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Does Limit on Work-In-Progress (WIP) in Software development matter?

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Abstract

Background: In software engineering there are several principles with impact on a software project. If these principles are applied the wrong way, or don't take it into account, it can starve a software project. WIP-limit is one of those principles. WIP-limit is used to limit number of tasks people can work with. There is little evidence proving the impact of limiting work-in-progress for software development.

Aim: The aim for this work is to investigate the impact of WIP-limits in software development.

Methods: The methods used to investigate the research question were a case study of an in house software development company. The case study was based on a data set with recorded data from 2008 to 2013. The data set was analyzed using an application developed for this project, described in this work. The data produced by the application was interpreted with correlation and case summaries in SPSS.

Results:

The results show that team size has an impact on both WIP and throughput. The results also show the impact both lead time and throughput has on a development process.

Conclusion:

The conclusion is that WIP-limit have no impact matter in software development.

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Preface

Chapter 1

Introduction

This work focuses on Work In Progress (WIP)-limit, which is one of the principles in Kanban. Kanban is a software development method defined as a WIP-limited pull system visualized by a Kanban board (D. Anderson et al., 2011), the Kanban method is further explained in Chapter 2. The focus of this work will be to evaluate what kind of impact WIP limit has in a development process. In order to do so, a data set gathered by an in house software company in Norway called Software Innovation (SI) was used. SI is a Scandinavian software company that delivers Enterprise Content Management applications.

The data set had already been interpreted by another study. That study investigated Scrum vs. Kanban for SI. For interested readers the case study can be found in the paper "Quantifying the Effect of Using Kanban versus Scrum: A Case Study" (Sjøberg, Johnsen and Solberg, 2012).

1.1 Motivation

In software development, processes and methods are important in order to deliver the right product on time and one rarely solves two identical problems for different stakeholders. The problems in software development are getting bigger and more complex, which means that new processes and methods are introduced and the already existing processes and methods need to be adapted to solve the complex problems in the most efficient ways. The number of popular software development methods (e.g. Extreme programming, Spiral, Scrum and Kanban) emerged in the recent years, proves this assumption (Gandomani et al., 2013) (Marko Ikonen et al., 2010).

This is why this work will focus on software development methods, the methods in each development project is such a key element to make a project successful. The main focus of this work will be the Kanban method and the principle to limit Work In Progress (WIP). In Kanban the WIP-limit is used to limit the number of tasks each developer can work on at each workflow state to prevent bottlenecks and to ensure flow of tasks through the development cycle (Gandomani et al., 2013) (Marko Ikonen et al., 2010).

There are published various literature on Kanban in software development such as "Kanban: Successful Evolutionary Change for Your Technology Business" (D. J. Anderson, 2010), "Kanban and Scrum - making the most of both" (Kniberg, 2010) and "Lean Software Management: BBC Worldwide Case Study" (Middleton and Joyce, 2012). Although there is various literature, there is no information on how to apply WIP limit, even though most of the experienced Kanban enthusiasts agree that WIP limit is an important principle. There is no research backing this statement. The literature states that one should experiment with WIP limits in order to find the best WIP limit for one's case (M. Ikonen et al., 2011) (Kniberg, 2010).

Because there is lack of available research on WIP limit my motivation is to investigate WIP-limit in this case study.

1.2 Research Question

In this work the overall research question will be to study the effects of WIP limits for an in house software company, in particular:

- Does WIP limit in software development matter?
- If so, how can one find the optimal WIP-limit?
- Which parameters should be considered in order to optimize WIP-limits?

1.3 Approach

This work will a use case study as an approach to answer the research questions. A data set from an in house software company will be used to conduct the case study. The data set will be evaluated at team level. The software company consists of ten teams, all of them will be investigated.

A software program was developed for this work to convert the data set into more suited data set. The new data set is interpreted by SPSS. SPSS is a statistic analyze program that was used to compute correlation and descriptive statistic.

1.4 Chapter overview

Chapter 2: Background:

Chapter 2 introduces background information and introduces relevant concepts and methods in software development as well as information about the in house software company, Software Innovation.

Chapter 3: Research Methods:

Chapter 3 introduces and explains the research methods used in this work as well as complementary information about Software Innovation and why the data set from Software Innovation is used in this work.

Chapter 4: Data collected and calculations:

Chapter 4 gives information about the data set and the calculations. Complementary information about how the developed program operates is given in as well as information about how the output data from the program is measured using SPSS.

Chapter 5: Results:

Chapter 5 presents the result produced by the developed application and SPSS, with descriptive statistics and correlation tables.

Chapter 6: Discussion:

Chapter 6 discuss the findings from the case study. There is also a discussion of the finding against findings from other research.

Chapter 7: Conclusion:

Chapter 7 provides the answers to the research questions as well as recommending future work.

Chapter 2

Background

In this chapter there will be a brief introduction to Waterfall (Section 2.1), Scrum (Section 2.2), Lean (Section 2.3) and Kanban (Section 2.4) with affiliated tools. The software development company Software Innovation is briefly introduced (Section 2.9)

2.1 Waterfall

"The waterfall model is the classical model of software engineering. This model is one of the oldest models and is widely used in government projects and in many major companies" (Munassar and Govardhan, 2010). The main goal of the waterfall model is to plan in early stages to ensure design flaws before coding is started. Since planning is so critical in the waterfall method it fits projects where quality control is a major concern (Munassar and Govardhan, 2010).

The waterfall method consists of several non-overlapping stages as shown in figure 2.1. The figure is an example of the waterfall model with a life cycle of establishing system requirements and software requirements and continues with architectural design, detailed design, coding, testing and maintenance (Munassar and Govardhan, 2010). One of the main principles of the waterfall method discourages return to an earlier phase. For example returning from detailed design to architectural design. However, if returning to an earlier phase is needed, it involves costly rework. When a phase is completed, the phase requires formal review and extensive documentation development. Therefore, if something is missed out an earlier phase, it is expensive to correct it later (Munassar and Govardhan, 2010)

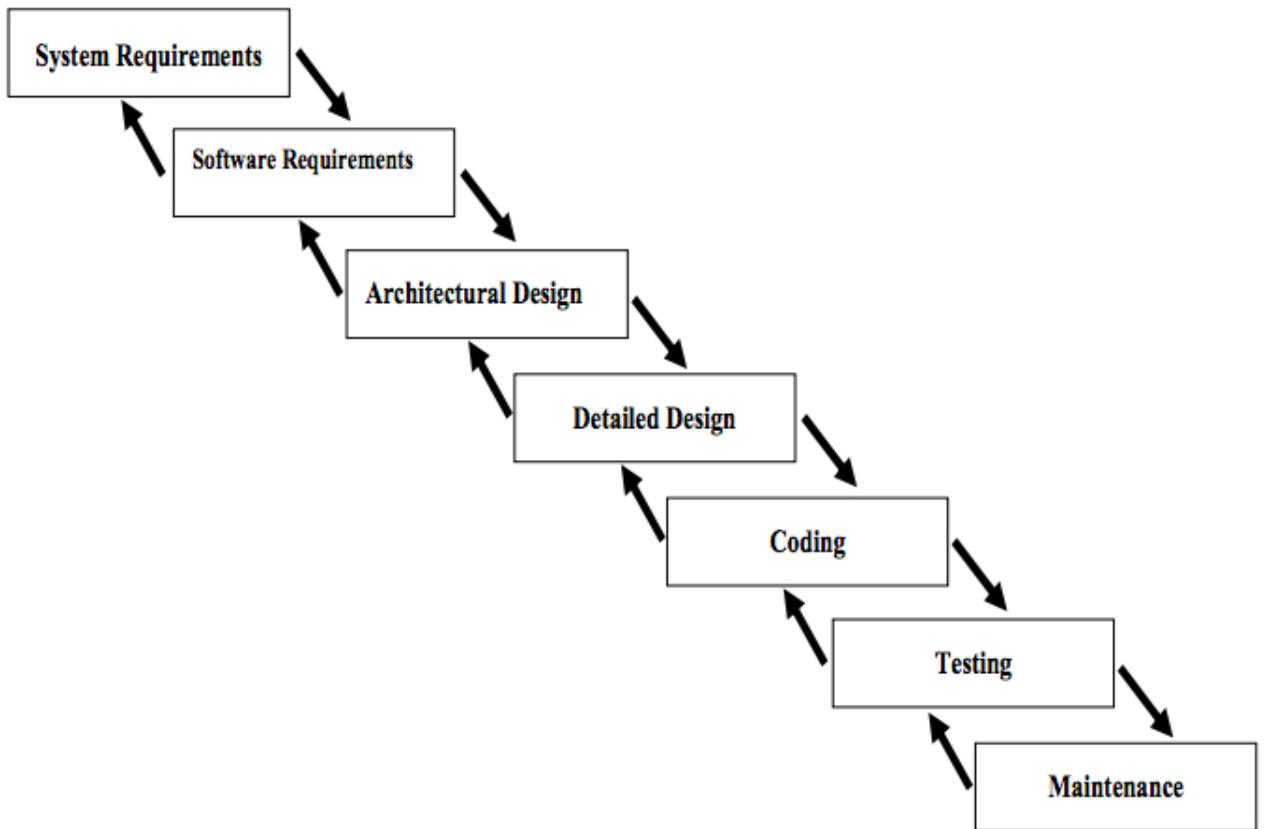


Figure 2.1: Waterfall model

2.2 Scrum

"Scrum is the best-known of the Agile frameworks. It is the source of much of the thinking behind the values and principles of the Agile Manifesto". These values are:

Individuals and interactions over processes and tools
Working software over comprehensive documentation
Customer collaboration over contract negotiation
Responding to change over following a plan
 (Alliance, 2012).

These principles of Scrum and Agile manifesto are not so rigid as the principles of the Waterfall method. Some may say that Scrum is the opposite of the Waterfall method (Cocco et al., 2011).

Scrum have three main roles, the Product Owner, the Scrum Master and the members of the development team. The Product owner in collaboration with the Scrum Master decides which work to be prioritized in the backlog. The backlog represents the tasks to be done in order to complete the project. The Scrum Master acts like a team leader and helps the development team and the organization to take best advantages of Scrum. The development team works on tasks specific for current sprint (Alliance, 2012).

Sprint is a time-boxed interval over a given time. The Scrum framework suggests duration of sprints to be from one to four weeks. Before each sprint, a sprint planning meeting is conducted with all the team members attending. A Sprint planning meeting is held so the team can discuss tasks from the backlog and come to an agreement of which tasks to be put in the minimal backlog (Alliance, 2012).

In each sprint a minimal backlog is created so the developer knows which tasks to work on in the current sprint. The Product Owner and the team members discuss and decide which tasks from the backlog to be added to the minimal backlog. After the minimal backlog is complete, the Product Owner and the team members discuss each task in order to get a better and shared understanding of what is required to complete the tasks (Alliance, 2012).

One of the main principles in Scrum is that it requires that at least one new feature is ready for release after each sprint. The feature should be a visible part of the product in order to get feedback from end-users. So all the tasks in the minimal backlog combined should be a visible part of the product (Alliance, 2012).

2.3 Lean

"Lean is all about getting the right things to the right place at the right time the first time while minimizing waste and being open to change" (Raman, 1998). The Lean approach was introduced around 1948 in manufacturing in Japan. In 1975, Toyota was able to create almost 50 more production units per employee than in 1948 due to the Lean approach (Manning, 2013). Lean strives to maximize the value produced by an organization and delivered to customer. This is done by finding and eliminate waste, controlling variability and maximizing the flow of delivered software all within the culture of continuous improvements (D. Anderson et al., 2011). In 2003 Mary and Tom Poppendieck first introduced Lean thinking to software development. Poppendieck published the book "Lean Software Development: An Agile Toolkit" (M. Poppendieck and T. Poppendieck, 2003). In the book, Poppendieck stated that an important tool to manage work flow is the concept of pull-systems, which means tasks are put in production only when a customer asks for it (M. Poppendieck and T. Poppendieck, 2009). The pull based method Kanban has in recent years been introduced more and

more to software development, and is becoming one of the keys to Lean practice in software development (D. Anderson et al., 2011). In Lean there are eight fundamental principles (M. Poppendieck, 2003).

1. **Start Early:** Don't wait for details. As soon as enough information is gathered start the development activity. Get everyone involved in figuring out the details. Don't build any walls between people, make people collaborate and start a two-way communication as soon possible. This will start the learning cycle as well.
2. **Learn Constantly:** Start with a breadth-first approach, explore multiple options. The system is expected to change, so focus on creating simplicity code and robustness so the system is easy to change
3. **Delay Commitment:** In order to delay commitment, automated testing and refactoring are essential for keeping code changeable.
4. **Deliver Fast:** Deliver fast mark of excellent operational capability. The whole idea of **delaying commitment** is to make every decision as late as possible when one have the most knowledge.
5. **Eliminate Waste:** The only thing worth doing is deliver value to the costumer, anything else is waste. Discover waste and eliminate it is the first key of Lean. Lean suggests using a value stream map for removing waste. A Value Stream Map (VSM) is a map over the whole company chain. VSM helps visualize where waste is located within the company.
6. **Empower the team:** When one is going to deliver fast, there is no room for central control. The work environment should be structured so work and workers are self-directing.
7. **Build Integrity In:** Lean software is build with integrity. That's why one of the principles in Lean suggests that tests are integrated into software development just as any code, so it becomes a part of the delivered product.
8. **Avoid Sub-optimization:** In software development it's normal to break down a complex problem into small parts of the problem in order to minimize the complexity. If some of the parts are sub-optimized, bottlenecks can occur. For example, if ten developers are hired to work on tasks, but only three testers are hired. The development process is sub-optimized since the developers will likely produce more than the tester can test and that could cause bottleneck.

2.4 Kanban

Toyota production system introduced Kanban as a scheduling system for Lean and just-in-time (JIT) production during late 1940's and in the early 1950's in order to catch up with the American car industry. The Kanban method combined with the Lean approach was a success for Toyota. The success was noticed by the software development industry among others (Conboy, 2009), (Ohno, 2001). In the recent years, the software industry has seen an increasing amount of project that applies Kanban and Lean principles (D. Anderson et al., 2011), and this is one of the reasons why this work will focus on Kanban, more specific, one of its key principles WIP limits.

"One can define Kanban software process as a WIP limited pull system visualized by the Kanban board" (D. Anderson et al., 2011). One of the most important people in Kanban software development, David Anderson also referred to as "father of Kanban in the software development industry" (Gupta, 2013) and author of the book "Kanban: Successful Evolutionary Change for Your Technology Business"(D. J. Anderson, 2010) stated "If you think that there was Capability Maturity Model Integration, there was Rational Unified Process, there was Extreme Programming and there was Scrum, Kanban is the next thing in that succession." (Leonardo Campos, 2013) .

In software development, Kanban splits the major problem into many small pieces of problems. When the small pieces are defined by the team, the problems are put up on the Kanban board to visualize the problems, track what others are working on and see potential bottlenecks during development. Shinkle stated that when people start to understand Kanban, they easily discover where the bottlenecks are (Shinkle, 2009). In short, Kanban systems focus on (D. Anderson et al., 2011):

- continuous flow of work,
- no fixed iterations or sprints,
- work is delivered when it's done,
- teams only work on few tasks at the time specified by the WIP limit and
- make constant flow of released tasks.

Contrary to Scrum, Kanban do not use the principles of sprints or estimations. In Kanban the tasks do not need to be estimated or finished within a certain time. In the paper "Simulation of software maintenance process, with and without a work-in-process limit" (Concas et al., 2013) the authors found out that if they let the developers work with small tasks and are not interrupted, they will be more effective. They also

found out that Scrum was too rigid for the development team because when the team had to estimate tasks, they felt interrupted. The estimation and sprint meetings worked counterproductive in their case. The authors made the developers change to Lean-Kanban. The change implied the removal of sprints and estimation. After removing sprints and estimation the teams increased the ability to perform work, lower the lead time and meet the production dates (Concas et al., 2013).

In the papers "Quantifying the Effect of Using Kanban versus Scrum:" the company also felt that the Scrum approach was too rigid. The paper also reported positive results when the team changed to Kanban. The company almost halved its lead time, reduced the number of weighted bugs by 10 percent, and improved productivity (Sjøberg, Johnsen and Solberg, 2012). Other papers also state that Scrum maybe too rigid and that's Kanbans advantages over Scrum (Beedle et al., 1999) (Brekkan and Mathisen, 2010) .

2.4.1 Kanban Board

"The Kanban board makes it clear to all the team members the exact status of progress, blockages, bottlenecks and they also signal possible future issues to prepare for"(Middleton and Joyce, 2012). The Kanban board is one of many tools in Kanban. It's used to control WIP, increase the information flow with visualization (Concas et al., 2013). A Kanban board is illustrated in figure 2.2. Each column in figure has 2.2 an intuitive name in order to describe itself so the developers easily can track where each task is.

The columns are named "Backlog", "In progress" and "Done". Each column can have a WIP limit to specify how many items in progress there are allowed in the column (Middleton and Joyce, 2012). In figure 2.2 the WIP limit is stated under the column name. The backlog column has a WIP limit of 4, In progress has 5 and Done doesn't need a WIP limit.

The yellow stickers represent the tasks. Some development teams follow the path to mark stickers with different colors representing the severities or by marking if its a feature or a bug. In the paper "Kanban Implementation in a Telecom Product Maintenance" for instance, the stickers has three different colors, green, yellow and red depending on how close to overdue the tasks are. If the sticker is red, the task is already overdue, if the tasks are soon-to-overdue its marked with yellow stickers (Seikola, Loisa and Jagos, 2011). In another project, they used yellow sticky notes for scenarios, blue for bugs, pink for issues (Shinkle, 2009).

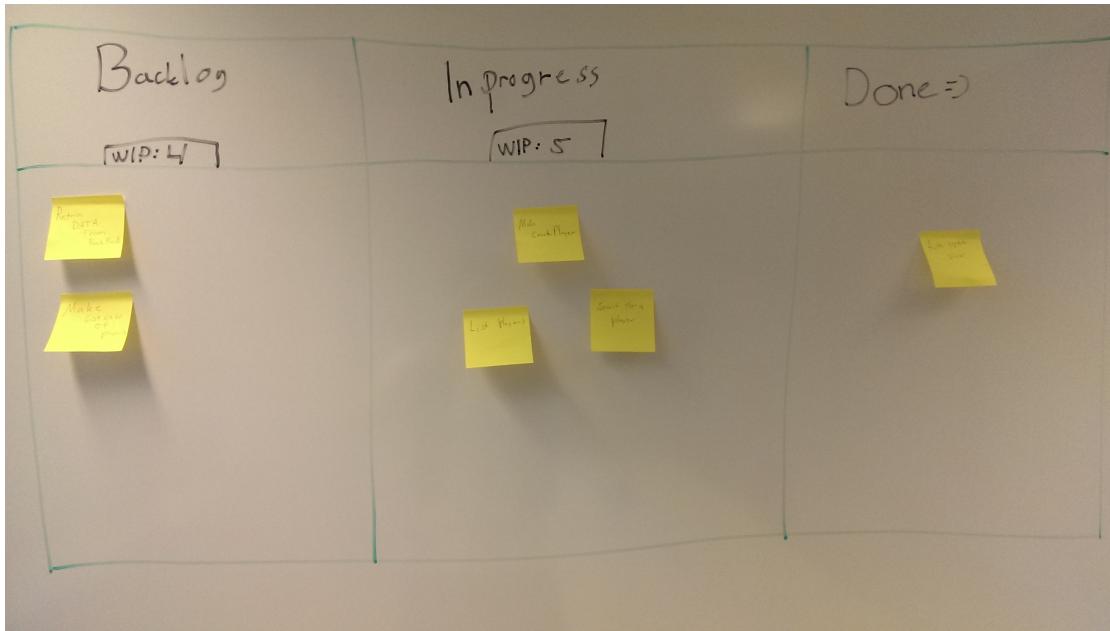


Figure 2.2: Example of a Kanban board

2.4.2 WIP limit

"WIP limits seem to be the worst understood part of the Kanban system. When used properly, it exposes bottlenecks and reduces lead time for individual work items. Used improperly, it can starve developers for work or result in too many people working on the same work items." (Shinkle, 2009)

WIP limit is one of the core principles in Kanban (Seikola, Loisa and Jagos, 2011). WIP limit helps to reduce overhead by limit task-switching for each developer and make constant flow of tasks throughout the development (D. Anderson et al., 2011). One way to explain WIP and the asserted impact of WIP limit is to use cars and roads as analogy. All roads have a maximum capacity of cars. When this limit is reached, traffic jam occurs and the throughput of cars decreases and lead time increases. The same can be said about software development teams. A software team has a maximum number of tasks they can perform, if the team is pushed over the maximum limit, the throughput of tasks may decreases and lead time may increases.

When first implementing Kanban, Shinkle explains that the users often don't care about WIP or setting a WIP limit, but rather the visibility of Kanban through the Kanban board. When users gain more experience with Kanban, they start to attempt the principles of WIP limit (Shinkle, 2009). Srinivasan, Ebbing and Swearing said that setting the WIP limit is not easy. They suggest that the WIP limit is set, and then

observe throughput, and adjust after that (Srinivasan, Ebbing and Swearingen, 2003). In the book "Kanban and Scrum - making the most of both" suggests Kniberg that you start by limiting WIP, then experiment with it (Kniberg, 2010). The paper "Lean Software Management" (Kniberg, 2010) and the "Impact of Kanban on Software Project Work" (M. Ikonen et al., 2011) both suggest that WIP should be minimized as well. The conclusion of the studies are to keep the WIP limit low and experiment by slowly increase the WIP limit until the throughput decreased and lead time increased, then you know that the previous WIP limit was the perfect one.

The Section 2.4.2.1 shows a summary of the the papers by Giulio Concas, Hongyu Zhang (Concas et al., 2013) and David Anderson, Giulio Concas, Maria Ilaria Lunesu, and Michele Marchesi (D. Anderson et al., 2011). The papers researched the difference between limit WIP and unlimited WIP. Section 2.4.2.2 shows the importance of limit WIP, stated by various researches.

On "how to determine WIP limit", one paper was found. If one implements Kanban with sprints or uses Scrum, Łukasz proposes to use the effectiveness metric to help determine the WIP limit. The effectiveness metric shown in formula 2.1, should be applied after end sprint according to Łukasz. After each sprint, one can apply the effectiveness metric and the result could be used as a guideline for WIP limit for the next sprint. The effectiveness metric takes the number of bugs found (ai) and the number of bugs found by external people (e.g. lawyers, accountants, coaches, consultants, translators, internal and external service providers etc.) (ei), and minus ai and ei , then divide the result by ai and multiply it by 100% as shown in formula 2.1 (Sienkiewicz, 2012)

$$Ei = \frac{(ai - ei)}{ai} * 100\% \quad (2.1)$$

2.4.2.1 Limit WIP vs. Unlimited WIP

In an paper cite by Giulio Concas and Hongyu Zhang (Concas et al., 2013), they simulated two different software maintenance processes. The first process was based on 4 years of experience with Microsoft maintenance team. The second process was from a Chinese software firm. The simulation executed 10 runs and one of the results were the average of closed tasks was 4145 when the WIP was limited and 3853 when the limit was not limited (about 7% less). The paper concludes findings as; developers are more focused on fixing few issues, because the number of issues they can work on is limited. The developers are more likely to continue on the issue from the day before, rather than starting on another issue. This reduces overhead, because when developers start on a new issue, they need time to familiarize themselves with the code and the

issue. That could create unnecessary overhead if some developer already has done it, but that developer is now working on another issue.

The study also showed that WIP-limit could improve throughput and work efficiency, because WIP-limits prevents task switching. In the paper, the authors also simulated a software process, the process was originally without WIP-limits, with WIP-limits. The simulated process with WIP-limits out performed the original process. (Concas et al., 2013).

The paper by David Anderson et al. (D. Anderson et al., 2011) did a simulation of lean-kanban approach with the impact of WIP limit vs. no WIP limit on developers with skills in different activities. The four skill activities from the paper were design, development, testing and deployment.

The paper did four different simulations. A simulation with WIP limits and seven developers with skill in two of the four activities. A simulation with no WIP limit and seven developers with skilled in two of the four activities. A simulation with WIP limits and seven developers with skill in all of the activities. A simulation with no WIP limits and seven developers with skill in two of the four activities.

The paper concluded that the last two is unlikely in the real world, because there is rarely a whole team with developers skilled in all activities. When the developers had skill in two out of four activities, the WIP limit simulation used 100 days, but the non WIP-limit simulation used 120 days. The simulation with WIP limit showed an almost constant flow of features that completed, while in the same simulation with no WIP limit, the flow of features was much more irregular (D. Anderson et al., 2011).

2.4.2.2 Benefits with setting WIP limit

This subsection contains excerpt from papers from various authors that have done study on WIP limit.

1. Lowering the WIP limit will help people avoid task switching. When switching tasks, it is more difficult to be able to fully concentrate. (M. Ikonen et al., 2011).
2. There's stated when using short-cycle times and Kanban board to limit WIP, the software development team's learning is increased (Middleton and Joyce, 2012):
3. WIP - limit increases productivity (Middleton and Joyce, 2012).
4. WIP - limit reduce cycle time (Birkeland, 2010)

5. When WIP was too high, lead times grew and as a result so did the bugs and rework (Shinkle, 2009).
6. WIP-limits are important to reduce lead times (The-Kanban-Way, 2011)

Both the studies on WIP limit vs. no limit and the papers shows the importance of WIP limit. If Łukasz's effectiveness equation 2.1 is regarded , there is no clear rule on how to determine WIP limit even though WIP is supposed to be a crucial principle in order to take full advantage of Kanban.

2.5 Lead time

"Lead time is the total elapsed time from when a customer requests software to when the finished software is released to the customer" (Middleton and Joyce, 2012). Lead time is measured to track how quickly software is delivered to customers (Middleton and Joyce, 2012). Lead time could be an essential ingredient when you look for the optimal WIP, if there is one. Often in a project, lead time is split into pieces, so every task has its own lead time. This gives the development teams the advantages to experiment with different WIPs in order to see the different lead times, then measure which WIP that suits this project the best.

According to the paper "Quantifying the effect of Using Kanban versus Scrum" (Sjøberg, Johnsen and Solberg, 2012) the citation by Middleton and Joyce above is close to definition of what lead time is. They define lead time as the amount of time that passed from the moment that the development team receives a request to the moment that it completes the work item. The reason why the paper disapproves the definition by Middleton and Joyce is because: "The amount of time a work item remains in the backlog queue before it's put on the board is a function of priority, not whether the company uses Scrum, Kanban or other development methods. Furthermore, companies that develop and sell products to many customers might propose new features themselves and put them on the backlog before any customers request them. Second, given a policy of two or three releases a year, the result of a work item isn't delivered to the customer immediately after it's finished" (Sjøberg, Johnsen and Solberg, 2012).

