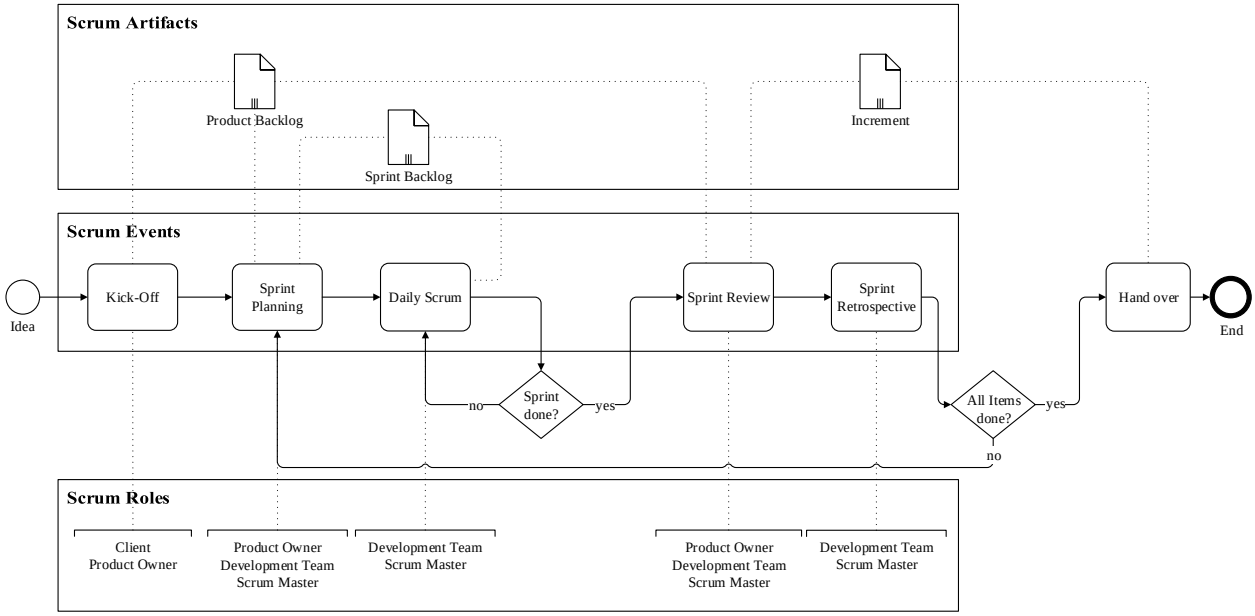

Figure 16: Typical Scrum Process

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. All competencies needed for the project are in this entity – there are no advisors to the Scrum Team. The management's sole purpose is to assist and support the Scrum Team to their best so that the Scrum Team achieves its goal.

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 and updating the Product Backlog Items (PBI; Section 2.2) and prioritizes the PBI as well. In addition, the Product Owner also takes into account other stakeholders interests.

The individuals that do the actual work (e.g., design, engineering) 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 Scrum Events (Section 2.3) and explains to individuals outside the Scrum Team how they can (or cannot) interact with the Scrum Team.

2.2. *Scrum Artifacts*

The Scrum Artifacts can be described as elements with a certain definition in the Scrum framework [6, 9] and are explained in the following: The *Product Backlog* is a prioritised list of different Items (e.g. creating floor plans,

defining fire 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. This list can only be adapted by the Product Owner based on new information regarding the project.

The Product Backlog contains a number of Items, which are selected by the Product Owner and the Development Team. Based on this selection, a list (*Sprint Backlog) is created containing the information* 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 suggest 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 (Fibonacci sequence). Everyone from the Development Team estimates the amount of work needed for a certain Item so it can be considered 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 field of expertise. If the returned card consists of 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 [10]. Throughout Scrum the schedules or the amount of work is not calculated with hours, it is done using points. This is done because Sutherland [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 does not hold up. For example, these points merely stipulate that an Item with an eight is more work than an Item with a three or five.

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 [9]. 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). During this Sprint Planning the Development Team guesses the amount of work for the most important Items of the Product Backlog with Planning Poker. Following, the Development Team chooses the Items they think can be done in the Sprint, starting with the most important one; this list is called *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 doing really necessary for this Sprint (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 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 comes prepared to this meeting and answers the following three questions:

- What did I do since the last Daily Scrum to help the Development Team to reach the Sprint Goal?
- What will I do until the next Daily Scrum to help the Development Team to reach the Sprint Goal?
- 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 adaptions 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. The following task are addressed during the Sprint Review:

- 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 where resolved.
- The Development Team presents the Increment and answers questions if needed.
- The Product Owner discusses the Product Backlog and guesses a completion date.

After the Sprint Review the *Sprint Retrospective* meeting is usually held. The goal of this meeting is to discuss involved parties, processes, techniques, relations and how they interacted. 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.

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 m^2 divided into eleven flats and 200 m^2 of commerce 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 is accordance to the Swiss Standard SIA 112 [2]. That standard includes six phases to construct a building using the traditional sequential approach:

- Phase 1: Strategic planning
- Phase 2: Preliminary studies
- Phase 3: Project
- Phase 4: Invitation to bid
- Phase 5: Implementation
- Phase 6: Management

Phase 1 was already completed so 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.

The initial target for this project was to apply for the building permit within a month 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, to 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.

4. Implementation of Scrum

As Scrum is empirical, it is based on transparency, inspection and adaptation [9]. The general Scrum framework with the multiple events, artifacts and roles (Figure 16) can be adapted to fit the requirements of a 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. The roles, events, and artifacts used in this case study are summarized in Table 13.

Table 13: 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
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

The Product Backlog was created by an architect from the Development Team and the Scrum Master, instead of the Product Owner. 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. The use of Planning Poker was not implemented until Sprint number five, and before that the number of Items that could be done in a Sprint was entirely based on the experience from the Development Team.

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.

5. Results

Every Daily Scrum was recorded and systematically analysed using a template specifically developed for this study with eight questions. Every question was graded by the authors 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, are summarized in Table 14.

Table 14: 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 weight shown in Table 14 was set to emphasise the core questions (Q1 and Q2). The evaluation of the Daily Scrums is summarized in Figure 17.

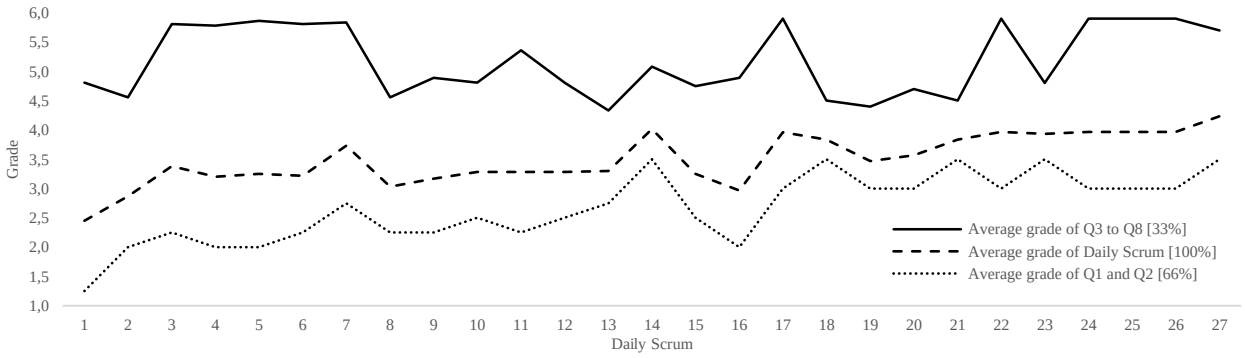

Figure 17: Weighted evaluation of Daily Scrums

The performance of the Daily Scrum, 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 stating what they had done since the last meeting, what they will be working on next and what the obstacles are/were. Question Q1 received to the end low marks as the Items did not consist of Tasks which could be completed in one or two days' work and therefore no improvement was possible.

Figure 18 shows the number of Items in the Product Backlog from the Kick-Off till Sprint number 5. The increase of Items shows that the goal of the project was not clear at the beginning and new Items were added along the way.

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 results from those interviews showed that the duration of the Daily Scrum was appropriate, the Sprint Planning and Retrospective were slightly too long, and the Sprint Review was slightly short. In addition, the efficiency of the Scrum Events was rated. The Daily Scrum received a 3.9, the Sprint Planning and Review each a 3.5 and the Sprint Retrospective a 3.0.