2.6 Just-In-Time

"Just-In-Time is based on delivering only the necessary products, to the necessary time and the necessary quantity" (Lai, Lee and Ip, 2003). Just-In-Time (JIT) was introduced

in the 1970s by Toyota in combination with Lean (Javadian Kootanaee, Babu and Talari, 2013). JIT has been introduced to increase productivity through waste reduction and increasing the value added in the production processes. To explain the JIT principle, Mary and Tom Poppendieck use the picture shown in Figure 2.3 (Lai, Lee and Ip, 2003) (M. Poppendieck and T. Poppendieck, 2006). The stream reflects the inventory. Under the stream, there are rocks located in different sizes. The rocks illustrates waste and problems that can occur. If the stream level is lowered, the rocks are more visualized. At this point you have to clear out rocks (remove waste and problems) in order to make the boat continue it's journey, or it will crash into the rocks. After the rocks are cleaned out, one can lower the stream level again and continue the procedure until there are only pebbles left. Then the boat can float without problems.

If one lower the stream (inventory), problems and waste will become visible (visualized by rocks). Lean wants to lower inventory in order to make problems and waste occur, because when problems and waste occurs, you are able to fix the problems and remove the waste. Fixing the problem and removing the waste has several benefits such as, your process could be optimized and you are one step closer to have zero problems and zero waste. (Lai, Lee and Ip, 2003) (M. Poppendieck and T. Poppendieck, 2006).

In Software development the JIT principle means one should not deliver anything before its demanded. For example, a development team adds two new features to a product without the stakeholders asking for it and it turns out the stakeholders do not want it. Then the team has produced waste.

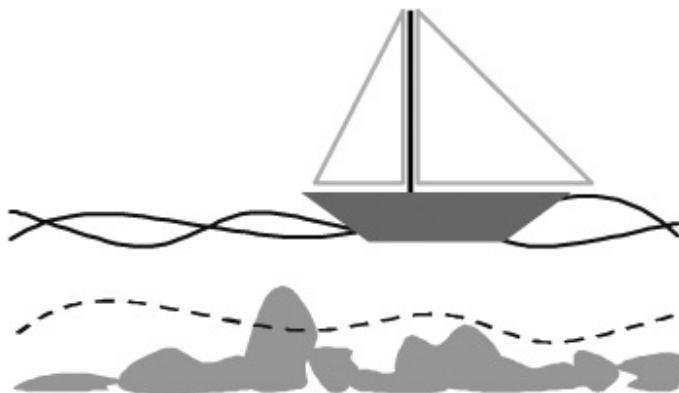


Figure 2.3: JIT example

2.7 Throughput

"The output of a production process (machine, workstation, line plant) per unit time (e.g., parts per hour) is defined as the systems throughput or sometimes throughput rate" (Adams and Smoak, 1990). The main concept of throughput is to measure how productive teams, people or companies are. Throughput is measured in number of finished delivered tasks or units per hour, day, week, month, quarter or year. A key factor in successfully measuring throughput in software development is to specify a standard size for each task. If the standard is not specified there is little use in throughput measurements. (Rouse, 2005). To illustrate throughput with different task sizes an example is provided:

Lets say Team x had a throughput of eighteen tasks after the first quarter, twenty after the second, fifteen after the third and twelve after the last quarter. Team x used Scrum the first two quarters and Kanban the last two as illustrated in table 2.1. It will look like team x benefits most from Scrum. But if the task during the Kanban time was twice the size of Scrum, Kanban would suite team x the best. So, to get valid result from throughput measurements, the size of tasks has to be agreed upon by the teams or company.

Quarter	Throughput	Method
1	18	Scrum
2	20	Scrum
3	15	Kanban
4	12	Kanban

Table 2.1: Throughput

2.8 Code churn

"Churn is defined as the sum of the number of lines added, deleted, and modified in the source code" (Sjøberg, Johnsen and Solberg, 2012). Churn is a measure that is not as familiar as lead time, throughput or WIP in the software industry. Churn is a term used as surrogates for effort in software engineering. Many studies in software engineering use code churn or revisions as surrogate measure of effort (D. Sjøberg, Anda, Mockus et al., 2012). Emam stated that "analysts should be discouraged from using surrogate measures, such as code churn, unless there is evidence that they are indeed good surrogates" (El-Emam, 2000). The study by Sjøberg et al. showed that

churn could be used as a surrogate for tasks size (D. Sjøberg, Anda, Mockus et al., 2012).

2.9 Software Innovation

Software Innovation¹ is a Scandinavian software company. SI develops and delivers Enterprise Content Management applications that helps organizations improve and increase efficiency in document management, case handling and technical document control. SI builds products around the Microsoft Sharepoint platform. (Sjøberg, Johnsen and Solberg, 2012), (*Software Innovation* 2013).

SI has approximately 300 employees in Oslo, Copenhagen, Stockholm and Bangalore (*Software Innovation* 2013). From 2001 to 2006, SI used the Waterfall process. In 2007, SI changed to Scrum, and in 2010, SI went from Scrum to Kanban (Sjøberg, Johnsen and Solberg, 2012).

¹<http://www.software-innovation.com/>

Table 2.4 shows the size of the ten teams vs. quarter. The team size is used as a variable to compute the result for work. Team seven, shown in Table 2.4g contribute data from 2010 to 2012. After 2012, team seven was shut down.

Year	Quarter	Team Size												
2010	3	6	2010	3	10	2010	3	6	2010	3	3	2010	3	5
2010	4	3	2010	4	15	2010	4	9	2010	4	8	2010	4	13
2011	1	16	2011	1	13	2011	1	7	2011	1	4	2011	1	14
2011	2	28	2011	2	12	2011	2	10	2011	2	4	2011	2	25
2011	3	2	2011	3	15	2011	3	9	2011	3	4	2011	3	21
2011	4	38	2011	4	14	2011	4	10	2011	4	4	2011	4	23
2012	1	35	2012	1	15	2012	1	11	2012	1	4	2012	1	25
2012	2	34	2012	2	7	2012	2	11	2012	2	2	2012	2	19
2012	3	32	2012	3	8	2012	3	13	2012	3	3	2012	3	24
2012	4	29	2012	4	9	2012	4	13	2012	4	5	2012	4	18
2013	1	24	2013	1	10	2013	1	13	2013	1	7	2013	1	31
2013	2	37	2013	2	7	2013	2	7	2013	2	5	2013	2	29
2013	3	23	2013	3	7	2013	3	8	2013	3	5	2013	3	27
2013	4	23	2013	4	8	2013	4	8	2013	4	5	2013	4	11
Total		330	Total		150	Total		135	Total		63	Total		285

(a) Team size - team one	(b) Team size - team two	(c) Team size - team three	(d) Team size - team four	(e) Team size - team five																																																																																																																																																																																			
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Figure 2.4: Caption of team size for teams in SI

Chapter 3

Research Methods

In this chapter the research methods used in this work will be introduced and the reason why the data set from Software Innovation was chosen. Section 3.1 gives a brief introduction to the research method "Case Study". Section 3.2 is about the choice of case and complementary information about Software Innovation.

3.1 Case study

To answer the research questions, a case study was conducted. A case study is used to explore causation in order to find underlying principles (Shepard and Greene, 2002)(R. K. Yin, 2008). But which methods one can use in a case study or how the case study is conducted is ambiguous. It might be that the case study is qualitative or quantitate. A case study might utilize a particular type of evidence (for example ethnographic, participant observation or field research). Jennifer Platt stated: "Much case study theorizing has been conceptually confused because too many different themes have been packed into the idea "case study" (Gerring, 2006). John Gerring stated: "A case study may be understood as the intensive study of a single case where the purpose of that study is – at least in part to shed light on a larger class of cases (Gerring, 2006). As one can see, there is no clear rule of how to conduct a case study or what it is.

In this work, the case study is used to explore WIP limit's effect in software development. The purpose is to shed light on WIP limit in software development and if it matters.

3.2 Choice of case

The data set from SI contains information about each task SI has worked on from 2008 to 2013. The data set is represented in an excel document. An excerpt of some of the columns in the document is shown in table 3.1. Although the data set contains items from 2008-2013, data from year 2008, 2009 and the two first quarters of 2010 will be excluded. The dates will be excluded partially because the transition between processes and it was inaccurate measurements when SI first started with TFS.

The reason SI and the data set from SI is analyzed in this work is because the paper "Quantifying the Effect of Using Kanban versus Scrum" (Sjøberg, Johnsen and Solberg, 2012) used the same data set. Because Dag is the supervisor of this work and he had access to the data set, it was convenient to use the data set.

ID	Type	Created Date	From Day	Date To	Lead Time	Team
3027	Bug	2008-10-07	2008-10-09	2008-10-16	20	Team one
3028	Bug	2008-10-07	2008-10-07	2008-10-08	10	Team six
3029	Feature	2008-10-07	2008-12-30	2008-12-30	105	Team two
3030	Feature	2008-10-07	2008-10-07	2008-10-07	1	Team three
3035	Bug	2008-10-08	2008-11-20	2008-11-28	17	Team five
3037	Feature	2008-10-08	2008-10-19	2008-10-19	7	Team three
3040	Bug	2008-10-10	2008-11-19	2008-11-19	48	Team one

Table 3.1: Excerpt from the data set

The data set contains thirty columns with different data for each task, most of this columns are irrelevant for this study but the important columns is stated in table 3.2.

Variable	Description
Created Date	When a task is put in backlog
Date From	When a given task is pulled out from the backlog
Date to	When a task is finished and ready for release.
Lead Time	The amount of days elapsed from the date the task was created until the tasks has finished
Type	The type column is labeled as either bug or feature depending on the type of the task
Lines added	Number of lines added to a feature or bug
Lines modified	Number of lines modified when working on a feature or bug
Lines deleted	Number of lines deleted from a bug or feature
Team	States the team who has been working on the task.

Table 3.2: Variables from the SI dataset

The **Created date** column consist of dates for when tasks where created. The **Date from** column contains the date the tasks was pulled from the backlog. The **Date to** column consist of all of the dates when tasks where marked as finished. The **Lines added**, **Lines Modified** and **Lines Deleted** columns contains the amount of lines added, modified or deleted in order to finish the task. The **Type** column consists of a string that has the value as either "Bug" or "Feature". The **Lead time** column consists of the lead time value. The **Team** column consist of which team the task belongs to.

The data from SI was analyzed on team level. The data from SI was analyzed using the software program, which computed the variables shown in table 3.3 for all of the teams.

Computed variable	Description	Columns from SI
WIP	Items in progress on the given day	Date From and Date To.
Throughput	Number of tasks finished on a given day	Date To
Churn	Lines added, lines modified and lines deleted added together	Lines Added, Lines Modified, Lines Deleted and Date To
Bugs	The number of tasks labeled as Bug and not feature	Type and Created Date
Lead time	The time used on a task, measured in days	Lead time and Date To
Bugs finished, quarter	Number of bugs finished, per quarter	Created date, Date to and Type
Avg days backlog, bug	Average days in backlog for bugs, per quarter	Created date, Date from and Type

Table 3.3: Relationship between variable and columns from SI

Both the variable churn and throughput is split up in two sub variables with suffix of "Feature" and "Bug". The variable with suffix of feature means tasks labeled with type feature are the only one that counted. The same goes for variables with suffix bug. These variables are referred to as sub variables in this work. The Bugs finished, quarter variable represents how many tasks labeled bug that are finished within the same quarter as it was created. The Avg days backlog, bug variable represent the average number of days bugs were in backlog before it was pulled out.

3.2.1 Software Innovation's development process

From 2001 to 2006 SI used the Waterfall process with a life cycle of:

1. Design
2. Implementation
3. Testing
4. Deployment for each new release

(Sjøberg, Johnsen and Solberg, 2012).

In 2007, SI examined their development process, which resulted in a decision to change to Scrum. Scrum was implemented with the standard elements of Scrum:

- Cross functional teams
- Sprint planning meetings
- Estimation of work items using planning poker
- Daily standup meetings
- Sprints

(Sjøberg, Johnsen and Solberg, 2012).

SI implemented three weeks sprint, after each sprint a fully tested shippable system was ready. In 2010, SI went from Scrum to Kanban. SI felt that Scrum was too rigid and didn't fit their purpose, they also feared that inaccurate estimation and time boxing gave them longer lead time. SI also saw Scrum planning meetings as waste which reduced productivity and quality (Sjøberg, Johnsen and Solberg, 2012).

SI decided to implement Kanban in the following manner. When a work item is pulled from the backlog, SI tries to make the item flow through all the stages until it's ready for release. This procedure happens as quickly as possible. In order for an item to be ready for release, it has to be at a satisfactory quality level, which is defined by SI. SI also implemented WIP limits. If the WIP limit is reached, no new tasks are started until another task is finished which is based on the principle of just-in-time (Sjøberg, Johnsen and Solberg, 2012).

3.3 Correlation

The correlation coefficient between two variables is used to reflect the linear relationship between these variables. The most common used is Pearson correlation. The range of the correlation is [-1, +1], where +1 represents a perfect positive relationship and -1 represents a perfect negative relationship (L. Yin, Xiao and Xu, 2013). In this work I want to look at the linear relationship between two variables, so I have chosen to use Pearson correlation.

Chapter 4

Data collected and calculations

This chapter introduces how the algorithms of the software program works as well as a brief introduction to SPSS. The first section gives a short introduction to the statistical analyzes program SPSS (Section 4.1). The next section, Section 4.2 introduces the algorithm of how the program measures WIP for each day. The subsection 4.2.4 provides a comprehensive example of how the program measures WIP per day. The consecutively sections reveal the algorithms of how the program measures throughput (Section 4.3.1), churn (Section 4.3.2), lead time (Section 4.3.3), sub variables (Section 4.3.5), number of bugs finished per quarter (Section 4.3.6) and average days for bugs in the backlog (Section 4.3.7).

Table 4.1 shows how quarters, dates and days are represented in this work.

- The date standard is specified as YYYY-MM-DD.
- All seven days in the week are taken into account when the software program calculates.
- Quarter of a year is defined as:
 - January, February and March (Q1),
 - April, May and June (Q2),
 - July, August and September (Q3),
 - October, November and December (Q4).

(Investopedia, 2013)

Table 4.1: The standard of the data set

4.1 SPSS

"IBM®SPSS®Statistics is a comprehensive system for analyzing data. SPSS Statistics can take data from almost any type of a file and use them to generate tabulated reports, charts and plots of distributions and trends, descriptive statistics, and complex statistical analyses." (IBM, 2014). After the software program has finished the measurements of the data, SPSS will be used to analyze the derived data with help of two statistics method: correlation and case summaries.

4.2 WIP per day

4.2.1 Step 1: Gather all unique dates into a ArrayList

The first step of this WIP algorithm is to create a WIP object with the attributes in Table 4.2. The values that are assigned to the object are gathered from the data set file, which is shown in Listing 4.1. After the values are assigned, the program puts the WIP object into the right ArrayList¹ based on the team variable as shown in listing 4.2.

Type	Variable name
Date	start
Date	end
String	team
String	processType
int	WIP

Table 4.2: Variables of the WIP objects

¹ArrayList is a resizable array implementation of a list. The ArrayList class provides function for manipulating the size of the array, check the size of the list and convert the list to an array (Oracle, 2013).

```
1 While inputFile != EOF // EOF = End Of file
2     WIP = New WIP()
3     WIP.start = inputFile.start
4     WIP.end = inputFile.end
5     WIP.team = inputFile.team
6     WIP.processType = inputFile.processType
7     WIP.WIP = 1
8     FindTeam(WIP)
9
```

Listing 4.1: Gather all unique dates into ArrayList

```
1 void FindTeam (WIP w)
2     if w.team EQUALS "TeamOne"
3         TeamOne.add(w)
4     if w.team EQUALS "TeamTwo"
5         TeamTwo.add(w)
6     if w.team EQUALS "TeamThree"
7         TeamThree.add(w)
8 /* And so on for the rest if the seven teams */
9
```

Listing 4.2: Gather WIP object to the right data structure

4.2.2 Step 2: Gather the remaining dates

There are some dates missing as shown in Table 4.3. For example, the date 2010-10-08 is missing. In order to generate WIP for each day, the program has to create the dates that are not in the set. In order to create the remaining dates, the program takes the first date and the last date from each of the teams' ArrayList, this is shown in Subsection (4.2.1) as shown in line one and two of Listing 4.3. Then the program checks if all the dates between the first date and the last date are in the team's ArrayList. Each of the ArrayLists are sorted by date. If the dates are not in the ArrayList, the program will generate the date and put it into the ArrayList, as show at the method addToArraylist (lines 10-13). In order to keep the pseudocode simple, the generateWIP method stated in line twelve was omitted. The generateWIP method creates a new WIP object and returns it.

```
1 WIP first = ArrayList.get(0)//points to the first WIP object in the ArrayList
2 WIP last = ArrayList.get(ArrayList.size() - 1)//points to the last WIP object
   in the ArrayList
3 Next_date //points to the next date
4 Next_date = first.getDate() // Next_date assigned before iteration
5 while Next_date NOT EQUALS last.getDate()
6   New_date = Next_date + 1 //Compute the next date
7   AddToArraylist(New_date, first.getTeam())
8   Next_date = New_date
9
10 void addToArraylist(Date d, String team)
11   if d NOT CONTAINS IN ArrayList
12     WIP = generateWIP(d, team)
13     ArrayList.add(WIP)
14
```

Listing 4.3: Gather the remaining dates.

4.2.3 Step 3 Measure WIP

The ArrayLists from section 4.2.1 and 4.2.2 now contains a WIP object for each date for each team. In this step, the program will loop through each of the teams ArrayLists. During the iteration each WIP object is extracted from the ArrayList and the WIP is measured. The two methods stated in line 10 and 17 respectively gather the current WIP (method in line 10) and finds how many tasks are finished (method in line 18) and returns the result. The result is used in line 6 to compute the current WIP. The conditional statement on line 4 assures only one instance of each date is measured.

```

1 void measureWIP()
2     lastWIP = 0
3     for WIP Object IN ArrayList
4         if(DateNotMeasured(WIP.getStartdate()) == true)
5             WIP_for_this_date = get_current_WIP(WIP.getStartdate())
6             WIP_measured = WIP_for_this_date - Nr_of_finishedDates(WIP.getStartdate)
7             ) + lastWIP
8             WIP.setWIP(WIP_measured)
9             lastWIP = WIP_measured
10
11 int get_current_WIP(Date date)
12     current_WIP = 0
13     for WIP in ArrayList
14         if date EQUALS WIP.getStartdate()
15             Nr_of_dates_to_decrement++
16     return current_WIP
17
18 int Nr_of_finished_dates(Date date)
19     Nr_of_dates_to_decrement = 0
20     for WIP in ArrayList
21         if date AFTER WIP.getEnddate() DO
22             if date not picked
23                 Nr_of_dates_to_decrement++
24                 dateIsPicked(WIP)
25     return Nr_of_dates_to_decrement

```

Listing 4.4: WIP measurement

4.2.4 Example

This section will provide a comprehensive example of how the WIP algorithm works. Figure 4.1 shows task ids on the y-axis and dates on the x-axis. The green line indicates the duration of the task. The figure helps visualize how many WIPs there are in progress for a given date. For example on the date 2010-10-12, tasks 3, 5 and 6 are in progress, which means the WIP is 3 for 2010-10-12. The dates from Table 4.3 will be used to illustrate how the algorithm measures WIP.

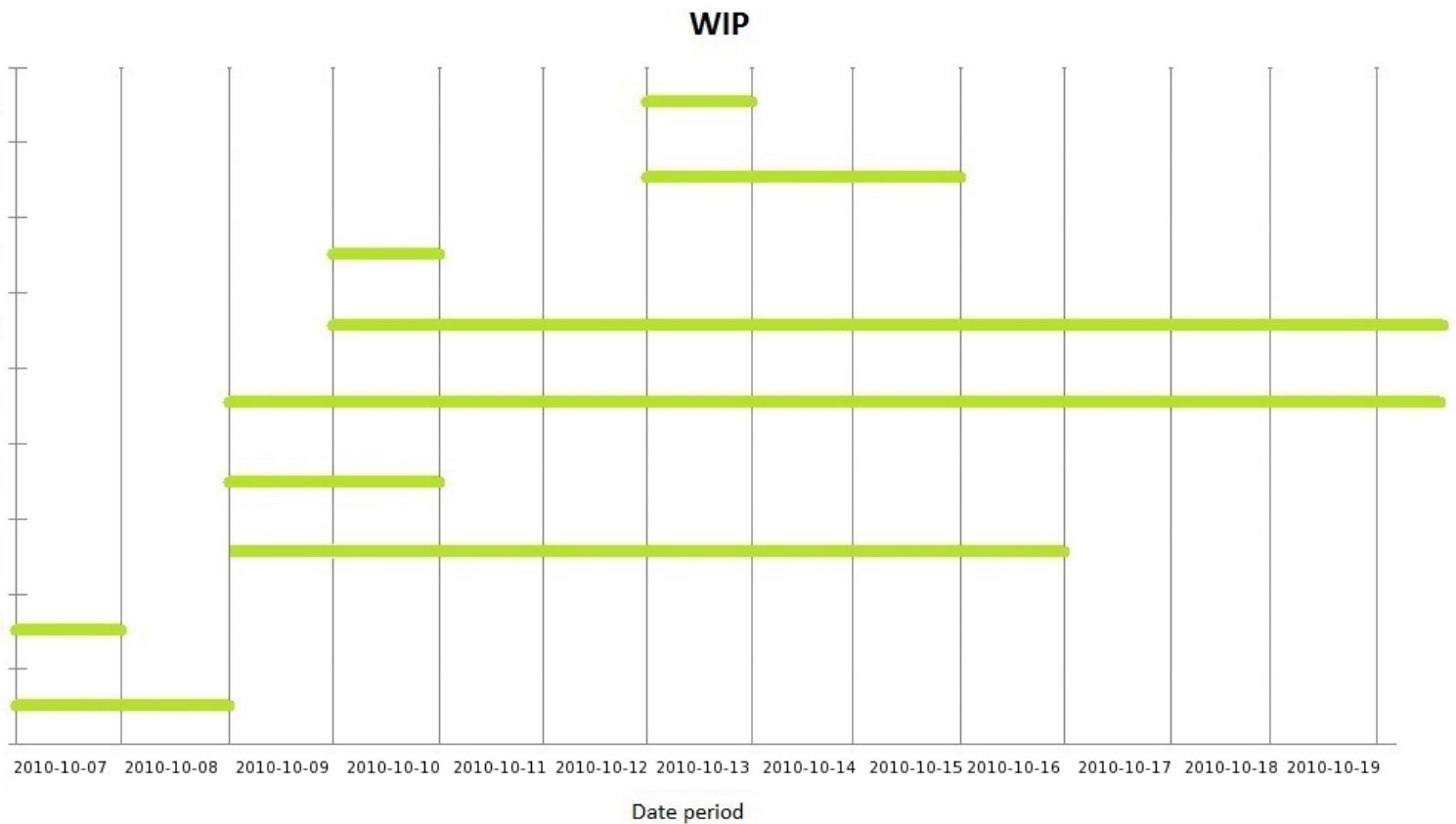


Figure 4.1: Illustrating the WIP timeline for example stated in section 4.2.4

Task ID	Date From	Date To	Team	Process Type
1	2010-10-07	2010-10-08	Team One	Kanban
2	2010-10-07	2010-10-07	Team One	Kanban
3	2010-10-09	2010-10-16	Team One	Kanban
4	2010-10-09	2010-10-10	Team One	Kanban
5	2010-10-09	2010-11-04	Team One	Kanban
6	2010-10-10	2010-11-05	Team One	Kanban
7	2010-10-10	2010-10-10	Team One	Kanban
8	2010-10-13	2010-10-15	Team One	Kanban
9	2010-10-13	2010-10-13	Team One	Kanban

Table 4.3: Showing Task ID, Date From and Date to

4.2.4.1 Step 1

The program will first read in line 1 of table 4.3. Line 1 is the one with task id one. The program creates the WIP-object line 1 and it will look like the Listing 4.5. The program will follow the exact same procedure until all the dates are read.

```
1 WIP = new WIP()
2 WIP.start = 2010-10-07
3 WIP.end = 2010-10-08
4 WIP.team = "Team One"
5 WIP.processType = "Kanban"
6 WIP.WIP = 1
```

Listing 4.5: Creating WIP-object

4.2.4.2 Step 2

Now that the whole set has been read and saved, the next thing to do is to create the remaining dates. The ArrayList contains all the dates from Table 4.3. The program will now extract the first and the last date from the ArrayList. Before this step, the objects in the ArrayList are sorted by date. The first date is 2010-10-07 and the last date is 2010-10-13. The program will check if the date after 2010-10-07 contains in the set, which it does not. The program then generates a WIP object for the date 2010-10-08 and adds it to the ArrayList as shown in Listing 4.6. After the date is created, the program will see if the date 2008-10-09 exists and will do so for all dates up to the date 2010-10-13.

```
1 void createNewWIP(Date d, String team)
2   WIP.start = d
3   WIP.end = d
4   WIP.team = team
5   WIP.processType = "Unknown"
6   WIP.WIP = 0
```

Listing 4.6: Creating WIP-object

4.2.4.3 Step 3

The ArrayList now contains the dates from 2010-10-08 to 2010-10-13. The next and last step is to measure WIP for each date. The program will now loop through the ArrayLists. The first date is 2010-10-07. The get_current_wip method from line nine in Listing 4.4 will be called with the date 2010-10-07 as parameter. The method will return

two, because both tasks one and two were started at 2010-10-07 as shown by Figure 4.1. The next thing to do is to find out how many tasks to decrement the current WIP with. The method `Nr_of_finished_dates` in line seventeen is called with the date 2010-10-07. As shown by the Table 4.3 and Figure 4.1 there was no task finished at the date 2010-10-07, so the method returns 0. The program then updates the WIP objects' counter to be two and saves the WIP value in the `lastWIP` variable. The next date is 2010-10-08, which the program made in Subsection 4.2.4.2. There is no task started at 2010-10-08, but task one is finished at the date. So the `Nr_of_finished_dates` returns one and flags the current date as shown in Listing 4.4 by the line 23. The result of `WIP_measure` in line five is 1 ($0 - 1 + 2 = 1$). WIP at date 2010-10-08 is one, as shown by figure 4.1. The program will continue this procedure until all the dates are measured. The reason why the date is flagged is to be sure that each date is only evaluated ones.

4.3 Rest of the variables

To compute the remaining variables a new algorithm is required. The first part of the algorithm for the remaining variables is equal. First the program reads in the data set from SI. For each of the lines in the data set, the program creates an object and saves the valuable information from the data set in the object. Then each object is saved in a data structure based on team association as showed in Listing 4.7. After all the lines has been read and all objects has been put in the right data structure the algorithms differs.

```
1 void addBug(Bug b)
2   if b.team EQUALS "TeamOne"
3     if dateExists(b.date, TeamOne) EQUALS false
4       // if date don't exists, then add the bug
5       TeamOne.add(b)
6
7   if b.team EQUALS "TeamTwo"
8     if dateExists(b.date, TeamTwo) EQUALS false
9       // if date don't exists, then add the bug
10      TeamTwo.add(b)
11
12  if b.team EQUALS "TeamThree"
13    if dateExists(b.date, TeamThree) EQUALS false
14      // if date don't exists, then add the bug
15      TeamThree.add(b)
16
17  if b.team EQUALS "TeamFour"
18    if dateExists(b.date, TeamFour) EQUALS false
19      // if date don't exists, then add the bug
20      TeamFour.add(b)
21
22  /* And so on for the rest of the teams */
23
24
25
```

Listing 4.7: Pseudocode example of how throughput objects are added

4.3.1 Throughput

When the steps described in Section 4.3 are finished, the program takes the teams data structures and compute throughput. To compute throughput, a counter representing the throughput for each date is created. The method dateExists in listing 4.8 does the actual computation. The method starts of with a test. If the date of the throughput object is in the data structure, the corresponding counter is incremented. If the date is not in the data structure, the new throughput object is added to the data structure.

```

1 void dateExists(Throughput tp, ArrayList list)
2   for Throughput t in list
3     if t.date EQUALS tp.date
4       t.counter++
5       return
6
7   structure.add(tp);

```

Listing 4.8: Pseudocode example of how throughput is measured

4.3.2 Churn

As stated in Section 2.8 in order to take churn into account one has to know its good surrogates. SI has gathered churn with help of Microsoft's Team Foundation Server (TFS) (Sjøberg, Johnsen and Solberg, 2012). The TFS system automatically records data such as churn and lead time. Based on TFS one can know that churn for SI is a good surrogate.

To measure churn the data set from SI contains three columns ("Lines added", "Lines modified" and "Lines deleted") shown in Table 4.4. These three variables are summed together and saved in a variable called "churn" when the data set is read. For example; for task id one, the churn is 2028 ($352 + 307 + 1369 = 2028$). Some tasks has zero churn, for example task with id six, these tasks don't need code in order to be finished such tasks need technical support to be finished. The churn algorithm is shown in listing 4.9

Task id	Lines added	Lines modified	Lines deleted
1	352	307	1369
2	314	31	15
3	314	31	15
4	62	327	153
5	21	3	0
6	0	0	0

Table 4.4: How churn is presented in the excel document

```

1 void updateChurn(Churn c, ArrayList list)
2   for Churn ch in list
3     if ch.date EQUALS c.date
4       ch.churn += c.churn
5       return
6   structure.add(c);

```

Listing 4.9: Pseudocode example of how throughput is measured

4.3.3 Lead time

The program does not need to analyze the lead time for each task. The lead time for each task is recorded by TFS. The lead time is represented in the data set by a column as shown in Table 4.5. The program will gather all the tasks that are started on the same date and belong to the same team and add up their lead time together as showed in code Listing 4.10.

ID	Type	Lead time
84096	Feature	1
84118	Bug	25
84096	Feature	7
84118	Bug	13

Table 4.5: How lead time is recorded in the excel document

```
1 addLeadTime(Leadtime t, ArrayList list)
2   for lead_time in list
3     if lead_time.date EQUALS t.date
4       lead_time.lead_time+= t.lead_time
5     return
6
7
8   structure.add(t)
```

Listing 4.10: Pseudocode example of lead time is measured

4.3.4 Lead time and churn

As stated in the paper "Quantifying the Effect of Using Kanban versus Scrum" (Sjøberg, Johnsen and Solberg, 2012) to prevent outliers from having a large effect on the results, the top and lowest ten percent of lead time and churn are removed from the data set. Churn is removed because a module or a feature, which consists of hundreds or thousands of lines of code could be removed without much work. Lead time is removed because some tasks could be given low priority due to lack of manpower in a given period. Or, tasks could be labeled as not critical and the lead time of these tasks will effect the result.

4.3.5 Sub variables

To measure sub variables, the software program and SPSS was used. The program will generate throughput and churn as described in Sections 4.3.1 and 4.3.2, one of the variables churn and throughput contains is "Type". The output from the program when churn is taken into account will look like Table 4.6. The output from the program will be used by SPSS. SPSS will use a function called case summaries, the case summaries function groups variables based on a common value. With the case summaries function the variable "Team name", "Quarter" and "Type" will be grouped and the independent variable is churn. The result from case summaries will provide the sub variables.

Team name	Churn	Date	Quarter	Type
Team one	25	2011-12-20	2011-4	Feature
Team two	3	2012-04-19	2012-2	bug
Team one	7	2010-08-06	2010-3	Feature

Table 4.6: A excerpt from the result data produced by the program

4.3.6 Bugs finished, quarter

To get the statistics on number of bugs finished the same quarter as it was recorded the software program and SPSS was used. The program extracted the "created date" and the "date to" values from each task and checks if their quarters match. If they do, a boolean value is set to true, otherwise it is set to false. The output is used in SPSS, where the boolean value is grouped together with "Team name" and "Quarter". After the SPSS has measured, the number of finished bugs is divided by the total in order to find the percentages of bugs finished within a quarter.

4.3.7 Average days backlog, bug

To get the statistics on the average number of days bugs are in backlog per quarter, the program measures the number of days between the created date and the date from value. The number of days is saved together with the task. SPSS is used on the output of the program to measure the average days backlog for bugs variable.

The sub variables, Bugs finished, quarter and Average days backlog, bug are used as help variables. These variables will not have their own correlation table.

Chapter 5

Results

The first correlation result showed a medium-high correlation relationship between *team size* and both *WIP* and *throughput*. Based on the correlation values, it was hard to find any evidence if WIP-limit matters in software development. This resulted in a new analyze where each variable for each quarter was divided by the corresponding team size.

Each section except Section 5.6 "Team size" and Section 5.7 "All teams combined" is presented with two correlation tables and two corresponding descriptive statistics tables, one correlation table and descriptive statistic table for the first analysis and the same two tables for the second analyze. Team size is presented with one correlation table and one descriptive statistic table, while all teams combined is presented with one correlation table for the two analyzes. The content of the sections will consist of highlighting the variables with a significant correlation and describe the descriptive statistic tables.

5.1 Correlation - WIP

Table 5.1 displays the first correlation tables for *WIP*. The variables are listed vertically in the correlation table. Horizontally are the corresponding teams. The team names are shortened, team one is shortened to T1, team two is shortened to T2 and so on. The correlation Table 5.1 shows **team one** has a positive correlation to *throughput*, *throughput feature*, *bugs*, *lead time*, *churn feature* and *team size*. **Team two** has a significant negative correlation value to *churn* and *churn bug*. **Team three** has a positive correlation value to all *throughput* variables, *bugs* and *team size*. **Team four** has significant positive correlation to all variables except *team size*. **Team five** has positive correlation to

throughput bug, lead time and team size.

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Throughput	0.74**	0.21	0.76**	0.83**	0.52	0.64*	0.67*	0.47	0.89**	0.61*
Throughput Feature	0.73**	-0.14	0.83**	0.82**	0.25	0.68**	0.63*	0.56*	0.82**	0.20
Throughput bug	0.02	0.25	0.73**	0.82**	0.54*	0.07	0.55	0.15	0.88**	0.63*
Bugs	0.72**	0.20	0.60*	0.56*	0.50	0.46	0.62	0.04	0.58*	0.18
Bugs finished, quarter	0.35	0.10	-0.07	0.56*	0.19	0.19	0.85**	0.23	0.52	0.35
Avg days in backlog, bugs	-0.03	0.44	0.42	0.54*	-0.18	0.02	0.10	0.14	-0.20	-0.18
Lead time	0.75**	0.46	0.49	0.70**	0.57*	0.29	0.68*	0.16	0.23	0.72**
Churn	0.47	-0.71**	-0.32	0.66*	0.03	-0.30	0.15	0.16	-0.09	0.16
Churn feature	0.72**	-0.25	-0.34	0.72**	0.06	-0.36	0.10	0.20	-0.12	0.32
Churn bug	0.15	-0.60*	-0.52	0.62*	0.11	0.77**	-0.05	-0.22	-0.30	-0.10
Team size	0.68**	0.35	0.78**	0.06	0.57*	0.77**	0.62	0.65*	0.54	0.76**

Table 5.1: Correlation - WIP - When team size is **not** taken into account

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Team six has a positive correlation to *throughput*, *throughput feature*, *churn bug* and *team size*. **Team seven** has a positive correlation to *throughput*, *throughput feature*, *bugs finished, quarter* and *lead time*. **Team eight** has positive correlation value to *throughput feature* and *team size*. **Team nine** has positive correlation value to the three *throughput* variables and *bugs*. **Team ten** has a positive correlation to *throughput*, *throughput bug*, *lead time* and *team size*.

Throughput feature and *throughput bug* is subset of *throughput*. It is natural that these sub variables have a significant positive correlation to *WIP*, when *throughput* has. That's not the case for all teams. There is a gap in the relationship between the *churn* variables and *throughput* variables for both team **one** and **six**. The *throughput* variables for teams **five, seven, eight** and **ten** also have a gap, the same goes for the *churn* variables for **team two**, showed in Table 5.1. The relationship between these variables is explained in Section 6.1.

The descriptive statistics tables in each section are based on summary of the correlation values. The tables show number of values measured (N), mean, median, standard deviation (Std.dev), maximum (Max) and minimum (Min) values from the correlation tables. In Table 5.2, the mean correlation value for *throughput* and *team size* is 0.6. The mean correlation value for *lead time*, *throughput feature*, *throughput bug* is 0.5. The *bug* variables have a mean correlation value of 0.4 and *bugs finished, quarter* has an value of 0.3. Rest of the values has a mean value of ± 0.2 or less.

	N	Mean	Median	Std.Dev	Max	Min
Throughput	10	0.6	0.7	0.2	0.9	0.2
Throughput ft	10	0.5	0.7	0.3	0.8	-0.1
Throughput bug	10	0.5	0.5	0.3	0.9	0
Bugs	10	0.4	0.5	0.2	0.7	0
Bugs finished, quarter	10	0.3	0.3	0.3	0.9	-0.1
Avg days backlog, bugs	10	0.1	0.1	0.3	0.5	-0.2
Lead time	10	0.5	0.5	0.2	0.7	0.2
Churn	10	0	0.1	0.4	0.7	-0.7
Churn ft	10	0.1	0.1	0.4	0.7	-0.4
Churn bug	10	-0	-0	0.4	0.8	-0.6
Team size	10	0.6	0.6	0.2	0.8	0.1

Table 5.2: Descriptive Statistic - Correlation - WIP - When team size is **not** taken into account

In Table 5.3, **team two** has a significant positive correlation between *WIP* and *throughput*, *throughput bug*, *bugs finished, quarter* and *lead time*. **Team three** has a significant positive correlation value between *WIP* and *throughput*, *throughput feature* and a significant negative correlation for *bugs finished, quarter*. **Team four** has a positive correlation between all variables except *bugs*, *avg days in backlog*, *bugs* and *churn bug*.

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Throughput	0.37	0.59*	0.57*	0.86**	0.11	0.08	0.49	0.28	0.66*	-0.21
Throughput Feature	0.31	0.47	0.71**	0.85**	0	0.14	0.46	-0.26	0.60*	-0.16
Throughput bug	0.09	0.65*	0.52	0.85**	0.11	0.07	0.57	0.37	0.58*	-0.22
Bugs	0.10	0.49	0.25	0.27	0.11	0.25	0.75*	0.32	-0.05	-0.28
Bugs finished, quarter	-0.28	0.71**	-0.62*	0.74**	-0.24	-0.04	0.85**	0.82**	0.32	-0.28
Avg days in backlog, bugs	0.03	-0.31	0.51	0.10	-0.14	0	0.16	-0.17	-0.40	-0.61*
Lead time	-0.09	0.67**	-0.03	0.87**	0.03	0.32	0.77*	-0.09	-0.18	-0.05
Churn	-0.27	0.16	-0.29	0.77**	-0.09	-0.35	-0.17	0.39	-0.34	-0.37
Churn feature	0.37	0.03	-0.38	0.78**	-0.15	-0.39	-0.17	-0.04	-0.17	0.08
Churn bug	-0.29	0.21	-0.39	0.26	-0.07	0.12	-0.17	0.66*	-0.49	-0.43

Table 5.3: Correlation - WIP - When team size is taken into account

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Team seven has a significant positive correlation for the three variables *bugs*, *bugs finished quarter* and *lead time*. **Team eight** has a significant correlation for *bugs finished, quarter* and *churn bug*. **Team nine** has a significant positive correlation to all *throughput*

variables. **Team ten** have a significant negative correlation for *avg days in backlog, bugs*.

In Table 5.3, teams **two** and **three** have a significant correlation value for two of the three *throughput* variables. **Team four** has a positive correlation for two of the three *churn* variables and **team eight** has significant correlation to one *churn* of the three *churn* variables. The relationship between these sub variables is explained in Section 6.1. The descriptive statistic Table 5.4 shows that *throughput* has an average correlation value of 0.4. The rest of the variables except *throughputs* sub variables have an average correlation values ± 0.2 or less.

	N	Mean	Median	Std.Dev	Max	Min
Throughput	10	0.4	0.4	0.3	0.9	-0.2
Throughput ft	10	0.3	0.4	0.4	0.9	-0.3
Throughput bug	10	0.4	0.4	0.3	0.9	-0.2
Bugs	10	0.2	0.2	0.3	0.8	-0.3
Bugs finished, quarter	10	0.2	0.1	0.6	0.8	-0.6
Avg days backlog, bugs	10	-0.1	-0.1	0.3	0.5	-0.6
Lead time	10	0.2	0	0.4	0.9	-0.2
Churn	10	-0.1	-0.2	0.4	0.8	-0.4
Churn ft	10	0	-0.1	0.4	0.8	-0.4
Churn bug	10	-0.1	-0.1	0.4	0.7	-0.5

Table 5.4: Descriptive Statistic - Correlation - WIP - When team size is taken into account

5.2 Correlation - Lead time

Table 5.5 displays the first correlation table for *lead time*. **Team one** has a positive correlation for all variables except *throughput bug*, *avg days in backlog, bugs* and *churn bug*. **Team two** has a positive correlation value to *throughput* and *throughput bug*. **Team three** has a positive correlation value to *bugs* and a negative correlation value to *churn bug*. **Team four** has a significant positive correlation value to *WIP*, the three *throughput* variables, *churn* and *churn feature*. **Team five** has a significant correlation value to *WIP*.

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
WIP	0.75**	0.46	0.49	0.70**	0.57*	0.29	0.68*	0.16	0.23	0.72**
Throughput	0.70**	0.67**	0.49	0.68**	0.36	0.13	0.47	0.54	0.42	0.32
Throughput Feature	0.73**	0.09	0.44	0.64*	0.14	0.10	0.41	0.62*	0.41	-0.05
Throughput bug	-0.30	0.60*	0.52	0.64*	0.42	-0.01	0.61	-0.17	0.28	0.37
Bugs	0.77**	0.50	0.54*	0.31	0.32	-0.23	0.69*	-0.13	0.44	0.04
Bugs finished, quarter	0.70**	-0.14	0.20	0.23	-0.09	-0.27	0.73*	0.37	0.53	0.19
Avg days in backlog, bugs	0.06	0.40	0.07	0.07	-0.08	-0.03	0.57	-0.12	-0.48	-0.52
Churn	0.70**	-0.42	-0.45	0.97**	0.18	-0.34	0.37	0.91**	-0.37	-0.04
Churn feature	0.86**	0.20	-0.27	0.96**	0.11	-0.31	0.39	0.79**	-0.46	0.32
Churn bug	0.26	-0.39	-0.64*	0.20	0.24	0.28	0.16	-0.12	-0.08	-0.27
Team size	0.61*	0.38	0.44	-0.30	0.36	-0.11	0.59	0.22	0.38	0.53

Table 5.5: Correlation - Lead time - Without taken time size into account

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Team seven has a significant positive correlation value to *WIP*, *bugs* and *bugs finished, quarter*. **Team eight** has a significant correlation value to *throughput feature*, *churn* and *churn feature*. **Team ten** has a significant correlation value with *WIP*.

Table 5.5 displays the variances between the *throughput* variables for team **one**, **two** and **eight**. There is also variance for the *churn* variables for team **one**, **three**, **four** and **eight**. The relationship between these variables is explained in Section 6.1. Table 5.6 shows the average correlation value of 0.5 for *WIP* and *throughput*. *Throughput feature* has the average correlation value of 0.4 and *throughput bug*, *bugs*, *churn feature* and *team size* has the average value of 0.3 and rest of the values has a value of ± 0.2 or less.

	N	Mean	Median	Std.Dev	Max	Min
WIP	10	0.5	0.5	0.2	0.7	0.2
Throughput	10	0.5	0.5	0.2	0.7	0.1
Throughput ft	10	0.4	0.4	0.3	0.7	-0.1
Throughput bug	10	0.3	0.4	0.3	0.6	-0.3
Bugs	10	0.3	0.4	0.3	0.8	-0.2
Bugs finished, quarter	10	0.2	0.2	0.3	0.7	-0.3
Avg days backlog, bugs	10	0	0	0.3	0.6	-0.5
Churn	10	0.2	0.1	0.6	1	-0.5
Churn ft	10	0.3	0.3	0.5	1	-0.5
Churn bug	10	-0.1	-0.1	0.3	0.3	-0.6
Team size	10	0.3	0.4	0.3	0.6	-0.3

Table 5.6: Descriptive Statistic - Correlation - Lead time - Without taken time size into account

Table 5.7 displays the second correlation table. **Team one** has significant positive correlation for *bugs*, *bugs finished*, *quarter*, *churn* and *churn bug*. **Team two** has a significant positive correlation for *WIP*, *throughput* variables, *bugs*, *bugs finished*, *quarter* and *churn bug*. **Team four** has a significant positive correlation for *WIP*, the *throughput* variables, *churn* and *churn feature*. **Team five** has significant correlation value to *throughput*, *throughput bug*, *bugs*, *bugs finished*, *quarter*, *avg days in backlog*, *bugs*, *churn* and *churn bug*.

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
WIP	-0.09	0.67**	-0.03	0.87**	0.03	0.32	0.77*	-0.09	-0.18	-0.05
Throughput	0.06	0.88**	0.26	0.90**	0.80**	0.69**	0.33	0.24	0.32	0.90**
Throughput Feature	0.01	0.75**	0.16	0.89**	-0.05	0.61*	0.34	0.87**	0.20	-0.26
Throughput bug	0.51	0.84**	0.29	0.89**	0.84**	0.41	0.56	-0.27	0.25	0.91**
Bugs	0.83**	0.72**	0.48	0.22	0.72**	0.18	0.85**	-0.23	0.54	0.88**
Bugs finished, quarter	0.88**	0.79**	0.32	0.52	0.80**	0.36	0.77**	-0.04	0.45	0.57*
Avg days in backlog, bugs	0.41	-0.52	-0.04	-0.07	0.85**	-0.09	0.51	-0.20	-0.17	0.10
Churn	0.72**	0.49	0.16	0.96**	0.94**	0.04	0.08	0.71**	-0.18	0.01
Churn feature	-0.52	0.38	0.22	0.96**	-0.21	0.11	0.05	0.86**	-0.28	-0.24
Churn bug	0.73**	0.55*	0.07	0.13	0.95**	-0.17	-0.06	-0.12	0.24	0.03

Table 5.7: Correlation - Lead time - With team size taken into account

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Team six has a significant correlation for *throughput* and *throughput feature*. **Team seven**

has a significant correlation for *WIP*, *bugs* and *bugs finished, quarter*. **Team eight** has a significant correlation for *throughput feature*, *churn* and *churn feature*. **Team ten** has a significant positive correlation for *throughput*, *throughput bug* and *bugs*.

The *throughput* relationship for team **five**, **six**, **eight** and **ten** show variances according to Table 5.7. *Churn* variables also show variances for team **one**, **two**, **four**, **five** and **eight**. The relationship between the variables is explained in Section 6.1. The Table 5.8 displays an average correlation value of 0.5 for *throughput*, *throughput bug*, *bugs* and *bugs finished, quarter*. *Churn* and *throughput feature* has the average value of 0.4. The rest of the values have an average correlation value of ± 0.2 or less.

	N	Mean	Median	Std.Dev	Max	Min
WIP	10	0.2	0	0.4	0.9	-0.2
Throughput	10	0.5	0.5	0.3	0.9	0.1
Throughput ft	10	0.4	0.3	0.4	0.9	-0.3
Throughput bug	10	0.5	0.5	0.4	0.9	-0.3
Bugs	10	0.5	0.6	0.4	0.9	-0.2
Bugs finished, quarter	10	0.5	0.5	0.3	0.9	-0
Avg days backlog, bugs	10	0.1	-0.1	0.4	0.8	-0.5
Churn	10	0.4	0.3	0.4	1	-0.2
Churn ft	10	0.1	0.1	0.5	1	-0.5
Churn bug	10	0.2	0.1	0.4	1	-0.2

Table 5.8: Descriptive Statistic - Correlation - Lead time - With team size taken into account

5.3 Correlation - Bugs

This section contains information about the correlation table between the variables and *bugs*. In the first correlation Table 5.9, one can see **team one** has a significant correlation value with all the variables except *throughput bug*, *bugs finished, quarter*, *avg days in backlog*, *bugs*, and *churn bug*. **Team two** has a significant correlation with *throughput* and *throughput bug*. **Team three** has a significant correlation with *WIP*, the *throughput* variables and *lead time*. **Team four** has a significant correlation value with *WIP* and the *throughput* variables. **Team five** has a significant correlation value with the *throughput* variables and *team size*.

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
WIP	0.72**	0.20	0.60*	0.56*	0.50	0.46	0.62	0.04	0.58*	0.18
Throughput	0.69**	0.81**	0.88**	0.59*	0.97**	0.27	0.53	0.41	0.70**	0.56*
Throughput Feature	0.74**	0.01	0.82**	0.58*	0.88**	0.30	0.56	0.22	0.60*	-0.14
Throughput bug	-0.17	0.83**	0.87**	0.58*	0.96**	0.69**	0.50	0.92**	0.65*	0.59*
Bugs finished, quarter	0.50	-0.18	0.12	0.40	0.17	0.76**	0.79**	0.18	0.70**	0.05
Avg days in backlog, bugs	0.52	0.38	0.43	0.30	0.18	0.24	0.23	0.28	0.21	0.13
Lead time	0.77**	0.50	0.54*	0.31	0.32	-0.23	0.69*	-0.13	0.44	0.04
Churn	0.62*	-0.27	0.10	0.27	-0.06	-0.12	0.11	-0.16	-0.48	0.04
Churn feature	0.77**	0.01	0.09	0.35	0.43	-0.10	0.11	-0.25	-0.62*	0.07
Churn bug	0.42	-0.19	-0.19	0.53	-0.11	0.42	0.12	0.65*	-0.04	0
Team size	0.80**	0.26	0.27	0.17	0.71**	0.41	0.41	0.42	0.41	0.16

Table 5.9: Correlation - Bugs - Without team size is taken into account

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Team six has a significant correlation value with *throughput bug* and *bugs finished, quarter*. **Team seven** has a significant value with *bugs finished, quarter* and *lead time*. **Team eight** has a significant correlation relationship with *throughput bug* and *churn bug*. **Team nine** has a significant correlation relationship to *WIP*, the *throughput* variables, *bugs finished, quarter* and *churn feature*. **Team ten** has significant correlation with *throughput* and *throughput bug*.

Teams **one** and **eight** have variances in both the *throughput* and *churn* variables according to Table 5.9. Teams **two** and **ten** also have variances for the *throughput* variables, while **team nine** has a variances between the *churn* variables. The relationship between these variables is explained in Section 6.1. In Table 5.10, one can see that *throughput* and *throughput bug* has the average correlation value of 0.6, *throughput feature* has the value 0.5, *WIP* has an average correlation value of 0.4, *Bugs finished, quarter, avg days backlog, bugs, lead time* and *team size* has the average correlation value of 0.3 and rest of the values have an average mean value of ± 0.2 or less.

	N	Mean	Median	Std.Dev	Max	Min
WIP	10	0.4	0.5	0.2	0.7	0
Throughput	10	0.6	0.6	0.2	1	0.3
Throughput ft	10	0.5	0.6	0.3	0.9	-0.1
Throughput bug	10	0.6	0.7	0.3	1	-0.2
Bugs finished, quarter	10	0.3	0.3	0.3	0.8	-0.2
Avg days backlog, bugs	10	0.3	0.3	0.1	0.5	0.1
Lead time	10	0.3	0.4	0.3	0.8	-0.2
Churn	10	0	-0	0.3	0.6	-0.5
Churn ft	10	0.1	0.1	0.4	0.8	-0.6
Churn bug	10	0	0	0	0.6	-0
Team size	10	0.3	0.4	0.3	0.6	-0.3

Table 5.10: Descriptive Statistic - Correlation - Bugs - Without team size is taken into account

The second correlation table for bugs, displayed in Table 5.11, one can see **team one** has a significant correlation value to *throughput bug, bugs finished, quarter, avg days in backlog, bugs* and *lead time*. **Team two** has a significant correlation to all the *throughput* variable and *lead time*. **Team three** has a significant correlation value to all the *throughput* variables and all the *churn variables*. **Team five** has a significant correlation value to all variables except *WIP, throughput feature, bugs finished, quarter* and *churn feature*.

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
WIP	0.10	0.49	0.25	0.27	0.11	0.25	0.75*	0.32	-0.05	-0.28
Throughput	0.05	0.90**	0.81**	0.32	0.97**	-0.02	0.46	0.82**	0.57*	0.96**
Throughput Feature	-0.12	0.62*	0.66**	0.33	0.50	-0.10	0.48	-0.52	0.36	-0.25
Throughput bug	0.79**	0.92**	0.79**	0.33	0.95**	0.80**	0.60	0.98**	0.64*	0.96**
Bugs finished, quarter	0.59*	0.50	0.44	0.17	0.52	0.77**	0.86**	0.70**	0.19	0.59*
Avg days in backlog, bugs	0.76**	-0.07	0.38	0.18	0.75**	0.30	0.37	0.38	0.37	0.39
Lead time	0.83**	0.72**	0.48	0.22	0.72**	0.18	0.85**	-0.23	0.54	0.88**
Churn	0.47	0.29	0.67**	0.22	0.73**	0.20	-0.05	0.34	-0.02	0.19
Churn feature	-0.40	0.12	0.62*	0.27	-0.10	0.27	-0.07	-0.26	-0.24	-0.19
Churn bug	0.48	0.35	0.55*	0.44	0.73**	-0.19	-0.08	0.78**	0.43	0.23

Table 5.11: Correlation - Bugs - When team size is taken into account

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Team six has significant correlation value with *throughput bug* and *bugs finished, quarter*. **Team seven** has a significant relationship with *WIP, bugs finished, quarter* and *lead time*. **Team eight** has a significant correlation value to *throughput, throughput bug,*

bugs finished, quarter and *churn bug*. **Team nine** has a significant correlation value to *throughput* and *throughput bug*. **Team ten** has a significant correlation value to *throughput, throughput bug, bugs finished, quarter* and *lead time*.