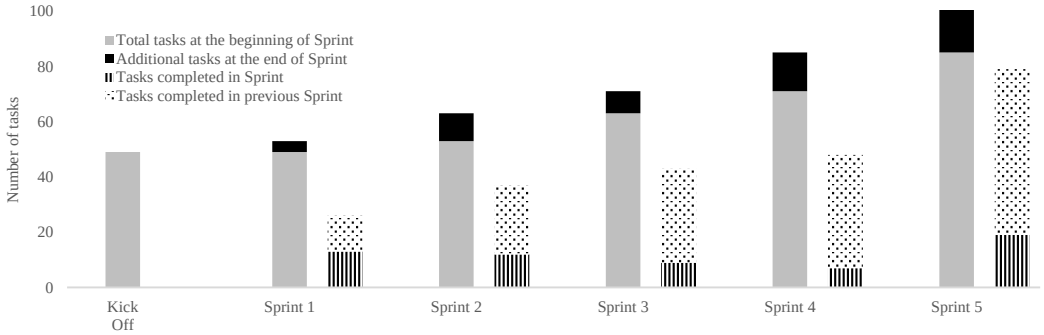

Figure 18: Product Backlog

As the Scrum Framework (Figure 16) states who has to 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 points:

- 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?
- Relevance: Do you like the application of Scrum for the Design Process?
- Continuity: Do you know who you can ask if you have questions about Scrum?

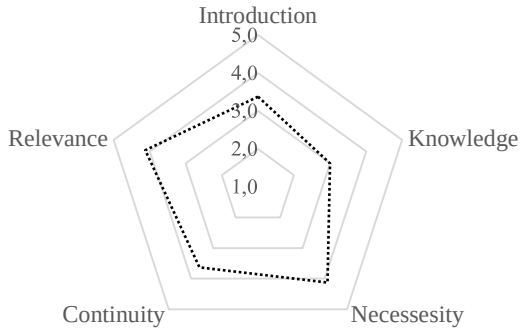

Figure 19: User's perception about implementation of Scrum with grades ranging from 1 (poor) to 5 (high)

Figure 19 shows that the Introduction and Knowledge about Scrum were low when the project 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 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. Another important advantage 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.

Overall, the disadvantages can be addressed to the low knowledge about Scrum at the beginning of the process; responsibilities and duties of each member were not clear or well defined. 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 is very valuable and can be re-used for future projects as the description of the Items remains the same and only the scope and some Tasks needs to be adjusted accordingly.

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 every Item 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.

We believe Scrum could be applied in the construction phase with Daily Scrums on-site as a means of communication between the different companies to reduce construction 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 relocating of workers would be needed and the time with no progress could be reduced. We see great potential of the use of Scrum for refurbishments, where a daily update about new information of the existing construction could be easily considered and significantly improve the way projects are managed.

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References

[1] Halamzie, F. (2013). Management von Softwareprojekten: klassisch, agil, lean und systemisch. Diplomica Verlag.

[2] SIA 112 (2001): Service Model. Swiss Society of Engineers and Architects, Zurich.

[3] Owen, R., Koskela, L. J., Henrich, G., & Codinhoto, R. (2006). Is agile project management applicable to construction?. In *Proceedings of the 14th Annual Conference of the International Group for Lean Construction* (pp. 51-66).

[4] Cervone, H. F. (2011). Understanding agile project management methods using Scrum. OCLC Systems & Services: International digital library perspectives, 27 (1), 18-22.

[5] Highsmith, J. A. (2002). Agile software development ecosystems (Vol. 13). Addison-Wesley Professional.

[6] Sutherland, J. (2014). Scrum. A revolutionary approach to building teams, beating deadlines and boosting productivity. Random House Business Books.

[7] Nonaka, I., & Takeuchi, H. (1986). The new new product development game. Harvard business review, 64 (1), 137-146.

[8] Fowler, M., & Highsmith, J. (2001). The agile manifesto. Software Development, 9(8), 28-35.

[9] Schwaber, K., & Sutherland, J. (2013). The definitive guide to Scrum: The rules of the game. Available online at: http://www.scrumguides.org/docs/scrumguide/v1/scrum-guide-us.pdf

[10] Cohn, M. (2005). Agile estimating and planning. Pearson Education.