Throughput and *churn* variables for team **five** and **eight** shows variance according to Table 5.11. Team **one** and **six** shows variance between the *throughput variables*. The variables relationship is explained in Section 6.1. Table 5.12 displays a mean correlation value of 0.8 for *throughput bug*, 0.6 for *throughput*, 0.5 for *bugs finished, quarter* and *lead time*, 0.4 for *avg days backlog, days* and *churn bug* and 0.3 for *churn*, while the rest has a mean value of ± 0.2 or less.

	N	Mean	Median	Std.Dev	Max	Min
WIP	10	0.2	0.2	0.3	0.8	-0.3
Throughput	10	0.6	0.7	0.4	1	0
Throughput ft	10	0.2	0.3	0.4	0.7	-0.5
Throughput bug	10	0.8	0.8	0.2	1	0.3
Bugs finished, quarter	10	0.5	0.6	0.2	0.9	0.2
Avg days backlog, bugs	10	0.4	0.4	0.2	0.8	-0.1
Lead time	10	0.5	0.6	0.4	0.9	-0.2
Churn	10	0.3	0.3	0.3	0.7	-0.1
Churn ft	10	0	-0.1	0.3	0.6	-0.4
Churn bug	10	0.4	0.4	0.3	0.8	-0.2

Table 5.12: Descriptive Statistic - Correlation - Bugs - When team size is taken into account

5.4 Correlation - Throughput

This section shows the correlation table between *throughput* and the variables. The first correlation Table 5.13, one can see that *throughput* has a significant correlation to either *throughput feature* or *throughput bug* for each of the teams. The teams **three, four, five, seven** and **nine** have a positive correlation to both the *throughput* sub variables. For teams **one, six** and **eight** are the variance between *throughput feature* and *throughput*. For teams **two** and **ten** are the variance between *throughput bug* and *throughput*, according to Table 5.13. The relationship between the *throughput* variables that have a variance is explained in Section 6.1.

The sub variables of *throughput* are highlighted above, so the sub variables will be left out of the highlighting in this section. **Team one** has significant correlation to *WIP, bugs, lead time, churn feature* and *team size*. **Team two** has a significant correlation value to *bugs* and *lead time*. **Team three** has significant correlation to *WIP* and *bugs*. **Team four** has a

significant correlation to *WIP*, *bugs*, *lead time*, *churn* and *churn feature*. **Team five** has a significant correlation to *bugs* and *team size*.

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
WIP	0.74**	0.21	0.76**	0.83**	0.52	0.64*	0.67*	0.47	0.89**	0.61*
Throughput Feature	0.96**	0.09	0.93**	1**	0.85**	0.99**	0.91**	0.94**	0.88**	0.43
Throughput bug	0.03	0.97**	0.99**	1**	0.99**	0.04	0.91**	0.44	0.96**	0.98**
Bugs	0.69**	0.81**	0.88**	0.59*	0.97**	0.27	0.53	0.41	0.70**	0.56*
Bugs finished, quarter	0.16	0.12	0.23	0.39	0.12	0.12	0.58	0.33	0.70**	0.59*
Avg days in backlog, bugs	0.16	0.12	0.45	0.37	0.14	-0.17	0.21	-0.17	-0.41	-0.09
Lead time	0.70**	0.67**	0.49	0.68**	0.36	0.13	0.47	0.54	0.42	0.32
Churn	0.37	-0.43	-0.18	0.72**	-0.06	-0.40	0.60	0.59*	-0.14	0.02
Churn feature	0.78**	-0.10	-0.20	0.81**	0.41	-0.40	0.43	0.43	-0.29	-0.20
Churn bug	-0.06	-0.21	-0.33	0.49	-0.10	0.57*	-0.10	0.03	-0.29	-0.06
Team size	0.70**	0.05	0.52	0.16	0.69**	0.86**	0.62	0.75**	0.53	0.57*

Table 5.13: Correlation - Throughput - Without time size is taken into account

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Team six has a significant correlation to *WIP*, *churn bug* and *team size*. **Team seven** has a significant correlation value to *WIP*. **Team eight** has a significant correlation value to *churn* and *team size*. **Team nine** has significant correlation to *WIP*, *bugs* and *bugs finished, quarter*. **Team ten** has a significant correlation value to *WIP*, *bugs*, *bugs finished, quarter* and *team size*.

For teams **one**, **four**, **six** and **eight** are there a variance between the *churn* variables; the relationship between these variables is explained in Section 6.1. According to Table 5.14 has *throughput feature* an average correlation value of 0.8, *throughput bug* has an average correlation value of 0.7, *WIP* and *bugs* has an average correlation value of 0.6, *lead time* and *team size* has an average of 0.5 and *bugs finished, quarter* has an average mean of 0.3. The rest of the values have an average mean of ± 0.2 or less.

	N	Mean	Median	Std.Dev	Max	Min
WIP	10	0.6	0.7	0.2	0.9	0.2
Throughput ft	10	0.8	0.9	0.3	1	0.1
Throughput bug	10	0.7	1	0.4	1	0
Bugs	10	0.6	0.6	0.2	1	0.3
Bugs finished, quarter	10	0.3	0.3	0.2	0.7	0.1
Avg days backlog, bugs	10	0.1	0.1	0.3	0.5	-0.4
Lead time	10	0.5	0.5	0.2	0.7	0.1
Churn	10	0.2	-0	0.4	0.7	-0.4
Churn ft	10	0.2	0.2	0.5	0.8	-0.4
Churn bug	10	-0	-0.1	0.3	0.6	-0.4
Team size	10	0.5	0.6	0.3	0.9	0.1

Table 5.14: Descriptive Statistic - Correlation - Throughput - Without time size is taken into account

The second correlation table, Table 5.15, one can see *throughput* has a significant correlation to either *throughput feature* or *throughput bug* for each of the teams. The teams **two, three, four** and **nine** have a positive correlation to both the *throughput* sub variables. For team **five, eight** and **ten** there is a variance between *throughput feature* and *throughput*. For team **one, six** and **seven** is there a variance between *throughput bug* and *throughput*, according to Table 5.15. The relationships between the *throughput* variables that have a variance are explained in Section 6.1.

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
WIP	0.37	0.59*	0.57*	0.86**	0.11	0.08	0.49	0.28	0.66*	-0.21
Throughput Feature	0.71**	0.72**	0.90**	1**	0.40	0.98**	0.90**	-0.02	0.82**	-0.11
Throughput bug	0.16	0.98**	0.98**	1**	0.99**	0.31	0.56	0.82**	0.95**	1**
Bugs	0.05	0.90**	0.81**	0.32	0.97**	-0.02	0.46	0.82**	0.57*	0.96**
Bugs finished, quarter	-0.11	0.69**	0.04	0.56*	0.57*	0.07	0.31	0.71**	0.55	0.67**
Avg days in backlog, bugs	0.02	-0.33	0.44	-0.12	0.80**	-0.35	-0.06	0.09	-0.27	0.27
Lead time	0.06	0.88**	0.26	0.90**	0.80**	0.69**	0.33	0.24	0.32	0.90**
Churn	-0.14	0.37	0.23	0.88**	0.79**	-0.28	0.46	0.75**	-0.14	0.06
Churn feature	0.05	0.20	0.18	0.90**	-0.11	-0.16	0.12	0.18	-0.29	-0.35
Churn bug	-0.17	0.47	0.14	0.18	0.80**	-0.17	0.01	0.70**	-0.11	0.11

Table 5.15: Correlation - Throughput - When time size is taken into account.

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Team two has significant correlation value with all variables except *avg days in backlog*, *bugs* and the *churn* variables. **Team three** has a significant correlation value to *WIP* and *bugs*. **Team four** has significant correlation value to *WIP*, *bugs finished*, *quarter*, *lead time*, *churn* and *churn feature*. **Team five** has a significant correlation value to all variables except *WIP* and *churn feature*.

Team six has positive correlation value to *lead time*. **Team eight** has a correlation value with *bugs*, *bugs finished*, *quarter*, *churn* and *churn bug*. **Team nine** has a significant correlation value to *WIP* and *bugs*. **Team ten** has a significant correlation to *bugs*, *bugs finished*, *quarter* and *lead time*. The *churn* variables for teams **four**, **five** and **eight** have variance, according to Table 5.15. The *churn* relationship is explained in Section 6.1.

Table 5.16, displays a mean correlation value of 0.8 for *throughput bug*, a value of 0.6 for *throughput feature* and *bugs*, a value of 0.5 for *lead time*, a value of 0.4 for *WIP* and *bugs finished*, *quarter* and a value of 0.3 for *churn*. The rest of the values have an average correlation value of ± 0.2 or less.

	N	Mean	Median	Std.Dev	Max	Min
WIP	10	0.4	0.4	0.3	0.9	-0.2
Throughput ft	10	0.6	0.8	0.4	1	-0.1
Throughput bug	10	0.8	1	0.3	1	0.2
Bugs	10	0.6	0.7	0.4	1	0
Bugs finished, quarter	10	0.4	0.6	0.3	0.7	-0.1
Avg days backlog, bugs	10	0	0	0.4	0.8	-0.3
Lead time	10	0.5	0.5	0.3	0.9	0.1
Churn	10	0.3	0.3	0.4	0.9	-0.3
Churn ft	10	0.1	0.1	0.4	0.9	-0.3
Churn bug	10	0.2	0.1	0.3	0.8	-0.2

Table 5.16: Descriptive Statistic - Correlation - Throughput - When time size is taken into account

5.5 Correlation - Churn

This section contains information about the correlation table between the variables and *churn*. Table 5.17 shows all teams have either one or both sub variables with significant positive correlation with *churn*. Teams **four**, **five**, **six**, **seven**, **eight**, **nine** and **ten** do not have a positive correlation between both the *churn* sub variables according to Table 5.17. The relationship between the *churn* variables is explained in Section 6.1.

In this section will *churn* variables be left out of the highlighting for the same reason as

in Section 5.4. Table 5.17 shows **Team one** has positive correlation to *bugs*, *bugs finished*, *quarter* and *lead time*. **Team two** has a significant correlation value to *WIP*. **Team four** has a significant correlation to all variables except *bugs*, *bugs finished*, *quarter*, *avg days in backlog*, *bugs* and *team size*. **Team five** has a negative correlation value with *team size*.

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
WIP	0.47	-0.71**	-0.32	0.66*	0.03	-0.30	0.10	0.16	-0.09	0.16
Throughput	0.37	-0.43	-0.18	0.72**	-0.06	-0.40	0.43	0.59*	-0.14	0.02
Throughput Feature	0.36	0	-0.12	0.69**	-0.03	-0.37	0.45	0.63*	0.02	-0.17
Throughput bug	-0.52	-0.42	-0.22	0.69**	-0.03	-0.03	0.54	-0.17	-0.20	0.07
Bugs	0.62*	-0.27	0.10	0.27	-0.06	-0.12	0.11	-0.16	-0.48	0.04
Bugs finished, quarter	0.80**	-0.22	-0.11	0.15	-0.31	0.04	0.17	0.49	-0.05	0.31
Avg days in backlog, bugs	0.19	-0.12	-0.06	0	0.15	0.56*	0.60	-0.17	-0.01	-0.11
Lead time	0.70**	-0.42	-0.45	0.97**	0.18	-0.34	0.39	0.91**	-0.37	-0.04
Churn feature	0.57*	0.58*	0.90**	0.99**	0.22	0.98**	0.91**	0.84**	0.62*	0.14
Churn bug	0.80**	0.70**	0.85**	0.13	0.94**	-0.02	0.13	-0.07	0.39	0.94**
Team size	0.42	-0.16	-0.51	-0.24	-0.54*	-0.18	0.36	0.14	0.11	0.12

Table 5.17: Correlation - Churn - Without taken team size into account.

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Team six has significant correlation value with *avg days in backlog*, *bugs*. **Team eight** has a significant correlation with *throughput*, *throughput feature* and *lead time*, but not *throughput bug*, according to Table 5.17. The *throughput* relationship for **team eight** is explained in Section 6.1. The Table 5.18 shows that there do not exists variables with a mean correlation value of ± 0.2 *churn* with out the *churn* sub variables

	N	Mean	Median	Std.Dev	Max	Min
WIP	10	0	0.1	0.4	0.7	-0.7
Throughput	10	0.1	0	0.4	0.7	-0.4
Throughput ft	10	0.1	0	0.4	0.7	-0.4
Throughput bug	10	0	-0.1	0.4	0.7	-0.5
Bugs	10	0	0	0.3	0.6	-0.5
Bugs finished, quarter	10	0.1	0.1	0.3	0.8	-0.3
Avg days backlog, bugs	10	0.1	-0	0.3	0.6	-0.2
Lead time	10	0.2	0.1	0.6	1	-0.5
Churn ft	10	0.7	0.7	0.3	1	0.1
Churn bug	10	0.5	0.5	0.4	0.9	-0.1
Team size	10	0	0	0.3	0.4	-0.5

Table 5.18: Descriptive Statistic - Correlation - Churn

The second correlation table for *churn*, Table 5.19 shows all teams have either one or both sub variables with significant positive correlation with *churn*. Teams **one, four, five, six, seven, eight** and **ten** do not have a positive correlation between both the *churn* sub variables according to Table 5.17, the relationship between these variables is explained in Section 6.1.

Team one has a significant positive correlation for *bugs finished, quarter* and *lead time*. **Team two** has a significant correlation value with *throughput feature, bugs finished, quarter* and *avg days in backlog, bugs*. **Team three** has a significant correlation value with *bugs, bugs finished, quarter*. **Team four** has a significant correlation for *WIP, all throughput* variables and *lead time*. **Team five** has a significant correlation value for *throughput, throughput bug, bugs, bugs finished, quarter, avg days in backlog, bugs* and *lead time*

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
WIP	-0.27	0.16	-0.29	0.77**	-0.09	-0.35	-0.17	0.39	-0.34	-0.37
Throughput	-0.14	0.37	0.23	0.88**	0.79**	-0.28	0.46	0.75**	-0.14	0.06
Throughput Feature	-0.39	0.68**	0.11	0.87**	-0.02	-0.39	0.56	0.48	0.04	0.08
Throughput bug	-0.03	0.30	0.20	0.87**	0.83**	0.28	0.08	0.34	-0.10	0.07
Bugs	0.47	0.29	0.67**	0.22	0.73**	0.20	-0.05	0.34	-0.02	0.19
Bugs finished, quarter	0.95**	0.68**	0.76**	0.34	0.90**	0.33	-0.16	0.61*	-0.12	0.44
Avg days in backlog, bugs	-0.11	-0.55*	0.15	-0.12	0.88**	0.56*	0.39	-0.18	0.21	0.76**
Lead time	0.72**	0.49	0.16	0.96**	0.94**	0.04	0.08	0.71**	-0.18	0.01
Churn feature	-0.40	0.79**	0.95**	0.99**	-0.10	0.98**	0.78**	0.66*	0.56*	0.33
Churn bug	1**	0.93**	0.95**	0.09	1**	-0.19	0.25	0.51	0.56*	0.99**

Table 5.19: Correlation - Churn - With size taken into account

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Team six has a significant positive correlation to *avg days in backlog, bugs*. **Team eight** has a significant positive correlation for *throughput, bugs finished, quarter* and *lead time*. **Team ten** has a significant positive correlation for *avg days in backlog, bugs*. Teams **two, five** and **eight** have a variance in their *throughput* relationship, according to Table 5.19. The relationship between these variables is explained in Section 6.1. The Table 5.20 displays a mean correlation value of 0.6 for both *churn* sub variables, 0.5 for *bugs finished, quarter*, 0.4 for *lead time* and 0.3 for *throughput, throughput bug* and *bugs*. The rest of the values have a value of ± 0.2 or less.

	N	Mean	Median	Std.Dev	Max	Min
WIP	10	-0.1	-0.2	0.4	0.8	-0.4
Throughput	10	0.3	0.3	0.4	0.9	-0.3
Throughput ft	10	0.2	0.1	0.4	0.9	-0.4
Throughput bug	10	0.3	0.2	0.3	0.9	-0.1
Bugs	10	0.3	0.3	0.3	0.7	-0.1
Bugs finished, quarter	10	0.5	0.5	0.4	0.9	-0.2
Avg days backlog, bugs	10	0.2	0.2	0.5	0.9	-0.6
Lead time	10	0.4	0.3	0.4	1	-0.2
Churn ft	10	0.6	0.7	0.5	1	-0.4
Churn bug	10	0.6	0.7	0.4	1	-0.2

Table 5.20: Descriptive Statistic - Correlation - Churn - With size taken into account

5.6 Correlation - Team size

The team size correlation Table 5.21, one can see **team one** has a significant correlation value to *WIP, throughput, throughput feature, bugs, lead time* and *churn feature*. **Team two** has a correlation value with *avg days in backlog, bugs*. **Team three** has a significant correlation value with *WIP* and *churn bug*. **Team five** has a significant correlation value to *WIP, throughput, throughput bug, bugs, churn and churn bug*.

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
WIP	0.68**	0.35	0.78**	0.06	0.57*	0.77**	0.62	0.65*	0.54	0.76**
Throughput	0.70**	0.05	0.52	0.16	0.69**	0.86**	0.62	0.75**	0.53	0.57*
Throughput Feature	0.74**	-0.22	0.53	0.20	0.48	0.89**	0.47	0.74**	0.48	0.18
Throughput bug	-0.10	0.06	0.51	0.20	0.67**	0	0.71*	0.40	0.48	0.64*
Bugs	0.80**	0.26	0.27	0.17	0.71**	0.41	0.41	0.42	0.41	0.16
Bugs finished, quarter	0.42	-0.53	0.25	-0.19	0.28	0.30	0.71*	0.05	0.38	0.34
Avg days in backlog, bugs	0.48	0.84**	0.04	0.44	0.03	-0.03	0.49	0.03	0.07	-0.03
Lead time	0.61*	0.38	0.44	-0.30	0.36	-0.11	0.59	0.22	0.38	0.53
Churn	0.42	-0.16	-0.51	-0.24	-0.54*	-0.18	0.33	0.14	0.11	0.12
Churn feature	0.79**	0.41	-0.42	-0.17	0.32	-0.23	0.36	0.07	0.01	0.36
Churn bug	0.26	-0.44	-0.61*	0.27	-0.55*	0.74**	-0.32	-0.14	-0.16	-0.10

Table 5.21: Correlation - Team size

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Team six has significant correlation value to *WIP, throughput, throughput feature* and *churn bug*. **Team seven** has a significant correlation value with *throughput bug* and *bugs finished, quarter*. **Team eight** has significant correlation value with *WIP, throughput* and

throughput feature. Team ten has a significant positive correlation with *WIP*, *throughput* and *throughput bug*.

Teams **one**, **five** and **six** have a variance for both *throughput* and *churn* variables, according to Table 5.21. Teams **seven** and **ten** have a variance between the *throughput* variables, while **team three** has it between the *churn* variables. The relationship between the sub variables is explained in Section 6.1. The Table 5.22 displays a mean correlation value of 0.6 for *WIP*, 0.5 for *throughput*, 0.4 for the *throughput* sub variables and *bugs* and 0.3 for *lead time*. Rest of the variables has a value of ± 0.2 or less.

	N	Mean	Median	Std.Dev	Max	Min
WIP	10	0.6	0.6	0.2	0.8	0.1
Throughput	10	0.5	0.6	0.3	0.9	0.1
Throughput ft	10	0.4	0.5	0.3	0.9	-0.2
Throughput bug	10	0.4	0.4	0.3	0.7	-0.1
Bugs	10	0.4	0.4	0.2	0.8	0.2
Bugs finished, quarter	10	0.2	0.3	0.3	0.7	-0.5
Avg days backlog, bugs	10	0.2	0.1	0.3	0.8	-0
Lead time	10	0.3	0.4	0.3	0.6	-0.3
Churn	10	-0	-0	0.3	0.4	-0.5
Churn ft	10	0.1	0.2	0.4	0.8	-0.4
Churn bug	10	-0.1	-0.1	0.4	0.7	-0.6

Table 5.22: Descriptive Statistic - Correlation - Team size

5.7 Correlation - All teams combined

The Tables 5.23 and 5.24 shows the correlation values for all the teams combined. Some of the horizontal values are shortened, *throughput* is shortened to *TP*, *bugs finished, quarter* is shortened to *bugs, qrt*, *Avg days in backlog, bugs* is shortened to *Avg backlog b* and *feature* is shortened to *ft*. Table 5.23 shows a significant positive correlation between *WIP* and *throughput*, *throughput feature*, *throughput bug*, *bugs*, *bugs finished, quarter*, *lead time*, *churn bug* and *team size*.

Throughput has a significant correlation value to *WIP*, both *throughput* sub variables, *bugs*, *bugs finished, quarter* and *team size*. Both *throughputs'* sub variables have a significant value to *WIP*, *throughput*, *bugs* and *team size*. *Throughput feature* also has a significant value to *bugs finished, quarter*.

Bugs has a significant correlation to all variables except the *churn* variables and *lead time*. *Bugs finished, quarter* has a significant correlation with *WIP*, *throughput*, *throughput*

	WIP	TP	TP ft	TP bug	Bugs	Bugs, qrt	Avg backlog b	Lead time	Churn	Churn ft	Churn bug	Team size
WIP	1	0.41**	0.28**	0.38**	0.41**	0.17*	0.17	0.27**	0.06	0.08	0.17*	0.41**
Throughput	0.41**	1	0.94**	0.58**	0.56**	0.20*	0.02	0.09	-0.12	-0.12	-0.08	0.57**
Throughput Feature	0.28**	0.94**	1	0.47**	0.48**	0.21*	-0.05	0.08	-0.13	-0.14	-0.11	0.56**
Throughput bug	0.38**	0.58**	0.47**	1	0.52**	0.11	0.15	-0.10	-0.10	-0.06	-0.09	0.21*
Bugs	0.41**	0.56**	0.48**	0.52**	1	0.33**	0.26**	0.05	-0.09	-0.01	0.05	0.39**
Bugs finished, quarter	0.17*	0.20*	0.21*	0.11	0.33**	1	-0.06	0.15	0.10	0.07	0.18*	0.14
Avg days in backlog, bugs	0.17	0.02	-0.05	0.15	0.26**	-0.06	1	0.06	0.04	0.13	0.22*	0.25**
Lead time	0.27**	0.09	0.08	-0.10	0.05	0.15	0.06	1	0.14	0.15	0.06	0.25**
Churn	0.06	-0.12	-0.13	-0.10	-0.09	0.10	0.04	0.14	1	0.76**	0.51**	-0.21*
Churn feature	0.08	-0.12	-0.14	-0.06	-0.01	0.07	0.13	0.15	0.76**	1	0.43**	-0.08
Churn bug	0.17*	-0.08	-0.11	-0.09	0.05	0.18*	0.22*	0.06	0.51**	0.43**	1	-0.06
Team Size	0.41**	0.57**	0.56**	0.21*	0.39**	0.14	0.25**	0.25**	-0.21*	-0.08	-0.06	1

Table 5.23: Correlation - All - Team size not taken into account

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

feature, bugs and churn bug. Avg days in backlog, bugs has a significant value with Bugs, churn bug and team size. Lead time has a significant correlation to WIP and team size. Churn has a significant correlation to the churn sub variables and team size. Churn feature has a significant relationship with churn and churn bug. Churn bug has a significant value with WIP, bugs finished, quarter, avg days in backlog, bugs, churn and churn feature. Team size has a significant value to WIP, throughput, throughput feature, throughput bug, bugs, avg days in backlog, bugs, lead time and churn.

Table 5.24, one can see WIP has a significant correlation value to bugs finished, quarter. Throughput has significant correlation value to throughput sub variables, bugs, bugs finished, quarter, avg days in backlog, bugs, lead time, churn and churn bug. Throughput feature has significant correlation value to throughput, and bugs. Throughput bug has significant value to throughput, bugs, bugs finished, quarter, avg days in backlog, bugs, lead time, churn and churn bug.

	WIP	TP	TP ft	TP bug	Bugs	Bugs, qrt	Avg backlog b	Lead time	Churn	Churn ft	Churn bug
WIP	1	0.05	-0.09	-0.01	0.12	-0.20*	-0.08	0.05	-0.07	-0.08	-0.05
Throughput	0.05	1	0.51**	0.33**	0.74**	0.36**	0.63**	0.66**	0.64**	-0.16	0.64**
Throughput Feature	-0.09	0.51**	1	0.16	0.23**	-0.06	-0.07	-0.10	-0.12	0.04	-0.14
Throughput bug	-0.01	0.33**	0.16	1	0.53**	0.21*	0.21*	0.29**	0.17*	-0.11	0.17*
Bugs	0.12	0.74**	0.23**	0.53**	1	0.50**	0.69**	0.71**	0.69**	-0.07	0.69**
Bugs finished, quarter	-0.20*	0.36**	-0.06	0.21*	0.50**	1	0.41**	0.67**	0.77**	-0.16	0.77**
Avg days in backlog, bugs	-0.08	0.63**	-0.07	0.21*	0.69**	0.41**	1	0.83**	0.84**	-0.05	0.84**
Lead time	0.05	0.66**	-0.10	0.29**	0.71**	0.67**	0.83**	1	0.93**	-0.16	0.94**
Churn	-0.07	0.64**	-0.12	0.17*	0.69**	0.77**	0.84**	0.93**	1	-0.06	1
Churn feature	-0.08	-0.16	0.04	-0.11	-0.07	-0.16	-0.05	-0.16	-0.06	1	-0.15
Churn bug	-0.05	0.64**	-0.14	0.17*	0.69**	0.77**	0.84**	0.94**	1	-0.15	1

Table 5.24: Correlation - All - With team size taken into account

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Bugs has a significant value to all values except *WIP* and *churn feature*. *Bugs finished, quarter* has a significant value to all values except *throughput feature* and *churn feature*. *Avg days in backlog, bugs, lead time, churn* and *churn bug* has a significant value to all values except *WIP, throughput feature* and *churn feature*. *Churn feature* has no significant values.

Chapter 6

Discussion

The first section, Section 6.1 will consist of an explanation of the relationship between the sub variables. To back up any assumptions about the variables, descriptive statistic tables listed in Appendix A and correlation graphs will be used. The next sections contain discussion based on the research questions, the different results from this study and what other literature has stated.

6.1 Discussion of the sub variables

In Chapter 5, there was highlighted the variance between sub variables for *churn* or *throughput*. The reason for variance is explained in the two following subsections.

6.1.1 Throughput

Team one has a significant correlation value for both *throughput* and *throughput feature*, but not for *throughput bug*, as showed in the WIP correlation Table 5.1. *Throughput* and *throughput feature* has correlation values 0.74 and 0.73, while *throughput bug* has the value of 0.02. The possible cause *throughput bug* does not have a significant correlation value with *WIP*, while *throughput* does, might be because *throughput bug* consists of 37% (108/290) of the *throughput* dates, as shown in the total rows in Tables A.1b and A.2b. But it is possible to have a close relationship although, since the correlation is based on the mean values. *Throughput feature* has a total mean of 13.7, *throughput bug* has the total mean of 6.4 and *throughput* has the total mean of 11, as shown by Tables A.1b, A.2a and A.2b. The mean values point towards the fact that *throughput feature* represents most of

the *throughput* variable. The correlation graphs in Figure 6.1 and *throughput* correlation table in Section 5.4 confirms it. The pattern of dots in Figure 6.1a shows a significant positive correlation, while the dots in Figure 6.1b has no specific pattern, which reflect the correlation value of 0.96 for *throughput feature* and 0.03 for *throughput bug*.

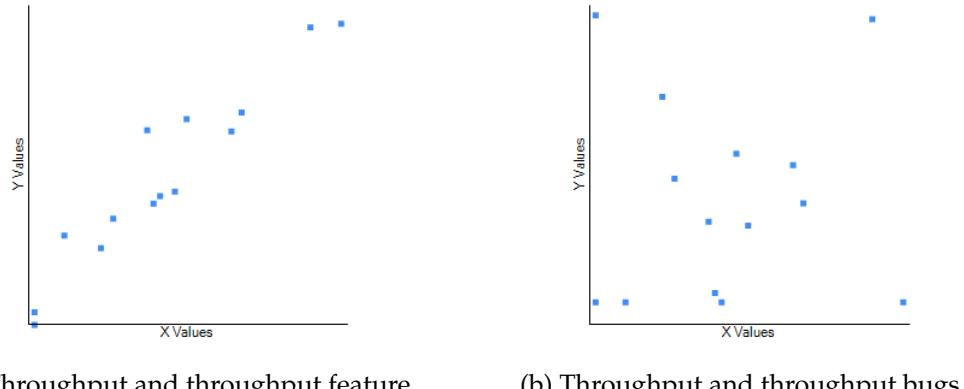
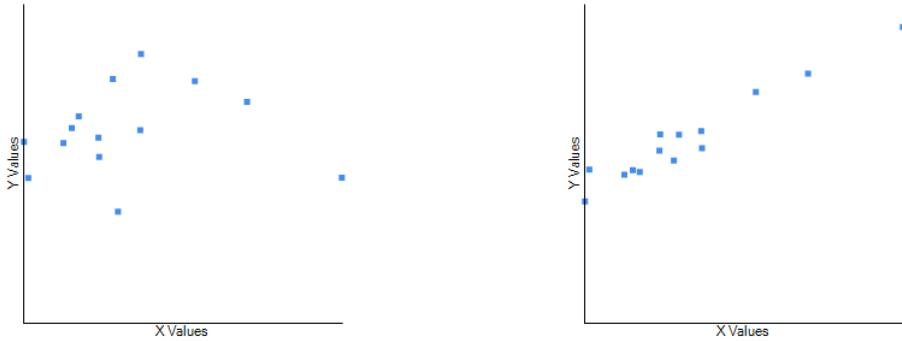


Figure 6.1: Correlation graphs between throughput (X-axis) and the throughput sub variables (Y-axis) for team one.

Team two's throughput feature differ from *throughput* based on the correlation values from the *bugs* correlation Table 5.9. One could believe the reason is because *throughput bug* consists of 2/3 of *throughput*'s (460/690) dates, as shown in the descriptive statistic Tables A.6b and A.7b. But the two tables and Table A.7a show that the total mean of *throughput* is 4.4. While for *throughput bug* it is 4.8 and 3.7 for *throughput feature*. These three variables are quiet close, which could reflect that these three variables could be close, based on correlation measurement. But, the Figures in 6.2 and the throughput correlation table in Section 5.4 shows otherwise. The Figure 6.2b shows a significant positive correlation, while Figure 6.2a shows dots that are more randomly placed. The throughput correlation Table 5.13 represents the same result with a value of 0.97 for *throughput bug* and 0.1 for *throughput feature*.



(a) Throughput and throughput feature

(b) Throughput and throughput bug

Figure 6.2: Correlation graphs between throughput (X-axis) and the sub variables (Y-axis) for team two.

Team three has the correlation values of 0.52 for *throughput bug*, 0.57 for *throughput* and 0.71 for *throughput feature*, showed in WIP correlation Table 5.3. With these correlation values, it looks like *throughput bug* represents most of the *throughput* variable. The descriptive statistic tables empower the assumption. *Throughput* contains 542 dates and has a total mean value of 3.7. *Throughput feature* represents 200 of these dates and has a mean value of 3.3, while *throughput bug* represents the remaining 342 dates and has a total mean value of 4, shown in tables A.11b, A.12a and A.12b. The *throughput* correlation Table 5.15 shows both sub variables contribute, but *throughput bug* contribute a little more with a correlation value of 0.98, while *throughput feature* has a correlation value of 0.90.

Team five has a significant correlation for *throughput bug* with a value of 0.54, *throughput* with a value of 0.52, but not *throughput feature*. *Throughput feature* has a correlation value of 0.25, as showed in WIP correlation Table 5.1. Based on these values, one can assume that *throughput bug* represents most of *throughput* for team five. The descriptive statistic Tables A.21b, A.22a and A.22b show *throughput* consist of 657 dates. Out of the 657 dates, represents *throughput feature* 108 dates, and *throughput bug* 556 dates. These values also point towards the fact that *throughput bug* represents most of *throughput*. The overall mean for *throughput* is 6.3, for *throughput feature* it is 5.7 and for *throughput bug* it is 6.4. Based on these values, it looks like both the sub variables contribute. The *throughput* correlation Table 5.13 proves with the values 0.85 for *throughput feature* and 0.99 for *throughput bug* that both the sub variables contribute, but *throughput bug* contribute most.

Team six has significant correlation to *throughput* and *throughput feature* showed in WIP correlation Table 5.1, while *throughput bug* does not. *Throughput*, *throughput feature* and *throughput bug* has the correlation values 0.64, 0.68 and 0.07. Based on these values, one can assume *throughput feature* contribute a greater proportion to *throughput* than

throughput bug. The total row in Tables A.26b, A.27a and A.27b show *throughput feature* consist of 609 dates and has a mean value of 4.8, while *throughput bug* consist of 82 dates and a mean value of 3.3. *Throughput* consists of 691 dates and has a mean value of 4.58. With the mean values and the number of dates, the assumption of *throughput feature* represents more of *throughput* than *throughput bug* is empowered. The throughput correlation Table 5.13 proves the assumption with a *throughput feature* correlation value of 0.99 and *throughput bugs* value of 0.04.

Team seven has a significant correlation value for *throughput*, *throughput feature*, but not *throughput bug*, as showed in WIP correlation Table 5.1. The table showed a correlation value of 0.67 for *throughput*, 0.63 for *throughput feature* and 0.55 for *throughput bug*. The difference between the correlation values is small, which also can be assumed by the total row in Tables A.31b, A.32a and A.32b. The total rows show *throughput* has a mean of 2.7, while *throughput feature* has a mean value of 2.8 and *throughput bug* has a mean value of 2.6. *Throughput feature* contributes 156 dates to *throughput* and *throughput bug* contributes 172 dates. Based on these numbers, it looks like both the sub variables contribute. The *throughput* correlation table in Section 5.4 proves the assumption with values of .91 for both *throughput feature* and *bug*.

Team eight has a significant correlation value for *throughput bug*, but not *throughput*, as showed in bugs correlation Table 5.9. The reason for this could be because *throughput bug* consist of 99 dates and has a total mean of 1.5. *Throughput feature* consist of 92 dates and a total mean of 3.2 and *throughput* has mean of 2.3 and contains 191 dates, as showed in the descriptive statistic Tables A.36b, A.37a and A.37b. On the basis of these numbers it will look like both of the sub variables of *throughput* contributes and both of them should have close relationship to *throughput*. Figures 6.3 shows otherwise. The Figure 6.3a shows dots in an upward direction, hence positive correlation, while in Figure 6.3b almost all the dots are all gathered around the low values of Y. The Figures in 6.3 reflects the correlation value 0.94 for *throughput feature* and 0.44 for *throughput bug*.

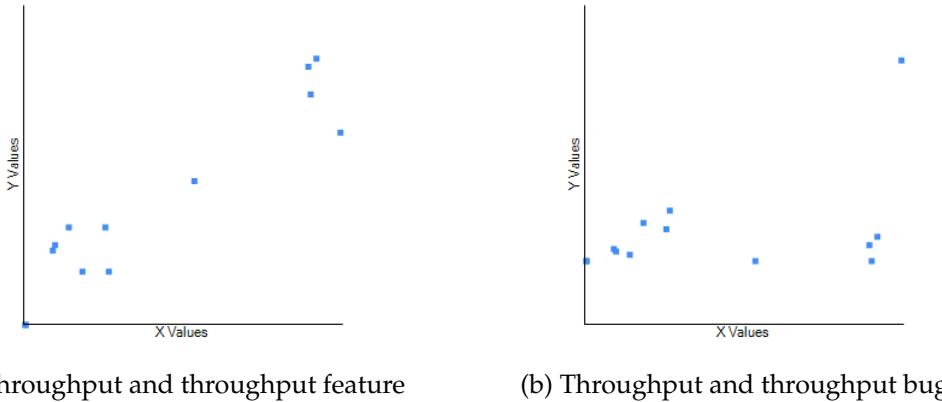
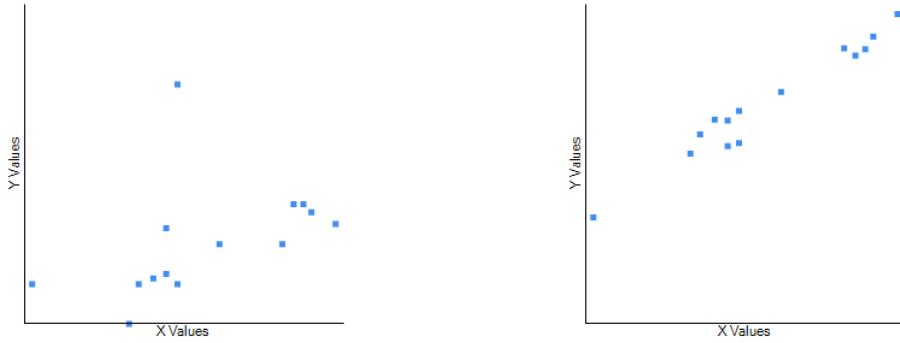


Figure 6.3: Correlation graphs between throughput (X-axis) and the sub variables (Y-axis) for team eight.

Team nine has a significant positive correlation for *throughput* and *throughput bug*. The reason *throughput feature* don't has a significant correlation while *throughput* has it, in respect of the bugs correlation Table 5.11, could be because *throughput bug* represents most of the *throughput* variable, as shown in Tables A.41b, A.42a and A.42b. The *throughput* variable contains 521 dates and has a mean value of 2.6. *Throughput feature* represents 214 of these dates and has a total mean of 2.4, while *throughput bug* represents the remaining 307 dates and has a total mean of 2.8. These variables indicate that both the *throughput* sub variables contribute. The throughput correlation Table 5.15 proves that both the attributes contributes, but *throughput bug* contributes the most with a correlation value of 0.95, while *throughput feature* has a correlation value of 0.82.

Team ten has significant positive relationship for *throughput* and *throughput bug*, but not for *throughput feature*, as showed in WIP correlation Table 5.1. *Throughput* for team ten consists of 404 dates as showed in the total row in Table A.31b. *Throughput bug* represents 335 of these dates, while *throughput feature* represents the remaining 69 dates as shown in Tables A.32a and A.32b. But the overall mean for *throughput*, *throughput feature* and *throughput bug* is 2.2, 2.3 and 2.2, which could reflect a close relationship between these three variables. The throughput correlation table in Section 5.4 and the correlation graphs in Figures 6.4 disproves that assumption. The Figure 6.4a shows a vague significant positive correlation, while Figure 6.4b shows a significant positive correlation. The correlation table shows *throughput bug* with a correlation of 0.98 and *throughput feature* with a correlation of 0.43. Which proves that *throughput bug* represents most of *throughput*.



(a) Throughput and throughput feature (b) Throughput and throughput bug

(b) Throughput and throughput bug

Figure 6.4: Correlation graphs between throughput (X-axis) and the sub variables (Y-axis) for team ten.

6.1.2 Churn

In WIP correlation Table 5.1 have the three churn variables for **team one** scattered correlation values. *Churn* has a value of 0.47, *churn feature* has a value of 0.72 and *churn bug* of 0.15. Judging from these variables, it will look both *churn feature* and *churn bug* contribute to *churn*. The descriptive statistic Tables A.3b, A.4a and A.4b empower the assumption. The total mean of *churn* is 20.2, while *churn feature* has total mean of 24.5 and *churn bug* has a total mean of 16.8. The descriptive statistic tables also shows that *churn feature* contribute 150 dates to *churn*, while *churn bug* contribute 189 dates. The churn correlation table in Section 5.5 proves the assumption. Both *churn feature* (0.57) and *churn bug* (0.80) has a significant positive correlation to *churn*. Judging from the correlation table from Section 5.4, one can assume that correlation is not transitive. The paper "The Non-Transitivity of Pearson's Correlation Coefficient: An Educational Perspective" (Vesaliusstraat, n.d.) proves the assumption.

Churn and *churn bug* has a significant negative correlation for **team two**. *Churn feature* on the other hand has a correlation value of -0.25, showed in WIP correlation Table 5.1. According to the correlation values, one can assume that *churn bug* represents most of *churn*. The Tables A.8b, A.9a and A.9b empower the assumption. *Churn bug* contribute 521 dates and has a total mean value of 36.3. *Churn feature* contribute 257 dates and has a mean value of 100.6. The total churn contains 778 dates and has a total mean of 57.6. The *churn* correlation table in Section 5.5 shows both the *churn* variables contribute with a correlation value of 0.7 for *churn bug* and 0.58 for *churn feature*.

The three *churn* variables for **team three** have the correlation values of -0.45 for *churn*, -0.27 for *churn feature* and -0.64 for *churn bug*, as showed in the correlation Table 5.5, for lead time. These values indicate more contribution from *churn bug* than *churn*.

feature. The total dates and the mean from Tables A.13b, A.14a and A.14b empower the assumption. The total *churn* consists of 576 dates and a total mean of 61.8. *Churn feature* represents 205 of these dates and has a total mean of 98.9. *Churn bug* answers for the remaining 371 dates and has a total mean of 41.4. The *churn* correlation table in Section 5.5 proves the assumption. Still, *churn bug* has a correlation of 0.85, while the correlation value between *churn feature* and *churn* is 0.90. The strong relationship between *churn* and *churn bug* shows that total dates and total mean can be used as an indicator of the relationship between variables, but it can't state it.

The *churn* variable for **team four** has the correlation value of 0.97, *churn feature* has the correlation value of 0.96 and *churn bug* has the correlation value of 0.2, as showed in the correlation Table for lead time, Table 5.5. The descriptive statistic Tables A.18b, A.19a and A.19b shows that *churn* consist of 574 dates. *Churn bug* represents 78 of these dates and *churn feature* represents the remaining 496 dates. *Churn features* has the total mean of 8.4, *churn bug*'s mean is 1 and *churn*'s mean is 7.4. These variables clearly indicate the strong relationship between *churn feature* and *churn*. The churn correlation Table 5.17 verifies the theory with *churn feature* has the correlation value of 0.99 and *churn bug* has the correlation value 0.13.

Churn bug for **team five** has a significant positive correlation of .94, while *churn feature* has the correlation value of 0.22, as shown in *churn* correlation Table 5.17. This proves that *churn bug* represents most of *churn*. The Tables A.23b, A.24a and A.24b show the same result. *Churn* consists of 698 dates and has a total mean of 33.4, while *churn feature* and *churn bug* represents has 123 dates and 575 dates. The total mean of *churn feature* is 52.1 and for *churn bug* it's 29.4.

Team six has a significant correlation value of 0.77 for *churn bug*, while both *churn* and *churn feature* has the values of -0.30 and -0.36, showed in WIP correlation Table 5.1. Based on these values, one can assume *churn feature* represents most of *churn*. The Tables A.28b, A.29a and A.29b back this theory. The tables show *churn feature* contribute 576 dates to *churn* and has a total mean of 105.9. *Churn bug* contains of 180 dates and has a total mean value of 73.8. *Churn* has 756 dates and a total mean value of 98.3. The churn correlation table in Section 5.5 proves the assumption of *churn feature* represent most of *churn*, with the correlation values 0.98 for *churn feature* and -0.02 for *churn bug*.

Churn feature for **team seven** has the correlation value of 0.91 while *churn bug* has the correlation value 0.13, as showed in *churn* correlation Table 5.17. The descriptive statistic Tables A.33b, A.34a and A.34b shows that *churn* contains 359 dates and has a total mean of 77.3. *Churn feature* represents 141 of these dates, and has a total mean of 121.2. *Churn bug* represents the 218 remaining dates and has a total mean of 48.9. Based on these values, one could assume that both *churn feature* and *churn bug* contribute to *churn*, but the churn correlation table and the graphs in Figure 6.5 disapproves that. Which once again shows that the descriptive statistic tables can be used as indication

of relationship, but cannot prove them.

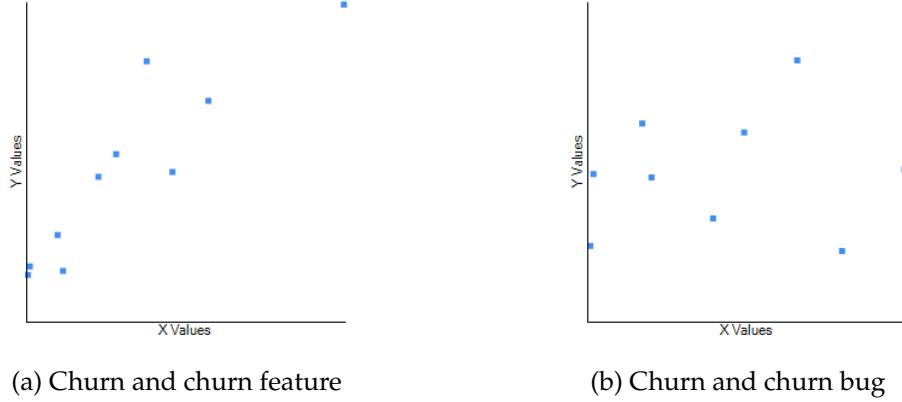


Figure 6.5: Correlation graphs between the churn (X-axis) and the sub variables (Y-axis) for team seven.

Team eight has a significant correlation to *churn* and *churn feature*, but not *churn bug*, as showed in lead time's correlation Table 5.5. The correlation values for *churn* is 0.91, for *churn bug* it is -0.12 and for *churn feature* it is 0.79. Based on these variables, it looks like *churn feature* represents a greater part of the *churn*. The Tables A.38b, A.39a and A.39b indicate otherwise. *Churn* is composed of 137 dates, and has a total mean of 13.4. *Churn feature* represents 79 of these tasks and has a total mean of 17.4. *Churn bug* represents the remaining 58 tasks and has a total mean of 8. The values indicate both *churn feature* and *churn bug* contribute to *churn*. The Figure 6.6 and correlation Table 5.17 disapproves the assumption. The *churn* correlation Table 5.17 shows that *churn feature* has the correlation of 0.84, while *churn bug* has the value of -0.1. This is the same as shown in the correlation graphs. The Figure 6.6a shows a clear positive correlation, while Figure 6.6b shows no pattern and shows a correlation close to 0.

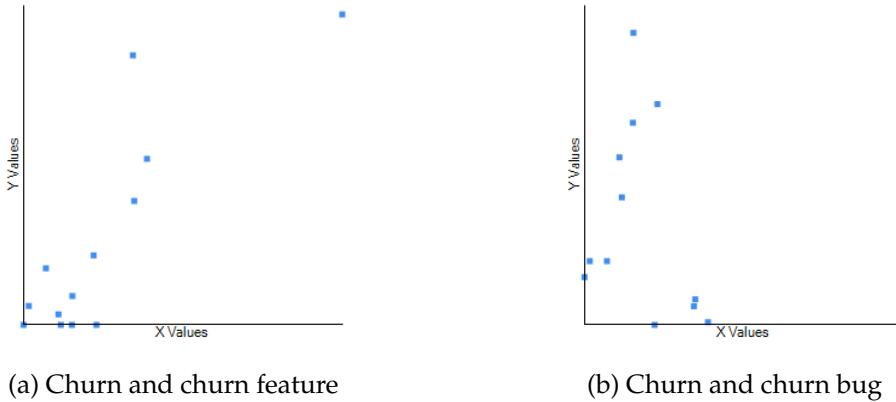


Figure 6.6: Correlation graphs between the churn (X-axis) and the sub variables (Y-axis) for team eight.

Team nine has a significant correlation value of -0.62 to *churn feature*, while *churn* has the value of -0.48 and *churn bug* has the value -0.04, as showed in bugs correlation Table 5.9. Based on the correlation values, it looks like *churn feature* represents most of *churn*. The descriptive statistic data show otherwise. *Churn* consists of 548 dates, *churn feature* represents 201 of these dates and *churn bug* represents the remaining 347 dates, as shown in Tables A.43b, A.44a and A.44b. The total mean of *churn feature* is 115.9, the total mean for *churn* is 72.2 and the total mean for *churn bug* is 46.1. Judging from these numbers, both *churn feature* and *churn bug* contribute to *churn*. In the graphs in Figure 6.7, one can see Figure 6.7a show a positive correlation. The Figure 6.7b represents a positive correlation, but not as high as Figure 6.7a. The *churn* correlation states the same, Table 5.17 shows *churn feature* correlation values is 0.60 and *churn bug* correlation value is 0.39. This proves that *churn feature* represents most of *churn*.

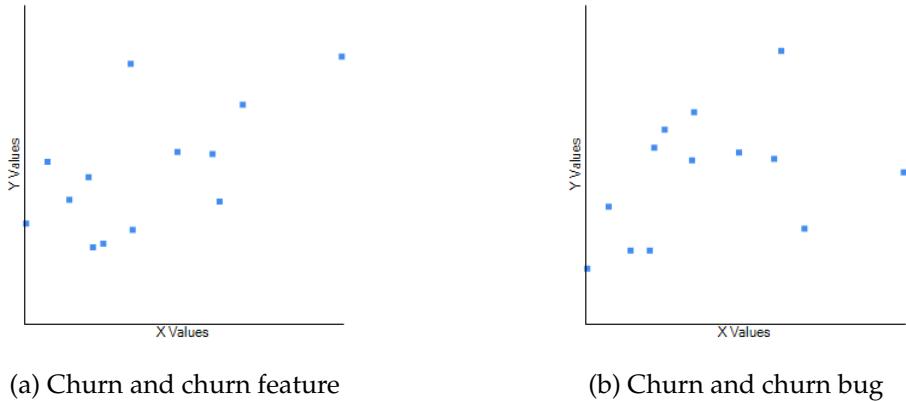


Figure 6.7: Correlation graphs between the churn (X-axis) and the sub variables (Y-axis) for team nine.

Team ten has a significant correlation value of 0.94 for *churn bug* and *churn feature* has the correlation value 0.14, as showed in *churn* correlation Table 5.17. This shows that *churn bug* represents most of *churn*. Based on the Tables A.48b, A.49a and A.49b, one can see that *churn* contains 361 dates and has a total mean value of 45.4. *Churn feature* represents 69 of these dates and has a total mean of 75.5, while *churn bug* represents 292 of *churn's* dates and has a total mean of 38.3. These data also shows the relationship between *churn* and *churn bug*.

6.2 WIP and throughput

In this work, throughput is a measure to see how productive teams are. In Section 2.4.2, there was stated by various people, when lowering WIP-limit the *throughput* increases. The paper "Studying Lean-Kanban Approach Using Software Process Simulation" (D. Anderson et al., 2011) simulated a lean-kanban process as stated in 2.4.2. The simulation showed when WIP was limit; the software process used 100 days and 120 otherwise. The paper "Simulation of software maintenance process, with and without a work-in-process limit" (Concas et al., 2013) showed that WIP-limit could lead to improvement in throughput. The paper also showed that when taking a process without WIP-limit, and simulate it using WIP-limit it outperformed the original process

The data from this study shows otherwise. In the Tables 5.14 and 5.16 there is no evidence showing that lowering WIP-limit will increase *throughput*. *Throughput* has the average correlation value of 0.6 when team size is **not** taken into account and 0.4 otherwise. One can argue that the throughput correlation value is biased when team size is **not** taken into account, based on the strong team size correlation. But the Table

5.16, where team size is taken into account shows an average correlation value of 0.4 between *throughput* and *WIP* when team size is taken into account.

When team size is **not** taken into account, all of the teams have a positive correlation between *WIP* and *throughput*, and seven of the teams have a significant correlation value, shown in Table 5.1. When team size is taken into account the Table 5.4 shows nine out of ten teams have a positive correlation between *WIP* and *throughput*. Team ten is the only team with a negative correlation. Team five, six, eight and ten has low correlation, team one and seven has a low-medium relationship, team two, three, four and nine has a significant linear relationship. The median between the teams when team size is **not** taking into account is 0.7 and 0.4 otherwise. The standard deviation is 0.2 when team size is **not** taking into account and 0.3 otherwise, shown by Tables 5.2 and 5.4. The median and standard deviation when team size is **not** taken into account shows most of the teams have a strong linear relationship between *WIP* and *throughput*. The median and standard deviation when team size is taken into account shows that more than half of the teams have a medium or high correlation relationship.

The combined Table 5.23 shows a significant correlation value of 0.41 when team size is **not** taking into account, while Table 5.24 shows a overall correlation of 0.05 when team size is taken into account. The values presented in this section point towards the fact that when *WIP* increases, so does *throughput*.

Despite the relationship between *WIP* and *throughput*, the *throughput* correlation Table 5.16 in Section 5.4 shows that *throughput bug* has a mean correlation value of 0.8, *bugs* and *throughput feature* has an average correlation value of 0.6 and *lead time* has the average value of 0.5. The combine Table 5.24 shows *throughput* has significant correlation values to all variables except *WIP* and *churn feature*, when team size is taken into account.

When team size is **not** taken into account the Table 5.14 shows that *throughput feature* has a mean correlation value of 0.8, *throughput bug* has an average value of 0.7, *bugs* and *WIP* has a value of 0.6 and both *lead time* and *team size* has an average correlation value of 0.5. The combined Table 5.23 shows *throughput* has a significant correlation relationship to all variables except *WIP* and *churn feature*.

The *throughput*'s correlation values are isolated and can only be used to see what impact *throughput* has on a software process. One cannot say if *WIP* decreases, then *throughput* decreases and then all the variables with a significant positive correlation to *throughput* decreases. The *throughput* correlation values also shows the *WIP* relationship decreases when *team size* is taken into account, but the relationship between the other variables don't differ in the same extent.

6.3 WIP and lead time

As stated in Section 2.5, lead time could be used to track how quickly software is delivered to customers. Each development process would like to get their lead time as low as possible. In Section 2.4.2 there is stated that WIP-limits are important to reduce lead times. The result from this work when team size was **not** taken into account shows mean correlation relationship of 0.5 between *WIP* and *lead time* across the teams, as shown in Table 5.2. The correlation Table 5.1 shows Team one, four, five, seven and ten has significant positive correlation relationship and both team two and three has a medium correlation relationship.

The result from when team size was taken into account shows an average linear relationship of 0.2, which is a weaker linear relationship than when team size was **not** taken into account. Three of the ten teams have a significant positive correlation, while the rest of teams' correlation values vary from -0.18 to 0.32, as shown by Tables 5.3 and 5.4.

The standard deviation shows a variation of 0.2 and a median of 0.5 when team is **not** taken into account. The standard deviation when team size is taken into account is 0.4 and the median is 0, as shown in Tables 5.2 and 5.4. The standard deviation shows a high proliferation of values when team size is taken into account. The standard deviation shows evidence of spread relationship between *WIP* and *lead time* across the teams when team size is taken into account. The standard deviation value of 0.2 shows that each of the ten *lead time* values are closer to each other when team size is **not** taken into account.

The combine correlation Table 5.23 shows that all teams combined have a significant correlation value of 0.27, when team size is **not** taken into account. The correlation Table 5.24 shows a non-significant correlation value of 0.05 when team size is taken into account. The value presented in this section shows when time size is taken into account, there is no linear relationship between *WIP* and *lead time*. When team size is **not** taken into account; there is a low significant correlation value for all the teams combined and medium-strong positive correlation when each team is measured independently. Either way, based on these results, there is no evidence showing that *WIP* limit will decrease *lead time*, it is more likely to decrease *lead time*.

Despite the relationship between *WIP* and *lead time*, *lead time* has a close positive relationship to four of the five individual variables, shown in Table 5.8. *Throughput*, *Bugs* and *Bugs finished*, *quarter* has the average correlation value 0.5, while *churn* has the value of 0.4 when team size is taken into account. When team size is **not** taken into account, *WIP* and *throughput* has an average correlation value of 0.5 and *throughput feature* has the value 0.4, while the rest variables has a value of ± 0.3 or less. The Table 5.23 shows an overall significant positive correlation between *lead time* and both

team size and *WIP*, when team size is **not** taken into account. When team size is taken into account *throughput*, *throughput bug*, *bugs*, *bugs finished quarter*, *avg days in backlog*, *bugs*, *churn* and *churn feature* has a significant positive correlation, as shown by Table 5.24. These values show the impact *lead time* has on a development process. The significant correlation value and the high average correlation value between *lead time* and *throughput* is odd, these values should be further investigated.

6.4 WIP and bugs

To minimize bugs should be a goal independent of software process and methods. If *WIP-limit* could reduce bugs without compromising, one could conclude that *WIP-limit* matter in software development. The paper cited by Shinkle stated; when *WIP* was too high, the number of bugs increased (Shinkle, 2009).

When team size is **not** taken into account, the average correlation value between *WIP* and *bugs* is 0.4 and four of the teams have a significant positive correlation value between *bugs* and *WIP*. All ten teams have a positive correlation value, as shown in Table 5.1. The two variable *bug finished*, *quarter* and *avg days backlog bugs* is used as a side measure to how long bugs are in backlog and the amount of bugs fixed vs. the amount of bugs recorded in system per quarter. The average correlation value between *WIP* and both *bug finished*, *quarter* is 0.3 and *avg days backlog bugs* is 0.1. The value *bug finished*, *quarter* shows a low-medium correlation relationship. The 0.1 correlation value for *avg days backlog bugs* and the fact that there is one team with a significant correlation relationship between *avg days backlog bugs* and *WIP* shows that *WIP limit* has no influence on the number of days bugs are in backlog.

When team size is taken into account, the average correlation value is 0.2 for *bugs*, as shown by Table 5.4. Eight out of ten teams have a positive correlation relationship, but only one team has a significant positive value. The *bug finished*, *quarter* and *avg days backlog bugs* has the average correlation values 0.2 and -0.1. For *bug finished*, *quarter* are there four teams with a positive significant correlation and one team with a negative. For *avg days backlog bugs* is there one team with a negative significant correlation.

The standard deviation when team size is **not** taken into account is 0.2 and the median is 0.5. The median when team size is taken into account is 0.2 and the standard deviation is increased is 0.3. The median numbers shows significant impact of team size between the relationship of *WIP* and *bug*. The standard deviation values for the two cases shows a minor variation between the two results variables, shown in 5.2 and 5.4

When team size is **not** taken into account, the overall correlation value is significant with a value of 0.41, shown in Table 5.23. The correlation Table 5.24 shows the

correlation values from when time size is taken into account. The table shows an overall correlation value of 0.12. The values from this section shows there is no evidence of that WIP-limit helps increase or decrease bugs when team size is taken into account.

The *bug* correlation tables in Section 5.3 shows the *bugs* variable has a average correlation of 0.6 to *throughput* and a correlation value of 0.3 to *bugs finished, quarter avg days backlog, bugs, lead time* and *team size*. When team size is taken into account, *bugs* has a average correlation value of 0.6 to *throughput* again, *bugs finished quarter* has the average correlation value 0.5, *avg days in backlog, bugs* has the average value of 0.4, *lead time* 0.5 and *churn* 0.3. When team size is taken into account, the linear relationship between the variables and *bugs* increases for almost each variable.

6.5 WIP and Churn

Churn is used as surrogates for effort in this work. It turns out based on the results, independently of team size; there is no relationship between *WIP* and *churn* or the sub variables of churn. The results show respectively an average correlation of -0.1 in Table 5.4 and 0 in Table 5.2. When team size is **not** taken into account, two of the teams have a significant correlation, one of them has a positive correlation and the other has a negative. When team size is taken into account, there is one team with a significant positive correlation value.

The standard deviation for both the results are 0.4, while the median is 0.1 when team size is **not** taken into account and -0.1 for the other case. The standard deviation empowers the assumption of a relationship between *churn* and *WIP*, because the values are spread and there is no pattern. The Table 5.23 shows an overall correlation value of 0.06 when team size is taken into account. The Table 5.24 shows a correlation value of -0.07. These values also show that *WIP*-limit has no impact on *churn*.

Section 5.5 shows *churn* correlation table. When team size is **not** taken into account, *churn* has no linear relationship between any of the other variables, if the *churn*'s sub variables are disregard, as shown in Table 5.18. When team size is taken into account, *bugs finished, quarter* has a strong average relationship with a value of 0.6, while *lead time* has a value of 0.4 which, shown in Table 5.20. The combine Table 5.23 shows *churn* has a significant positive correlation value to both the sub variables and a significant negative correlation to *team size*. When team size is taken into account, *churn* has a significant positive correlation to *throughput, throughput bug, bugs, bugs finished, quarter, avg days in backlog, bugs, lead time* and *churn bug*.

6.6 Team size

As the different results sections in Chapter 5 and the sections above states, it is important to take team size into account when a case study like this is conducted. If team size were left out as a variable in this case study, *WIP* would have an average linear relationship of 0.6 with *throughput*, 0.4 with *bugs* and 0.4 with *lead time*. These three correlation values decreased by 0.2 compared to when team size was taken into account. The combine correlation Table 5.23 shows that seven of the variables have a significant positive correlation with *team size*. The table also shows eight out of eleven variables has a significant correlation value with *WIP*, while Table 5.24 shows one out of ten variables has a significant relationship, when team size is taken into account. If team size were not taken into account the result from this work would have been biased.

Chapter 7

Conclusion

In this work the main goal was to investigate the research question "Does WIP limit in software development matter?" If so, "how can one find the optimal WIP-limit" and "Which parameters should be considered in order to optimize WIP-limits". To answer the research questions a data set from a company called Software Innovation was interpreted. The data set is based on metadata about tasks from 2010 to 2013.

In light of the previous findings, the results from when team size was **not** taken into account are discarded. Because the data showed team size had a great impact on the correlation tables, which gave wrong results.

If WIP limit matters in software development some of its benefits should be to reduce bugs, increase throughput, decrease lead time etc. Based on the results from the case study, *WIP* has a positive medium relationship with *throughput* on team level. On company level has *WIP* and *throughput* no linear relationship. The previous research has stated to lower WIP to decrease throughput, which this case study disproves. On company level there was one significant correlation. The significant correlation was a negative one for *bugs finished, quarter*.

However, the results from this paper show some other findings. The importance of taking team size into account when measuring a similar research, the churn variable has no or little impact on the software process and the great impact the variables *lead time, bugs* and *throughput* has in a software process.

7.1 Future work

The conclusion from this work is made on one case study. I would recommend doing the same calculation as in this work with another data set and comparing the outcome. I would also suggest a different approach as looking more deeply into the relationship between *WIP* and *team size*. I suggest one measure the number of employees working on each task instead of take the number of employees per quarter and divide on the mean of each variables value.

I will also suggest looking at the values up against release dates. The number of WIP's, throughput, bugs et cetera usually decrease around release date, which could cause bias in the data. There is also done another research on the data from SI, I would suggest comparing the results.

Appendices

Appendix A

Descriptive statistics (DS) for the ten teams

A.1 Team 1 - Descriptive Statistics

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	25	3.6	4	0.6	5	3
2010-4	92	0.7	1	0.7	3	0
2011-1	90	3.4	1	6.9	30	0
2011-2	91	13.2	4	14.5	51	2
2011-3	92	1.8	2	0.6	3	1
2011-4	92	14.3	4	22.7	97	1
2012-1	91	22.2	21	14.5	67	4
2012-2	91	30.3	23	29	107	9
2012-3	92	36	38.5	13.6	65	18
2012-4	92	34.7	28.5	16.9	99	25
2013-1	90	32.8	25	13.7	85	25
2013-2	91	67.1	54	44.3	178	3
2013-3	92	7.4	3	8.8	31	1
2013-4	76	5	1	8.1	35	1
Total	1197	20.5	12	26.2	178	0

(a) DS - WIP

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	3	3	1	3.5	7	1
2010-4	3	1	1	0	1	1
2011-1	7	10.4	11	8.1	25	1
2011-2	32	9.4	10	6.7	26	1
2011-3	2	1	1	0	1	1
2011-4	25	14.9	10	14.6	49	1
2012-1	49	8.6	5	8.1	33	1
2012-2	45	11.2	3	16	56	1
2012-3	34	5.5	3	6.3	23	1
2012-4	17	14.2	14	13.7	44	1
2013-1	13	19.5	17	17	58	1
2013-2	26	21.6	18	16.9	60	1
2013-3	17	9	7	7.7	27	1
2013-4	17	6.3	3	7.5	24	1
Total	290	11	6	12.5	60	1

(b) DS - Throughput

Table A.1: Caption of Descriptive Statistic for WIP and Throughput a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	1	7	7	-	7	7
2011-1	7	10.4	11	8.1	25	1
2011-2	24	10.1	10	5.6	24	1
2011-3	1	1	1	-	1	1
2011-4	11	16.6	13	11	35	4
2012-1	16	15.2	15	9.3	33	1
2012-2	26	16.1	5	17.7	56	1
2012-3	23	6	4	6.6	23	1
2012-4	14	15.1	14.5	14.3	44	1
2013-1	10	23.3	20	17.4	58	3
2013-2	21	23.6	24	18.1	60	1
2013-3	16	9.5	7.5	7.7	27	1
2013-4	12	8.3	7.5	8.1	24	1
Total	182	13.7	10	13.2	60	1

(a) DS - Throughput feature

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	2	1	1	0	1	1
2010-4	3	1	1	0	1	1
2011-2	8	7.5	2	9.3	26	1
2011-3	1	1	1	-	1	1
2011-4	14	13.6	5	17.3	49	1
2012-1	33	5.3	5	5	21	1
2012-2	19	4.5	1	10.5	47	1
2012-3	11	4.4	3	5.8	21	1
2012-4	3	10	3	12.1	24	3
2013-1	3	7	3	8.7	17	1
2013-2	5	13.4	13	7.1	21	3
2013-3	1	1	1	-	1	1
2013-4	5	1.4	1	0.9	3	1
Total	108	6.4	3	9.6	49	1

(b) DS - Throughput bug

Table A.2: Caption of Descriptive Statistic for Throughput feature and Throughput bug
a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	1	13	13	-	13	13
2010-4	2	8.5	8.5	9.2	15	2
2011-2	28	13.1	7.5	16.5	78	1
2011-3	1	5	5	-	5	5
2011-4	28	15.7	14.5	11.2	45	1
2012-1	66	12.5	9	11.5	49	1
2012-2	47	18.7	12	19	107	1
2012-3	32	9.9	7	11.3	49	1
2012-4	26	18.1	5.5	58.3	303	1
2013-1	19	18.7	6	27	103	2
2013-2	48	27.9	8.5	75.8	508	1
2013-3	25	15.6	5	25.1	110	1
2013-4	16	14.5	4.5	24	76	1
Total	339	16.7	8	36.2	508	1

(a) DS - Lead time

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	1	13	13	-	13	13
2010-4	2	30	30	41	59	1
2011-2	28	20.1	13	18	74	1
2011-3	1	2	2	-	2	2
2011-4	28	22.9	17.5	19.9	86	0
2012-1	66	18.6	12.5	19.8	97	0
2012-2	47	20.9	17	20	103	0
2012-3	32	13.9	5	20.6	75	0
2012-4	26	24	9	58.8	302	0
2013-1	19	17.8	9	25.3	99	0
2013-2	48	27.9	9.5	73.5	495	0
2013-3	25	14.7	5	23	99	0
2013-4	16	15.1	4.5	23.2	72	0
Total	339	20.2	10	36.8	495	0

(b) DS - Churn

Table A.3: Caption of Descriptive Statistic for Lead time and Churn a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2011-2	8	23.2	22	21.2	49	1
2011-4	8	24.5	14.5	28	86	4
2012-1	20	17.9	17	12.4	48	0
2012-2	21	23.8	16	25.6	103	0
2012-3	20	11.2	3	19.4	75	0
2012-4	16	30.9	9.5	74.1	302	0
2013-1	11	24.7	9	31.8	99	0
2013-2	23	42.6	7	104.9	495	0
2013-3	17	16.6	4	26.7	99	0
2013-4	6	30.3	16	31.3	72	0
Total	150	24.5	10	51.6	495	0

(a) DS - Churn bug

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	1	13	13	-	13	13
2010-4	2	30	30	41	59	1
2011-2	20	18.9	13	17	74	2
2011-3	1	2	2	-	2	2
2011-4	20	22.2	19	16.5	65	0
2012-1	46	18.9	10.5	22.4	97	0
2012-2	26	18.6	18	14.2	43	0
2012-3	12	18.4	6.5	22.7	63	1
2012-4	10	12.9	8.5	15.2	52	0
2013-1	8	8.2	8.5	4.4	16	1
2013-2	25	14.4	13	9.6	34	2
2013-3	8	10.8	5.5	12.6	38	0
2013-4	10	5.9	3	10.1	33	0
Total	189	16.8	11	17.2	97	0

(b) DS - Churn bug

Table A.4: Caption of Descriptive Statistic for Churn feature and Churn bug a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	1	1	1	-	1	1
2010-4	4	1	1	0	1	1
2011-2	32	4.2	3.5	3.6	14	1
2011-3	5	1	1	0	1	1
2011-4	36	4.9	2.5	5.4	22	1
2012-1	43	3.5	3	2.3	10	1
2012-2	33	5.4	3	5.5	21	1
2012-3	16	2.4	1.5	1.8	6	1
2012-4	13	2.8	2	1.8	6	1
2013-1	8	3.5	3	2.5	7	1
2013-2	27	5.8	4	4.8	17	1
2013-3	11	1.3	1	0.5	2	1
2013-4	10	1.7	1	1.9	7	1
Total	240	4	2	4	22	1

(a) DS - Bugs

Quarter	Finished	Not finished	Total	Finished	Not finished
2010-3	1	0	1	100	0
2010-4	4	0	4	100	0
2011-2	130	3	133	97.7	2.3
2011-3	1	4	5	20	80
2011-4	156	22	178	87.6	12.3
2012-1	146	4	150	97.3	2.7
2012-2	176	3	179	98.3	1.7
2012-3	37	2	39	94.9	5.1
2012-4	33	3	36	91.7	8.3
2013-1	24	4	28	85.7	14.3
2013-2	157	0	157	100	0
2013-3	13	1	14	92.9	7.1
2013-4	17	0	17	100	0
Mean	63.9	3.3	67.3	83.3	16.7

(b) DS - Bugs per quarter

Table A.5: Caption of Descriptive Statistic for Bugs and Bugs finished within quarter a, b

A.2 Team 2 - Descriptive Statistics

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	25	14.4	15	6.2	23	6
2010-4	92	21.4	20	7.2	41	9
2011-1	90	27.2	27.5	4.9	38	17
2011-2	91	29.7	27	14.4	62	12
2011-3	92	32.6	30	9.2	56	18
2011-4	92	30.1	30	10.1	46	13
2012-1	91	20	19	4.6	31	8
2012-2	91	25.3	26	10.3	51	6
2012-3	92	24.2	22.5	7.9	45	11
2012-4	92	21.6	23	10.5	47	3
2013-1	90	19.7	20	5.8	35	8
2013-2	91	28	27	4.4	37	15
2013-3	92	18.7	19	4.5	28	9
2013-4	87	13.3	14	6.6	29	2
Total	1208	23.8	23	9.8	62	2

(a) DS - WIP

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	16	4.2	3	4	16	1
2010-4	54	4.1	3	3.9	21	1
2011-1	57	4.6	4	3.6	17	1
2011-2	41	6.9	5	5.7	25	1
2011-3	52	3.8	2	3.6	15	1
2011-4	52	3.7	3	2.7	11	1
2012-1	55	4.3	3	3.4	12	1
2012-2	51	4.1	3	3.5	21	1
2012-3	57	5.8	5	4.3	18	1
2012-4	52	5.2	4.5	3.7	15	1
2013-1	51	4.6	3	3.6	16	1
2013-2	50	3.3	3	2.4	9	1
2013-3	55	3.9	4	2.9	16	1
2013-4	47	3.2	3	2.7	13	1
Total	690	4.4	3	3.7	25	1

(b) DS - Throughput

Table A.6: Caption of Descriptive Statistic for WIP and Throughput a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	5	4.6	3	3.2	10	2
2010-4	22	3.1	2.5	2.8	11	1
2011-1	15	5.1	4	4.4	17	1
2011-2	5	3.2	3	1.3	5	2
2011-3	25	3.7	2	3.8	14	1
2011-4	10	3.4	3	2.9	11	1
2012-1	9	2.1	1	2	7	1
2012-2	16	3.5	3.5	2.3	8	1
2012-3	12	4.2	3.5	1.9	8	1
2012-4	25	4.6	3	3.9	13	1
2013-1	11	3.6	3	3.3	11	1
2013-2	27	2.7	2	2	9	1
2013-3	29	3.9	3	2.7	11	1
2013-4	19	3.4	2	3	10	1
Total	230	3.7	3	3	17	1

(a) DS - Throughput feature

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	11	4.1	3	4.4	16	1
2010-4	32	4.8	4	4.4	21	1
2011-1	42	4.4	4	3.3	13	1
2011-2	36	7.4	5.5	5.9	25	1
2011-3	27	3.9	3	3.5	15	1
2011-4	42	3.7	3	2.7	11	1
2012-1	46	4.7	3.5	3.5	12	1
2012-2	35	4.3	3	4	21	1
2012-3	45	6.3	5	4.6	18	1
2012-4	27	5.8	5	3.3	15	1
2013-1	40	4.8	4	3.7	16	1
2013-2	23	3.9	3	2.8	9	1
2013-3	26	3.8	4	3.2	16	1
2013-4	28	3.1	3	2.5	13	1
Total	460	4.8	4	3.9	25	1

(b) DS - Throughput bug

Table A.7: Caption of Descriptive Statistic for Throughput feature and Throughput bug a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	19	15	9	14.2	55	1
2010-4	53	13.7	9	13.2	55	1
2011-1	67	14.4	11	11.3	67	2
2011-2	41	19.4	13	17.5	79	2
2011-3	55	15.6	11	14	55	1
2011-4	49	14.5	10	13.9	61	1
2012-1	63	11.4	8	10.3	41	1
2012-2	58	11.2	10	8.8	38	1
2012-3	83	15.4	13	12	66	1
2012-4	70	12.5	9	12.1	68	1
2013-1	70	12.6	9.5	10.7	44	1
2013-2	40	11.8	7.5	11.1	44	1
2013-3	59	11.3	6	12.1	49	1
2013-4	51	12	10	12.3	71	1
Total	778	13.5	10	12.3	79	1

(a) DS - Lead time

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	19	69.6	14	106.2	352	3
2010-4	53	78.6	26	120.7	493	1
2011-1	67	35.1	20	57.3	407	1
2011-2	41	40.5	21	64.5	383	2
2011-3	55	57.8	30	86.3	379	1
2011-4	49	46.9	28	55.7	294	2
2012-1	63	58.4	23	81.3	377	0
2012-2	58	58.1	19	99.3	408	0
2012-3	83	43.4	20	68.6	433	0
2012-4	70	69.8	20	112.9	513	0
2013-1	70	47.4	14.5	94.1	467	0
2013-2	40	43.1	11.5	76.3	310	0
2013-3	59	77.7	26	114.5	459	0
2013-4	51	91.3	32	138.8	474	0
Total	778	57.6	22	94.2	513	0

(b) DS - Churn

Table A.8: Caption of Descriptive Statistic for Lead time and Churn a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	6	148	93.5	152.8	352	12
2010-4	18	178.4	118	164.1	493	10
2011-1	19	48.9	37	53.2	214	1
2011-2	4	134.5	70.5	168.8	383	14
2011-3	16	128.1	91	128.1	379	1
2011-4	11	106.3	120	87.6	294	12
2012-1	16	112.8	54.5	125.1	377	0
2012-2	21	90.1	34	122.4	408	0
2012-3	29	52.7	19	67.2	226	0
2012-4	32	103.7	27	151.4	513	0
2013-1	23	93.7	32	150.3	467	0
2013-2	14	82.1	25	117.4	310	0
2013-3	28	97	20	142	459	0
2013-4	20	125.1	37.5	163.5	463	0
Total	257	100.6	38	131.3	513	0

(a) DS - Churn feature

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	13	33.5	12	52	193	3
2010-4	35	27.2	19	28.8	153	1
2011-1	48	29.6	18	58.5	407	1
2011-2	37	30.3	19	34	152	2
2011-3	39	29	20	34.3	196	1
2011-4	38	29.7	19.5	24.6	95	2
2012-1	47	39.9	20	49.3	237	1
2012-2	37	39.9	15	79.6	380	0
2012-3	54	38.4	22.5	69.5	433	0
2012-4	38	41.2	19.5	52.3	226	0
2013-1	47	24.7	12	29.5	127	0
2013-2	26	22.1	11	24.5	91	0
2013-3	31	60.2	26	80.9	296	0
2013-4	31	69.5	29	118.1	474	4
Total	521	36.3	19	58.4	474	0

(b) DS - Churn feature

Table A.9: Caption of Descriptive Statistic for Churn feature and Churn bug a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	20	2.6	2	3.5	17	1
2010-4	40	2.5	2	1.7	9	1
2011-1	47	2.4	2	1.8	8	1
2011-2	40	3.8	3	2.5	13	1
2011-3	43	2.6	2	2.4	13	1
2011-4	47	2.5	2	1.6	8	1
2012-1	35	3.3	3	3	16	1
2012-2	34	2.3	2	1.5	7	1
2012-3	43	3.6	2	2.6	10	1
2012-4	33	3.9	3	3.1	14	1
2013-1	38	2.2	2	1.2	6	1
2013-2	32	1.9	1.5	1.2	5	1
2013-3	35	1.8	1	1.1	5	1
2013-4	37	1.9	1	1.3	7	1
Total	536	2.7	2	2.2	17	1

(a) DS - Bugs

Quarter	Finished	Not finished	Total	Finished	Not finished
2010-3	30	23	53	56.6	43.4
2010-4	65	34	99	65.7	34.3
2011-1	101	13	114	88.6	11.4
2011-2	142	8	150	94.7	5.3
2011-3	87	24	111	78.4	21.6
2011-4	90	29	119	75.6	24.4
2012-1	94	23	117	80.3	19.7
2012-2	70	9	79	88.6	11.4
2012-3	146	7	153	95.4	4.6
2012-4	101	27	128	78.9	21.1
2013-1	78	5	83	94.0	6.0
2013-2	58	3	61	95.1	4.9
2013-3	62	2	64	96.9	3.1
2013-4	69	0	69	100	0
Mean	66.4	12.3	78.8	74.4	25.6

(b) DS - Bugs per quarter

Table A.10: Caption of Descriptive Statistic for Bugs and Bugs finished within quarter a, b

A.3 Team 3 - Descriptive Statistics

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	24	9.3	10	6.4	23	1
2010-4	92	13.9	13	3.9	25	5
2011-1	90	15.3	15.5	3.9	23	7
2011-2	91	23.5	24	4.2	37	13
2011-3	92	20.7	20	5.8	34	9
2011-4	92	23.3	23	6.9	36	9
2012-1	91	24.9	24	6.6	42	13
2012-2	91	23.9	23	3.4	34	19
2012-3	92	28	29	5.1	38	21
2012-4	92	29.6	28.5	5.3	44	22
2013-1	90	16.2	15	5	27	9
2013-2	91	7	6	3.2	13	2
2013-3	92	7	7	2	14	3
2013-4	67	5.6	5	2.6	13	2
Total	1187	18.5	19	9.1	44	1

(a) DS - WIP

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	16	3.3	3	2.9	12	1
2010-4	54	3.5	3	3	15	1
2011-1	42	2.2	2	1.4	7	1
2011-2	45	4.3	3	3.8	20	1
2011-3	51	4	3	3.4	15	1
2011-4	50	4.7	3	5.2	27	1
2012-1	46	6.5	5	5.7	20	1
2012-2	40	2.9	2	3.2	15	1
2012-3	36	3.4	2.5	3.1	13	1
2012-4	51	5	4	4.4	22	1
2013-1	42	3.2	2	2.9	10	1
2013-2	22	1.6	1	1	5	1
2013-3	29	2	1	2	11	1
2013-4	18	1.6	1	1.1	5	1
Total	542	3.7	3	3.8	27	1

(b) DS - Throughput

Table A.11: Caption of Descriptive Statistic for WIP and Throughput a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	3	2.3	3	1.2	3	1
2010-4	19	2.9	2	2.4	9	1
2011-1	29	2.3	2	1.5	7	1
2011-2	24	4	3.5	2.4	8	1
2011-3	23	4.3	3	3.5	13	1
2011-4	19	4	3	4.5	21	1
2012-1	10	5.4	2	5.6	16	1
2012-2	18	2.2	1.5	1.5	6	1
2012-3	12	3.9	1.5	4.3	13	1
2012-4	17	4.8	3	4.5	17	1
2013-1	8	2.1	1.5	1.7	6	1
2013-2	3	1.7	2	0.6	2	1
2013-3	8	1.8	1.5	0.9	3	1
2013-4	7	1.3	1	0.5	2	1
Total	200	3.3	2	3.2	21	1

(a) DS - Throughput feature

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	13	3.5	3	3.2	12	1
2010-4	35	3.9	3	3.3	15	1
2011-1	13	2.1	2	1	3	1
2011-2	21	4.8	3	4.9	20	1
2011-3	28	3.8	3	3.5	15	1
2011-4	31	5.2	3	5.5	27	1
2012-1	36	6.8	5	5.8	20	1
2012-2	22	3.5	2	4.1	15	1
2012-3	24	3.2	3	2.4	9	1
2012-4	34	5.2	4	4.5	22	1
2013-1	34	3.4	2	3	10	1
2013-2	19	1.6	1	1.1	5	1
2013-3	21	2.1	1	2.2	11	1
2013-4	11	1.7	1	1.3	5	1
Total	342	4	3	4.1	27	1

(b) DS - Throughput bug

Table A.12: Caption of Descriptive Statistic for Throughput feature and Throughput bug a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	21	10.6	11	6.4	24	1
2010-4	59	11.6	9	8.9	34	1
2011-1	27	8.7	8	5.9	18	1
2011-2	51	13	11	9.2	34	1
2011-3	48	14.4	10.5	11.3	49	2
2011-4	62	17.8	15	11.7	46	1
2012-1	59	22.6	18	16.6	76	1
2012-2	39	19.5	16	15.2	54	1
2012-3	40	17.1	12.5	17.3	72	1
2012-4	66	12.5	8	12.5	58	1
2013-1	44	12.1	6.5	12.7	60	1
2013-2	20	11	10	9.7	34	1
2013-3	28	7.9	4.5	8.1	29	1
2013-4	12	18	14	18.7	75	1
Total	576	14.6	11	12.9	76	1

(a) DS - Lead time

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	21	120.1	58	138.4	383	3
2010-4	59	60.2	28	67.2	295	2
2011-1	27	73.4	65	62.6	320	2
2011-2	51	79.7	36	104.8	423	1
2011-3	48	67.5	31.5	91	407	0
2011-4	62	37.4	18	66.3	343	0
2012-1	59	47.3	27	55.3	286	0
2012-2	39	38.2	20	66.4	365	0
2012-3	40	66.7	23.5	99.3	406	0
2012-4	66	79.7	28.5	114.5	494	0
2013-1	44	36.7	22	42.6	174	0
2013-2	20	59.5	40	60.9	216	0
2013-3	28	70.6	48.5	90.1	403	0
2013-4	12	79.2	49.5	80.5	237	0
Total	576	61.8	29	85.4	494	0

(b) DS - Churn

Table A.13: Caption of Descriptive Statistic for Lead time and Churn a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	7	197.4	141	136.1	383	16
2010-4	24	78.7	55.5	77	295	2
2011-1	15	89.9	75	73.8	320	14
2011-2	24	128.6	87.5	129.2	423	4
2011-3	24	88.4	40.5	108.8	407	0
2011-4	23	69.9	35	94.7	343	0
2012-1	17	80	59	76.2	286	0
2012-2	9	74.2	33	117	365	0
2012-3	15	111	66	126.1	406	0
2012-4	25	122.8	57	142.6	494	0
2013-1	11	53	65	52.7	174	0
2013-2	2	76.5	76.5	65.8	123	30
2013-3	5	146.6	120	149	403	24
2013-4	4	151.5	167.5	92	237	34
Total	205	98.9	62	109.2	494	0

(a) DS - Churn feature

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	14	81.5	20	126.8	383	3
2010-4	35	47.5	23	57.3	210	3
2011-1	12	52.8	41.5	38.5	121	2
2011-2	27	36.3	31	46.7	245	1
2011-3	24	46.5	13.5	64.5	222	0
2011-4	39	18.2	7	29	132	0
2012-1	42	34	21.5	37.9	157	0
2012-2	30	27.4	18	38.5	169	0
2012-3	25	40.1	15	69.2	302	0
2012-4	41	53.4	19	85	402	0
2013-1	33	31.3	18	38.1	146	0
2013-2	18	57.7	40	62.1	216	0
2013-3	23	54	18	65.8	223	0
2013-4	8	43.1	29.5	45.6	123	0
Total	371	41.4	20	59.8	402	0

(b) DS - Churn bug

Table A.14: Caption of Descriptive Statistic for Churn feature and Churn bug a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	14	2.8	2	2.9	12	1
2010-4	39	2.1	1	1.5	8	1
2011-1	22	1.8	1	1.3	5	1
2011-2	28	3.1	2	3.3	16	1
2011-3	38	2.4	2	1.9	10	1
2011-4	35	2.9	1	5	30	1
2012-1	39	3.7	2	4	23	1
2012-2	31	1.8	1	1.4	7	1
2012-3	28	2.5	2	1.8	8	1
2012-4	42	2.5	2	1.7	6	1
2013-1	30	1.8	1.5	1	4	1
2013-2	19	1.5	1	1	5	1
2013-3	26	1.3	1	0.5	2	1
2013-4	8	1.9	1	1.7	6	1
Total	399	2.7	1	2.6	30	1

(a) DS - Bugs

Quarter	Finished	Not finished	Total	Finished	Not finished
2010-3	30	9	39	76.9	23.1
2010-4	75	6	81	92.6	7.4
2011-1	27	13	40	67.5	32.5
2011-2	79	7	86	91.9	8.1
2011-3	77	13	90	85.6	14.4
2011-4	88	13	101	87.1	12.9
2012-1	132	11	143	92.3	7.7
2012-2	44	12	56	78.6	21.4
2012-3	54	15	69	78.3	21.7
2012-4	97	10	107	90.7	9.3
2013-1	48	5	53	90.6	9.4
2013-2	21	7	28	75	25
2013-3	32	1	33	97	3
2013-4	15	0	15	100	0
Mean	58.5	8.7	67.2	86	14

(b) DS - Bugs per quarter

Table A.15: Caption of Descriptive Statistic for Bugs and Finished bugs per quarter a, b

A.4 Team 4 - Descriptive Statistics

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	9	2.7	2	2.5	7	1
2010-4	92	4.5	4	2.9	14	0
2011-1	90	10.4	10	3.1	18	4
2011-2	91	13.8	13	4.5	31	5
2011-3	92	14.1	13	4.6	28	6
2011-4	92	16.4	16	4.8	30	6
2012-1	91	16	15	3.9	25	9
2012-2	91	11.7	12	3.5	20	5
2012-3	92	14	14	4.2	26	7
2012-4	92	20.6	19.5	5.6	33	10
2013-1	90	19.5	19	7.2	37	5
2013-2	91	16	16	4.8	29	6
2013-3	92	15.5	15	5.9	29	6
2013-4	91	10.5	11	4	19	1
Total	1196	14	14	6.2	37	0

(a) DS - WIP

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	4	3	1	4	9	1
2010-4	39	2.9	1	2.5	11	1
2011-1	48	3.8	3	2.8	15	1
2011-2	48	6.3	5	5.6	31	1
2011-3	54	6.3	5	5	31	1
2011-4	52	7.5	5	5.9	23	1
2012-1	61	6.8	5	4.4	17	1
2012-2	57	3.9	3	2.8	15	1
2012-3	33	6	5	4.4	15	1
2012-4	52	5.8	5	4.7	21	1
2013-1	61	8.6	7	6.9	34	1
2013-2	59	8.3	7	4.7	19	1
2013-3	60	8	7	5.1	26	1
2013-4	46	5	4	3.8	15	1
Total	674	6.2	5	5	34	1

(b) DS - Throughput

Table A.16: Caption of Descriptive Statistic for WIP and Throughput a, a

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	4	3	1	4	9	1
2010-4	39	2.9	1	2.5	11	1
2011-1	48	3.8	3	2.8	15	1
2011-2	48	6.3	5	5.6	31	1
2011-3	54	6.3	5	5	31	1
2011-4	52	7.5	5	5.9	23	1
2012-1	60	6.7	5	4.4	17	1
2012-2	57	3.9	3	2.8	15	1
2012-3	31	6.2	5	4.4	15	1
2012-4	48	5.8	5	4.8	21	1
2013-1	51	9.2	8	7.3	34	1
2013-2	50	8.5	7	4.8	19	1
2013-3	58	8.1	7.5	5.1	26	1
2013-4	44	5.1	5	3.8	15	1
Total	644	6.2	5	5.1	34	1

(a) DS - Throughput feature

Quarter	N	Mean	Median	Std.Dev	Max	Min
2012-1	1	11	11	-	11	11
2012-3	2	3.5	3.5	3.5	6	1
2012-4	4	4.8	5	3	8	1
2013-1	10	5.5	6	2.5	9	1
2013-2	9	7.2	7	4.7	15	2
2013-3	2	4.5	4.5	2.1	6	3
2013-4	2	1	1	0	1	1
Total	30	5.6	5.5	3.7	15	1

(b) DS - Throughput bug

Table A.17: Caption of Descriptive Statistic for Throughput feature and Throughput bug a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2011-2	34	13.2	10.5	10.7	50	1
2011-3	54	13.5	12.5	8.7	34	1
2011-4	49	17.9	14	14.4	61	1
2012-1	65	13.4	13	9.2	46	1
2012-2	56	9.4	8	7.2	33	1
2012-3	32	15.3	11	11.5	43	2
2012-4	63	10.2	8	10	66	1
2013-1	97	8.9	7	7.8	40	1
2013-2	80	9.4	8	8.6	48	1
2013-3	44	10.1	5.5	11.1	53	1
Total	574	11.6	9	10	66	1

(a) DS - Lead time

Quarter	N	Mean	Median	Std.Dev	Max	Min
2011-2	34	9.8	8	10.1	43	0
2011-3	54	8.4	7	6.9	26	0
2011-4	49	13.2	10	12.8	53	0
2012-1	65	8.4	6	8.7	41	0
2012-2	56	4.2	2	6.1	27	0
2012-3	32	9.2	5	10.7	37	0
2012-4	63	5.1	2	9.4	59	0
2013-1	97	5.5	3	7.3	33	0
2013-2	80	6.4	3.5	8.3	47	0
2013-3	44	7.9	3	11	52	0
Total	574	7.4	5	9.2	59	0

(b) DS - Churn

Table A.18: Caption of Descriptive Statistic for Lead time and Churn a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2011-2	33	10.2	8	10.1	43	0
2011-3	53	8.6	7	6.9	26	0
2011-4	49	13.2	10	12.8	53	0
2012-1	63	8.7	7	8.8	41	0
2012-2	55	4.2	2	6.2	27	0
2012-3	29	10.1	6	10.9	37	0
2012-4	50	6.1	3	10.3	59	0
2013-1	65	7.8	7	7.9	33	0
2013-2	62	7.9	5.5	8.9	47	0
2013-3	37	9.3	6	11.4	52	0
Total	496	8.4	6	9.5	59	0

(a) DS - Churn feature

Quarter	N	Mean	Median	Std.Dev	Max	Min
2011-2	1	0	0	-	0	0
2011-3	1	0	0	-	0	0
2012-1	2	0	0	0	0	0
2012-2	1	0	0	-	0	0
2012-3	3	0.7	0	1.2	2	0
2012-4	13	1.5	0	2.5	7	0
2013-1	32	0.9	0	1.6	5	0
2013-2	18	1.2	0	2.3	9	0
2013-3	7	0.4	0	1.1	3	0
Total	78	1	0	1.8	9	0

(b) DS - Churn feature

Table A.19: Caption of Descriptive Statistic for Churn feature and Churn bug a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2011-1	1	1	1	-	1	1
2011-2	2	1	1	0	1	1
2011-3	1	1	1	-	1	1
2012-1	2	1	1	0	1	1
2012-2	1	1	1	-	1	1
2012-3	4	1	1	0	1	1
2012-4	12	1.8	1.5	0.9	3	1
2013-1	32	1.6	1	0.9	4	1
2013-2	19	1.5	1	0.6	3	1
2013-3	12	1.2	1	0.4	2	1
2013-4	2	1	1	0	1	1
Total	88	1.4	1	0.8	4	1

(a) DS - Bugs

Quarter	Finished	Not finished	Total	Finished	Not finished
2011-1	1	0	1	100	0
2011-2	2	0	2	100	0
2011-3	1	0	1	100	0
2012-1	2	0	2	100	0
2012-2	1	0	1	100	0
2012-3	4	0	4	100	0
2012-4	21	1	22	95.5	4.5
2013-1	49	2	51	96.1	3.9
2013-2	27	1	28	96.4	3.6
2013-3	14	0	14	100	0
2013-4	2	0	2	100	0
Mean	11.3	.4	11.6	98.9	1.1

(b) DS - Bugs per quarter

Table A.20: Caption of Descriptive Statistic for Bugs and Bugs finished within quarter a, b

A.5 Team 5 - Descriptive Statistics

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	24	8.4	8	3.3	15	2
2010-4	92	18.7	18	6.2	40	8
2011-1	90	7.8	8.5	6.2	20	0
2011-2	91	21.3	18	12.9	58	0
2011-3	92	26.8	27	9.3	45	8
2011-4	92	27.8	27	9.9	46	10
2012-1	91	44.5	47	9.5	65	24
2012-2	91	51.3	51	7.5	74	38
2012-3	92	19.6	19	11.2	50	4
2012-4	92	20	19	9	38	7
2013-1	90	124.8	126	94.7	270	9
2013-2	91	231.1	266	85.9	286	12
2013-3	92	21.2	19	7.4	43	11
2013-4	51	9.6	10	4.3	19	1
Total	1171	48.4	24	70.5	286	0

(a) DS - WIP

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	12	3.6	3	2.2	7	1
2010-4	49	4.2	3	3.5	15	1
2011-1	34	3.6	3	2.7	12	1
2011-2	51	7.2	7	5.4	19	1
2011-3	63	5.6	4	5	24	1
2011-4	58	5	5	3.7	17	1
2012-1	59	6.2	5	4.5	17	1
2012-2	59	5.3	4	3.8	15	1
2012-3	49	6.4	5	5	27	1
2012-4	50	4.7	3	4.1	17	1
2013-1	60	15.8	9.5	15.1	59	1
2013-2	58	6.7	7	4.6	22	1
2013-3	53	4.6	3	4.3	17	1
2013-4	19	2	1	1.7	7	1
Total	674	6.3	5	6.9	59	1

(b) DS - Throughput

Table A.21: Caption of Descriptive Statistic for WIP and Throughput a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	1	1	1	-	1	1
2010-4	8	2.9	1	3.2	10	1
2011-1	7	3.4	4	2.2	7	1
2011-2	19	9.1	7	5.1	17	1
2011-3	23	6.4	4	5.7	24	1
2011-4	11	3.7	3	2.7	8	1
2012-1	6	4.7	3	4.2	10	1
2012-2	8	4.4	3	4.6	15	1
2012-4	10	5.1	3.5	4.2	14	1
2013-1	4	16.8	16.5	11.9	30	4
2013-2	1	2	2	-	2	2
2013-3	4	2.2	2	1.3	4	1
2013-4	6	1.7	1	1	3	1
Total	108	5.7	4	5.5	30	1

(a) DS - Throughput feature

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	11	3.8	3	2.1	7	1
2010-4	41	4.5	3	3.5	15	1
2011-1	27	3.6	3	2.8	12	1
2011-2	32	6.2	5.5	5.4	19	1
2011-3	40	5.2	4.5	4.6	22	1
2011-4	47	5.2	5	3.9	17	1
2012-1	53	6.4	6	4.6	17	1
2012-2	51	5.5	5	3.7	15	1
2012-3	49	6.4	5	5	27	1
2012-4	40	4.6	3	4.1	17	1
2013-1	56	15.7	9	15.4	59	1
2013-2	57	6.8	7	4.6	22	1
2013-3	49	4.8	3	4.5	17	1
2013-4	13	2.1	1	1.9	7	1
Total	566	6.4	5	7	59	1

(b) DS - Throughput bug

Table A.22: Caption of Descriptive Statistic for Throughput feature and Throughput bug a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	9	26.9	22	30	91	1
2010-4	37	24.6	20	19.3	71	2
2011-1	21	10.1	8	7.8	29	1
2011-2	47	15.2	14	10.2	41	1
2011-3	84	16.1	10	17.9	105	1
2011-4	69	24.5	15	25.8	153	1
2012-1	68	30.7	22	27.9	148	1
2012-2	72	36.3	26	30.3	138	1
2012-3	53	18.6	16	15.5	80	1
2012-4	54	27.3	14.5	39.7	259	1
2013-1	71	31.4	24	29.9	161	1
2013-2	60	34.5	21.5	37.5	178	2
2013-3	44	27.6	19	27	118	1
2013-4	9	11.9	10	9	31	1
Total	698	25.7	17	27.5	259	1

(a) DS - Lead time

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	9	63.2	70	51.5	168	6
2010-4	37	59.6	44	58.2	205	1
2011-1	21	41.1	17	60.2	201	1
2011-2	47	35	20	45.1	185	1
2011-3	84	24.1	8	37.2	151	0
2011-4	69	29	15	37.8	172	0
2012-1	68	27.4	14.5	37	170	0
2012-2	72	40	22	48.7	192	0
2012-3	53	20.8	17	24.8	110	0
2012-4	54	24.4	6.5	40.6	244	0
2013-1	71	41	27	45	206	0
2013-2	60	37.8	24	39.8	161	0
2013-3	44	30.6	13.5	41.6	164	0
2013-4	9	32	27	36.6	115	0
Total	698	33.4	17	43	244	0

(b) DS - Churn

Table A.23: Caption of Descriptive Statistic for Lead time and Churn a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-4	9	93.6	78	79.8	205	8
2011-1	4	88.5	74	88.3	201	5
2011-2	8	69	45.5	57.4	182	23
2011-3	30	29.4	8	47.5	151	0
2011-4	18	46.3	13	58.2	172	0
2012-1	10	26.3	0	52.9	170	0
2012-2	13	75.7	83	65.9	192	0
2012-3	2	27.5	27.5	9.2	34	21
2012-4	9	38.1	41	38	100	0
2013-1	8	94.2	71	75.1	206	7
2013-2	8	31.5	4	40.5	91	0
2013-3	4	73.5	65	86	164	0
Total	123	52.1	27	61.2	206	0

(a) DS - Churn feature

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	9	63.2	70	51.5	168	6
2010-4	28	48.7	38	46	157	1
2011-1	17	30	15	48.7	187	1
2011-2	39	28.1	17	39.6	185	1
2011-3	54	21.1	9	30.2	149	0
2011-4	51	22.9	15	25.4	107	0
2012-1	58	27.6	15	34.1	152	0
2012-2	59	32.2	21	40.7	187	0
2012-3	51	20.5	17	25.2	110	0
2012-4	45	21.6	6	41	244	0
2013-1	63	34.3	23	35.1	153	0
2013-2	52	38.8	25	40	161	0
2013-3	40	26.4	13.5	33.7	113	0
2013-4	9	32	27	36.6	115	0
Total	575	29.4	17	36.8	244	0

(b) DS - Churn bug

Table A.24: Caption of Descriptive Statistic for Churn feature and Churn bug a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	19	1.9	1	1.8	7	1
2010-4	46	2.6	2	1.7	8	1
2011-1	36	1.9	1.5	1.3	7	1
2011-2	45	5.5	4	4.7	19	1
2011-3	51	3	2	2.6	15	1
2011-4	53	3.5	3	2.4	11	1
2012-1	52	3.7	3	2.6	10	1
2012-2	56	2.7	2	1.9	7	1
2012-3	49	3.2	2	2.7	13	1
2012-4	35	3	2	2.7	15	1
2013-1	56	9.6	7	8.3	38	1
2013-2	49	4.2	4	2.7	12	1
2013-3	41	3.1	2	2.4	10	1
2013-4	11	1.4	1	0.9	4	1
Total	604	3.8	3	4.1	38	1

(a) DS - Bugs

Quarter	Finished	Not finished	Total	Finished	Not finished
2010-3	24	13	37	64.9	35.1
2010-4	108	13	121	89.3	10.7
2011-1	57	12	69	82.6	17.4
2011-2	202	47	249	81.1	18.9
2011-3	119	33	152	78.3	21.7
2011-4	147	37	184	79.9	20.1
2012-1	149	45	194	76.8	23.2
2012-2	116	35	151	76.8	23.2
2012-3	133	25	158	84.2	15.8
2012-4	99	5	104	95.2	4.8
2013-1	502	37	539	93.1	6.9
2013-2	183	21	204	89.7	10.3
2013-3	123	5	128	96.1	3.9
2013-4	15	0	15	100	0
Mean	109.9	18.6	128.5	74.3	25.7

(b) DS - Bugs per quarter

Table A.25: Caption of Descriptive Statistic for Bugs and Bugs finished within quarter a, b

A.6 Team 6 - Descriptive Statistics

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	24	9.5	9	3.6	16	4
2010-4	92	10.3	10	2.6	16	6
2011-1	90	9.8	10	2	17	7
2011-2	91	10.4	11	2.4	16	4
2011-3	92	19.5	20.5	7.3	34	6
2011-4	92	22.9	22	9.3	44	9
2012-1	91	15.6	16	3.7	27	6
2012-2	91	17.5	18	6.1	42	8
2012-3	92	15.2	15	4.5	26	6
2012-4	92	26.3	25.5	10.6	50	11
2013-1	90	32.6	31	8.4	51	15
2013-2	91	43.7	43	5	60	36
2013-3	92	30.6	29.5	8	61	17
2013-4	85	37.4	39	20.8	125	10
Total	1205	22.1	18	13.4	125	4

(a) DS - WIP

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	17	4.5	3	3.1	10	1
2010-4	51	3.3	3	2.6	10	1
2011-1	45	2.3	1	1.9	8	1
2011-2	37	2.8	3	1.9	8	1
2011-3	49	2.7	1	2.1	7	1
2011-4	40	3.2	3	2.3	9	1
2012-1	54	3.3	3	2.4	9	1
2012-2	51	5.2	3	5.8	37	1
2012-3	45	4	3	3.6	21	1
2012-4	63	6	5	4.5	23	1
2013-1	59	6.3	5	4.2	16	1
2013-2	61	4.4	3	3.7	15	1
2013-3	61	4.7	4	3.6	15	1
2013-4	58	9.1	5	23.8	181	1
Total	691	4.6	3	181	1	7.8

(b) DS - Throughput

Table A.26: Caption of Descriptive Statistic for WIP and Throughput a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	14	4.3	3	3.4	10	1
2010-4	47	3.5	3	2.7	10	1
2011-1	42	2.3	1	1.9	8	1
2011-2	33	2.7	3	1.9	8	1
2011-3	45	2.7	1	2.2	7	1
2011-4	38	3.2	3	2.4	9	1
2012-1	51	3.3	3	2.4	9	1
2012-2	51	5.2	3	5.8	37	1
2012-3	43	4	3	3.7	21	1
2012-4	55	6.4	5	4.5	23	1
2013-1	49	6.7	6	4.3	16	1
2013-2	47	5	3	3.8	15	1
2013-3	44	4.8	4	3.8	15	1
2013-4	50	10.1	5	25.5	181	1
Total	609	4.8	3	8.3	181	1

(a) DS - Throughput feature

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	3	5.3	6	2.1	7	3
2010-4	4	1	1	0	1	1
2011-1	3	2.3	1	2.3	5	1
2011-3	4	3.5	3	2.5	7	1
2011-4	4	2.5	2	1.9	5	1
2012-1	2	3.5	3.5	0.7	4	3
2012-2	3	3.7	2	2.9	7	2
2012-3	2	3	3	1.4	4	2
2012-4	8	3.5	2	3.3	11	1
2013-1	10	4.4	4.5	2.7	9	1
2013-2	14	2.4	1.5	2.9	12	1
2013-3	17	4.2	4	3.2	13	1
2013-4	8	2.5	3	1.1	4	1
Total	82	3.3	2.5	2.6	13	1

(b) DS - Throughput bug

Table A.27: Caption of Descriptive Statistic for Throughput feature and Throughput bug a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	19	4.7	2	7.9	34	1
2010-4	34	7.7	3.5	10.7	48	1
2011-1	35	10.9	8	9.1	33	1
2011-2	21	9.9	6	10.2	44	1
2011-3	20	15.9	15.5	10.7	46	3
2011-4	33	17.4	15	11.9	52	1
2012-1	59	16.1	14	13.2	70	1
2012-2	53	22.6	18	17.8	77	1
2012-3	55	15.4	13	12	53	1
2012-4	88	17.3	11	19.6	120	1
2013-1	109	12.9	8	11.8	54	1
2013-2	67	12	8	11.6	73	1
2013-3	84	13.5	10.5	13.4	94	1
2013-4	79	13.9	8	18.1	93	1
Total	756	14.3	10	14.5	120	1

(a) DS - Lead time

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	19	139.4	31	224.3	812	2
2010-4	34	185.4	67.5	255.5	1030	1
2011-1	35	110.5	31	214.6	901	1
2011-2	21	266.6	140	321.4	1187	1
2011-3	20	175.4	146	159.7	496	8
2011-4	33	68.5	7	149.4	596	0
2012-1	59	72.2	9	213.6	1191	0
2012-2	53	59.9	16	149.5	769	0
2012-3	55	60	8	196.9	1207	0
2012-4	88	75.7	16	160.1	658	0
2013-1	109	91.1	19	202.4	937	0
2013-2	67	144.3	40	213.5	766	0
2013-3	84	69.4	19	128.6	739	0
2013-4	79	92.2	19	198.5	1127	0
Total	756	98.3	19	197.3	1207	0

(b) DS - Churn

Table A.28: Caption of Descriptive Statistic for Lead time and Churn a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	13	191.1	37	255.8	812	2
2010-4	33	189	67	258.6	1030	1
2011-1	32	119.4	32.5	222.5	901	1
2011-2	21	266.6	140	321.4	1187	1
2011-3	20	175.4	146	159.7	496	8
2011-4	31	72.9	7	153.2	596	0
2012-1	52	81.2	14.5	226.3	1191	0
2012-2	53	59.9	16	149.5	769	0
2012-3	46	70.7	12.5	214	1207	0
2012-4	64	85.2	16	167.8	655	0
2013-1	62	87.8	20	199.3	937	0
2013-2	44	154.7	28	232.9	766	0
2013-3	54	72.4	24.5	128.2	739	0
2013-4	51	94.8	30	187.7	994	0
Total	576	105.9	21	204.9	1207	0

(a) DS - Churn feature

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	6	27.5	9	45.3	119	2
2010-4	1	68	68	-	68	68
2011-1	3	15.7	11	13.6	31	5
2011-4	2	0.5	0.5	0.7	1	0
2012-1	7	5.6	0	12.7	34	0
2012-3	9	4.8	1	8	24	0
2012-4	24	50.4	11.5	137.7	658	0
2013-1	47	95.4	12	208.4	934	0
2013-2	23	124.3	54	173.4	694	0
2013-3	30	64	13	131.2	574	0
2013-4	28	87.5	10.5	220.3	1127	0
Total	180	73.8	12	169.3	1127	0

(b) DS - Churn bug

Table A.29: Caption of Descriptive Statistic for Churn feature and Churn bug a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	10	1.5	1.5	0.5	2	1
2010-4	7	1	1	0	1	1
2011-1	5	1.4	1	0.9	3	1
2011-2	8	1.1	1	0.4	2	1
2011-3	4	1.2	1	0.5	2	1
2011-4	2	2	2	0	2	2
2012-1	7	1.1	1	0.4	2	1
2012-3	11	1.3	1	0.5	2	1
2012-4	24	1.8	1.5	1	4	1
2013-1	39	1.9	2	1.2	7	1
2013-2	33	1.5	1	0.7	3	1
2013-3	34	1.6	1	0.8	4	1
2013-4	27	1.8	2	0.9	4	1
Total	211	1.6	1	0.9	7	1

(a) DS - Bugs

Quarter	Finished	Not finished	Total	Finished	Not finished
2010-3	14	1	15	93.3	6.7
2010-4	6	1	7	85.7	14.3
2011-1	6	1	7	85.7	14.3
2011-2	7	2	9	77.8	22.2
2011-3	3	2	5	60	40
2011-4	3	1	4	75	25
2012-1	8	0	8	100	0
2012-3	12	2	14	85.7	14.3
2012-4	41	2	43	95.3	4.7
2013-1	66	9	75	88	12
2013-2	43	7	50	86	14
2013-3	52	1	53	98.1	1.9
2013-4	49	0	49	100	0
Mean	23.9	2.2	26.1	87.0	13.0

(b) DS - Bugs

Table A.30: Caption of Descriptive Statistic for Bugs and Bugs finished within quarter a, b

A.7 Team 7 - Descriptive Statistics

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	12	17.7	8.5	19.5	54	1
2010-4	64	13	8	11.9	50	1
2011-1	57	12.8	8	15.1	89	1
2011-2	37	14.3	9	13	51	1
2011-3	36	17.8	11.5	18.1	79	1
2011-4	51	15	9	14.9	63	1
2012-1	35	14.9	11	18.3	86	1
2012-2	23	18.8	9	27.8	124	1
2012-3	42	15.1	7	18.6	81	1
2012-4	2	1.5	1.5	0.7	2	1
Total	359	14.8	8	16.6	124	1

(a) DS - WIP

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	11	3.9	2	4	14	1
2010-4	53	3.7	3	2.5	13	1
2011-1	54	3.2	3	2.3	13	1
2011-2	33	2.3	2	1.2	5	1
2011-3	36	2	2	1.1	4	1
2011-4	44	2.2	2	1.5	6	1
2012-1	37	2	1	1.5	7	1
2012-2	25	2.2	2	1.4	6	1
2012-3	32	3.4	3	2.5	13	1
2012-4	3	1	1	0	1	1
Total	328	2.7	2	2.1	14	1

(b) DS - Throughput

Table A.31: Caption of Descriptive Statistic for WIP and Throughput a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	8	3.2	2.5	2.4	7	1
2010-4	37	4	3	2.7	13	1
2011-1	22	3.4	3	2.4	10	1
2011-2	10	2.7	2.5	1.7	5	1
2011-3	17	2.1	2	1.2	4	1
2011-4	26	2	1.5	1.3	5	1
2012-1	12	2	2	1.3	5	1
2012-2	9	2.2	2	0.8	3	1
2012-3	12	2.7	3	1.5	5	1
2012-4	3	1	1	0	1	1
Total	156	2.8	2	2.1	13	1

(a) DS - Throughput feature

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	3	5.7	2	7.2	14	1
2010-4	16	2.9	2.5	2	9	1
2011-1	32	3	3	2.3	13	1
2011-2	23	2.1	2	0.9	4	1
2011-3	19	1.9	2	1	4	1
2011-4	18	2.4	2	1.7	6	1
2012-1	25	2.1	1	1.6	7	1
2012-2	16	2.2	2	1.6	6	1
2012-3	20	3.8	3	2.9	13	1
Total	172	2.6	2	2.1	14	1

(b) DS - Throughput bug

Table A.32: Caption of Descriptive Statistic for Throughput feature and Throughput bug a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	12	17.7	8.5	19.5	54	1
2010-4	64	13	8	11.9	50	1
2011-1	57	12.8	8	15.1	89	1
2011-2	37	14.3	9	13	51	1
2011-3	36	17.8	11.5	18.1	79	1
2011-4	51	15	9	14.9	63	1
2012-1	35	14.9	11	18.3	86	1
2012-2	23	18.8	9	27.8	124	1
2012-3	42	15.1	7	18.6	81	1
2012-4	2	1.5	1.5	0.7	2	1
Total	359	14.8	8	16.6	124	1

(a) DS - Lead time

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	12	154.2	49.5	189	647	4
2010-4	64	94.1	30	137.1	662	1
2011-1	57	74.3	26	108.4	479	1
2011-2	37	106.7	29	183.6	726	0
2011-3	36	85.1	21.5	143.6	577	0
2011-4	51	68.1	23	112.8	458	0
2012-1	35	43.4	15	70.1	367	0
2012-2	23	55.7	33	73.6	302	0
2012-3	42	53.8	28	82.5	424	3
2012-4	2	44	44	1.4	45	43
Total	359	77.3	26	124.8	726	0

(b) DS - Churn

Table A.33: Caption of Descriptive Statistic for Lead time and Churn a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	7	248.4	248	201	647	41
2010-4	38	117.8	77.5	130.8	585	6
2011-1	18	131.7	67.5	153.5	479	4
2011-2	10	173.3	84.5	231.5	726	0
2011-3	11	204.3	115	208.8	577	0
2011-4	25	114	55	141.8	458	0
2012-1	9	37.6	31	31.6	82	1
2012-2	7	40.6	34	47	140	0
2012-3	14	68.6	43	87.7	318	3
2012-4	2	44	44	1.4	45	43
Total	141	121.2	57	150.7	726	0

(a) DS - Churn feature

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-4	26	59.5	11.5	141.2	662	1
2011-1	39	47.9	20	67	276	1
2011-2	27	82	21	160.6	719	0
2011-3	25	32.6	17	50.1	226	1
2011-4	26	24	14.5	44.9	234	0
2012-1	26	45.4	11	79.7	367	0
2012-2	16	62.3	28	83.1	302	0
2012-3	28	46.4	22	80.4	424	4
Total	218	48.9	18	94.8	719	0

(b) DS - Churn bug

Table A.34: Caption of Descriptive Statistic for Churn feature and Churn bug a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	17	1.8	2	0.8	3	1
2010-4	28	1.7	1.5	0.9	4	1
2011-1	39	3.1	2	2.5	12	1
2011-2	26	2	2	1.3	5	1
2011-3	26	1.6	1	1.1	5	1
2011-4	24	2.2	2	1.5	7	1
2012-1	29	1.7	1	1.4	8	1
2012-2	18	2.7	2	2.6	11	1
2012-3	29	2.3	2	1.3	5	1
Total	240	2.1	2	1.7	12	1

(a) DS - Bugs

Quarter	Finished	Not finished	Total	Finished	Not finished
2010-3	20	10	30	66.7	33.3
2010-4	47	1	48	97.9	2.1
2011-1	119	2	121	98.3	1.7
2011-2	45	8	53	84.9	15.1
2011-3	35	6	41	85.4	14.6
2011-4	45	7	52	86.5	13.5
2012-1	46	2	48	95.8	4.2
2012-2	36	12	48	75	25
2012-3	67	0	67	100	0
Mean	38.3	4.3	42.7	65.9	34.1

(b) DS - Bugs per quarter

Table A.35: Caption of Descriptive Statistic for Bugs and Bugs finished within quarter a, b

A.8 Team 8 - Descriptive Statistics

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-4	19	0.4	0	0.5	1	0
2011-1	90	3.7	3	2.4	9	0
2011-2	91	5.9	6	1.9	11	1
2011-3	92	11.2	12	2.6	16	7
2011-4	92	7.9	7	3.3	14	3
2012-1	91	9.7	9	3.7	16	3
2012-2	91	4.3	2	4.6	12	1
2012-3	92	9.1	9	7.3	32	1
2012-4	92	5.6	7	4.6	18	1
2013-1	90	8.4	4	9.1	30	1
2013-2	91	19.7	18	11.2	55	2
2013-3	92	8.2	4	8.5	29	0
2013-4	77	4	5	2.8	11	0
Total	1100	8.1	6	7.3	55	0

(a) DS - WIP

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-4	2	1	1	0	1	1
2011-1	12	1.5	1	0.7	3	1
2011-2	21	1.2	1	0.5	3	1
2011-3	15	1.7	1	1.1	4	1
2011-4	19	1.3	1	0.6	3	1
2012-1	16	1.4	1	1	5	1
2012-2	3	1	1	0	1	1
2012-3	23	2.5	2	2.5	12	1
2012-4	10	1.7	2	0.7	3	1
2013-1	25	3.8	3	3.4	14	1
2013-2	20	3.5	2.5	2.9	9	1
2013-3	21	3.5	2	3.5	13	1
2013-4	4	3.5	3	2.6	7	1
Total	191	2.3	1	2.4	14	1

(b) DS - Throughput

Table A.36: Caption of Descriptive Statistic for WIP and Throughput a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2011-1	2	1	1	0	1	1
2011-2	5	1.4	1	0.9	3	1
2011-3	1	1	1	-	1	1
2011-4	6	1.5	1	0.8	3	1
2012-1	6	1.8	1	1.6	5	1
2012-3	20	2.7	2	2.7	12	1
2012-4	6	1.8	2	0.8	3	1
2013-1	18	3.6	3	2.6	9	1
2013-2	12	5	5	2.8	9	1
2013-3	13	4.8	4	3.9	13	1
2013-4	3	4.3	4	2.5	7	2
Total	92	3.2	2	2.8	13	1

(a) DS - Throughput feature

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-4	2	1	1	0	1	1
2011-1	10	1.6	1.5	0.7	3	1
2011-2	16	1.2	1	0.4	2	1
2011-3	14	1.8	1	1.1	4	1
2011-4	13	1.1	1	0.4	2	1
2012-1	10	1.1	1	0.3	2	1
2012-2	3	1	1	0	1	1
2012-3	3	1	1	0	1	1
2012-4	4	1.5	1.5	0.6	2	1
2013-1	7	4.1	1	5	14	1
2013-2	8	1.4	1	0.7	3	1
2013-3	8	1.2	1	0.5	2	1
2013-4	1	1	1	-	1	1
Total	99	1.5	1	1.6	14	1

(b) DS - Throughput bug

Table A.37: Caption of Descriptive Statistic for Throughput feature and Throughput bug a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-4	1	1	1	-	1	1
2011-1	3	3	3	2	5	1
2011-2	8	19.6	9.5	25.8	71	1
2011-3	13	20.5	15	18.9	69	1
2011-4	10	21.4	18.5	16	43	2
2012-1	9	27	8	61.3	190	1
2012-2	1	1	1	-	1	1
2012-3	20	28.6	28.5	26.3	89	1
2012-4	10	17	15	13.3	45	3
2013-1	22	14.6	9.5	17.2	75	1
2013-2	16	23.1	5	41.4	150	1
2013-3	20	24.9	13.5	39.2	161	1
2013-4	4	70.2	75.5	56.3	129	1
Total	137	22.6	11	32.2	190	1

(a) DS - Lead time

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-4	1	3	3	-	3	3
2011-1	3	7.7	3	9	18	2
2011-2	8	9.5	1.5	12.3	26	0
2011-3	13	12.8	3	16.4	51	0
2011-4	10	6	1.5	10.2	32	0
2012-1	9	17.7	0	50.4	152	0
2012-2	1	8	8	-	8	8
2012-3	20	12.4	2	20.5	84	0
2012-4	10	3.7	0.5	5.2	13	0
2013-1	22	9.6	5	15.5	73	0
2013-2	16	19.6	1.5	40.6	149	0
2013-3	20	17.9	4.5	35.9	145	0
2013-4	4	45.8	29	57.2	125	0
Total	137	13.4	3	27.9	152	0

(b) DS - Churn

Table A.38: Caption of Descriptive Statistic for Lead time and Churn a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2011-1	1	2	2	-	2	2
2011-2	2	0	0	0	0	0
2011-3	1	0	0	-	0	0
2011-4	3	10.7	0	18.5	32	0
2012-1	3	50.7	0	87.8	152	0
2012-2	19	13.1	3	20.9	84	0
2012-3	7	3.6	1	4.9	13	0
2012-4	15	5.5	4	5.7	17	0
2013-1	10	31.2	6.5	48.4	149	0
2013-2	15	23.3	7	40.2	145	0
2013-3	3	58.3	50	62.9	125	0
Total	79	17.4	4	34.4	152	0

(a) DS - Churn feature

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-4	1	3	3	-	3	3
2011-1	2	10.5	10.5	10.6	18	3
2011-2	6	12.7	12.5	12.8	26	0
2011-3	12	13.8	6.5	16.7	51	0
2011-4	7	4	3	5.3	14	0
2012-1	6	1.2	0	2.9	7	0
2012-2	1	8	8	-	8	8
2012-3	1	0	0	-	0	0
2012-4	3	4	0	6.9	12	0
2013-1	7	18.3	12	25.1	73	0
2013-2	6	0.2	0	0.4	1	0
2013-3	5	1.6	0	3.6	8	0
2013-4	1	8	8	-	8	8
Total	58	8	1.5	13.6	73	0

(b) DS - Churn bug

Table A.39: Caption of Descriptive Statistic for Churn feature and Churn bug a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	1	1	1	-	1	1
2010-4	7	1.1	1	0.4	2	1
2011-1	9	1.2	1	0.4	2	1
2011-2	16	1.6	1	1.5	7	1
2011-3	15	1.3	1	0.6	3	1
2011-4	13	1.2	1	0.6	3	1
2012-1	9	1.2	1	0.4	2	1
2012-2	2	1	1	0	1	1
2012-3	4	1.2	1	0.5	2	1
2012-4	2	1	1	0	1	1
2013-1	10	3.3	2.5	2.8	10	1
2013-2	4	1	1	0	1	1
2013-3	4	1.5	1.5	0.6	2	1
2013-4	1	1	1	-	1	1
Total	100	1.5	1	1.3	10	1

(a) DS - Bugs

Quarter	Finished	Not finished	Total	Finished	Not finished
2010-3	0	1	1	0	100
2010-4	2	6	8	25	75
2011-1	7	4	11	63.6	36.4
2011-2	16	10	26	61.5	38.5
2011-3	16	4	20	80	20
2011-4	15	1	16	93.8	6.3
2012-1	9	2	11	81.8	18.2
2012-2	2	0	2	100	0
2012-3	2	3	5	40	60
2012-4	1	1	2	50	50
2013-1	27	6	33	81.8	18.2
2013-2	3	1	4	75	25
2013-3	6	0	6	100	0
2013-4	1	0	1	100	0
Mean	6.7	2.6	9.3	59.5	40.5

(b) DS - Bugs per quarter

Table A.40: Caption of Descriptive Statistic for Bugs and Bugs finished within quarter
a, b

A.9 Team 9 - Descriptive Statistics

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-4	52	4.5	4.5	3.4	10	0
2011-1	90	11.8	12.5	3.8	19	5
2011-2	91	11.2	8	6.9	34	3
2011-3	92	12.8	12	4	24	6
2011-4	92	16	17	5.1	25	5
2012-1	91	16.2	15	4.7	30	8
2012-2	91	35.4	33	16.4	67	8
2012-3	92	32.6	33.5	7.9	51	15
2012-4	92	21.8	23.5	10.4	39	3
2013-1	90	21.4	20.5	8	38	7
2013-2	91	26.6	21	12.7	47	11
2013-3	92	15.9	14	6.3	35	6
2013-4	84	17.1	17	4.5	29	7
Total	1140	19.2	16	11.6	67	0

(a) DS - WIP

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-4	15.0	1.7	1.0	1.0	4.0	1.0
2011-1	30.0	1.8	1.0	1.0	4.0	1.0
2011-2	31.0	2.2	2.0	1.8	9.0	1.0
2011-3	27.0	1.6	1.0	0.9	5.0	1.0
2011-4	33.0	2.0	2.0	1.3	6.0	1.0
2012-1	41.0	2.4	2.0	1.4	5.0	1.0
2012-2	48.0	3.4	3.0	2.0	9.0	1.0
2012-3	53.0	3.3	3.0	2.2	9.0	1.0
2012-4	43.0	2.9	2.0	2.0	10.0	1.0
2013-1	51.0	2.9	2.0	1.8	9.0	1.0
2013-2	46.0	3.5	3.0	2.5	12.0	1.0
2013-3	50.0	2.6	2.0	1.8	9.0	1.0
2013-4	53.0	2.4	2.0	1.5	7.0	1.0
Total	521.0	2.6	2.0	1.9	12.0	1.0

(b) DS - Throughput

Table A.41: Caption of Descriptive Statistic for WIP and Throughput a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-4	12	1.7	1	1	4	1
2011-1	13	1.6	1	0.8	3	1
2011-2	5	1.4	1	0.5	2	1
2011-3	9	1.2	1	0.4	2	1
2011-4	17	1.7	1	1.4	6	1
2012-1	11	1.6	1	0.8	3	1
2012-2	23	2.9	3	1.6	6	1
2012-3	12	3.8	3.5	2.8	9	1
2012-4	20	2.7	2	1.7	6	1
2013-1	15	2.1	2	1	4	1
2013-2	24	3.6	3	2.8	12	1
2013-3	22	2.5	2	1.7	7	1
2013-4	31	2.4	2	1.5	7	1
Total	214	2.4	2	1.8	12	1

(a) DS - Throughput feature

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-4	3	2	2	1	3	1
2011-1	17	1.9	1	1.1	4	1
2011-2	26	2.4	2	1.9	9	1
2011-3	18	1.7	1.5	1	5	1
2011-4	16	2.3	2	1.1	5	1
2012-1	30	2.7	2.5	1.5	5	1
2012-2	25	3.8	3	2.3	9	1
2012-3	41	3.1	3	2	9	1
2012-4	23	3	3	2.3	10	1
2013-1	36	3.2	3	1.9	9	1
2013-2	22	3.4	3	2.2	8	1
2013-3	28	2.6	2	1.9	9	1
2013-4	22	2.5	2	1.6	7	1
Total	307	2.8	2	1.9	10	1

(b) DS - Throughput bug

Table A.42: Caption of Descriptive Statistic for Throughput feature and Throughput bug a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-4	14	11.4	8	10.2	33	2
2011-1	23	20.3	14	15.2	56	3
2011-2	24	19.7	17	12.8	54	4
2011-3	18	10.8	9	7.6	32	2
2011-4	27	10.5	6	7.9	30	2
2012-1	44	12.1	10.5	9.3	46	2
2012-2	58	12.8	10.5	10.2	59	2
2012-3	62	17.6	14	14.2	62	2
2012-4	37	20.5	13	26.1	140	2
2013-1	63	16.8	16	11.6	48	2
2013-2	56	20.8	15	22	128	2
2013-3	60	15	12.5	12	62	2
2013-4	52	14.4	10.5	11.4	48	2
Total	538	15.9	12	14.7	140	2

(a) DS - Lead time

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-4	14	59.4	39.5	62	212	4
2011-1	23	69	56	63.8	204	1
2011-2	24	48.3	24.5	50.4	171	1
2011-3	18	68.6	17	104.3	309	1
2011-4	27	119.9	70	126.5	401	2
2012-1	44	79.9	35	102.8	426	1
2012-2	58	58.3	25	85.2	423	1
2012-3	62	61.9	31	93.6	472	1
2012-4	37	53.6	21	86.5	367	0
2013-1	63	43.1	21	62	218	0
2013-2	56	88.5	35	115.5	445	0
2013-3	60	90.2	31.5	113.3	432	0
2013-4	52	95.8	40	114.9	382	0
Total	538	72.2	30	97.5	472	0

(b) DS - Churn

Table A.43: Caption of Descriptive Statistic for Lead time and Churn a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-4	10	60.9	35.5	68.4	212	5
2011-1	7	74.6	61	44	154	19
2011-2	3	127.7	162	67.4	171	50
2011-3	2	204.5	204.5	130.8	297	112
2011-4	12	210.1	182.5	128.7	401	70
2012-1	14	135.5	72.5	133	426	12
2012-2	22	115.6	76.5	113.4	423	13
2012-3	17	63.8	41	82.1	310	3
2012-4	15	98.1	53	119.6	367	0
2013-1	26	79.3	44	82.8	218	0
2013-2	25	133.7	91	149.5	445	0
2013-3	24	96.7	29	114.1	354	0
2013-4	24	172.4	178.5	130.9	382	0
Total	201	115.9	72	118.8	445	0

(a) DS - Churn feature

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-4	4	55.5	49	50.7	120	4
2011-1	16	66.6	35.5	71.9	204	1
2011-2	21	37	20	37.3	136	1
2011-3	16	51.6	10.5	91.7	309	1
2011-4	15	47.7	28	64.3	242	2
2012-1	30	54	24	74.6	312	1
2012-2	36	23.3	13.5	27.8	134	1
2012-3	45	61.2	30	98.4	472	1
2012-4	22	23.3	12	30	110	0
2013-1	37	17.7	16	15.6	52	0
2013-2	31	52	31	59.3	244	0
2013-3	36	85.9	35	114.2	432	0
2013-4	28	30.2	21.5	25.9	102	0
Total	337	46.1	23	70.4	472	0

(b) DS - Churn bug

Table A.44: Caption of Descriptive Statistic for Churn feature and Churn bug a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	2	1	1	0	1	1
2010-4	13	1.9	2	1.1	4	1
2011-1	18	1.8	1	0.9	3	1
2011-2	20	2.2	1	2.6	12	1
2011-3	14	1.6	1.5	0.6	3	1
2011-4	23	1.8	1	1.2	5	1
2012-1	33	2.1	2	1.5	7	1
2012-2	43	2.2	2	1.5	7	1
2012-3	40	2.7	2	1.9	9	1
2012-4	33	2.2	2	1.7	8	1
2013-1	34	2.2	1	1.7	8	1
2013-2	39	2.1	2	1.6	6	1
2013-3	38	2.1	1.5	1.5	7	1
2013-4	42	1.5	1	0.8	4	1
Total	403	2.1	1	1.5	12	1

(a) DS - Bugs

Quarter	Finished	Not finished	Total	Finished	Not finished
2010-3	0	2	2	0	100
2010-4	8	17	25	32	68
2011-1	19	13	32	59.4	40.6
2011-2	42	3	45	93.3	6.7
2011-3	11	11	22	50	50
2011-4	22	19	41	53.7	46.3
2012-1	52	18	70	74.3	25.7
2012-2	73	22	95	76.8	23.2
2012-3	100	7	107	93.5	6.5
2012-4	58	16	74	78.4	21.6
2013-1	73	3	76	96.1	3.9
2013-2	80	4	84	95.2	4.8
2013-3	79	1	80	98.8	1.3
2013-4	63	0	63	100	0
Mean	37.9	8.3	46.17	58.4	41.6

(b) DS - Bugs per quarter

Table A.45: Caption of Descriptive Statistic for Bugs and Bugs finished within quarter a, b

A.10 Team 10 - Descriptive Statistics

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	24	2.7	3	0.9	5	1
2010-4	92	13.1	13.5	6	26	2
2011-1	90	8.1	8	6.2	22	0
2011-2	91	6	4	4.8	17	0
2011-3	92	0.9	1	0.8	3	0
2011-4	92	16.7	17.5	13.7	40	1
2012-1	91	24.6	24	3.8	36	17
2012-2	91	34.5	35	8.4	51	18
2012-3	92	12.7	10	8.7	44	4
2012-4	92	25.8	19.5	13.6	59	10
2013-1	90	16.3	6	14.5	49	5
2013-2	91	8.9	8	4.5	21	5
2013-3	92	12.5	12	5.8	29	3
2013-4	57	15.4	15	4.8	26	7
Total	1177	14.8	12	12.2	59	0

(a) DS - WIP

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	5	1.6	1	0.9	3	1
2010-4	44	2.2	2	1.6	7	1
2011-1	29	2.5	2	1.8	7	1
2011-2	21	1.9	1	1.4	6	1
2011-3	8	1	1	0	1	1
2011-4	34	2.6	2	1.7	7	1
2012-1	32	1.8	1	1.2	6	1
2012-2	52	2.7	2	1.6	7	1
2012-3	38	1.7	1	1.1	6	1
2012-4	47	2.7	2	3	16	1
2013-1	25	2.9	2	1.8	8	1
2013-2	10	1.9	1.5	1.1	4	1
2013-3	36	1.8	1.5	1.2	5	1
2013-4	23	1.8	1	1.2	5	1
Total	404	2.2	2	1.7	16	1

(b) DS - Throughput

Table A.46: Caption of Descriptive Statistic for WIP and Throughput a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-4	5	2	1	2.2	6	1
2011-1	2	2	2	0	2	2
2011-2	1	6	6	-	6	6
2011-3	3	1	1	0	1	1
2011-4	7	3	2	2.2	7	1
2012-1	7	1.1	1	0.4	2	1
2012-2	15	2.8	2	1.8	7	1
2012-3	6	1	1	0	1	1
2012-4	11	3	1	4.4	16	1
2013-1	2	2.5	2.5	0.7	3	2
2013-2	1	1	1	-	1	1
2013-3	4	1.2	1	0.5	2	1
2013-4	5	2.4	2	1.7	5	1
Total	69	2.3	1	2.3	16	1

(a) DS Throughput feature

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	5	1.6	1	0.9	3	1
2010-4	39	2.2	2	1.5	7	1
2011-1	27	2.6	2	1.9	7	1
2011-2	20	1.7	1	1.1	5	1
2011-3	5	1	1	0	1	1
2011-4	27	2.5	2	1.5	6	1
2012-1	25	1.9	1	1.3	6	1
2012-2	37	2.7	3	1.5	6	1
2012-3	32	1.8	1	1.2	6	1
2012-4	36	2.6	2	2.6	13	1
2013-1	23	2.9	2	1.9	8	1
2013-2	9	2	2	1.1	4	1
2013-3	32	1.9	2	1.2	5	1
2013-4	18	1.7	1	1	4	1
Total	335	2.2	2	1.6	13	1

(b) DS Throughput bug

Table A.47: Caption of Descriptive Statistic for Throughput feature and Throughput bug a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	1	18	18	-	18	18
2010-4	30	18	13.5	12.9	45	2
2011-1	26	11.6	8	9.6	41	3
2011-2	18	16.2	6	18.2	60	2
2011-3	7	9	6	7.2	21	3
2011-4	37	21.1	13	17.9	56	2
2012-1	20	27.8	27	21.6	78	2
2012-2	69	27	22	21.3	106	2
2012-3	27	22.7	17	23.2	97	2
2012-4	46	29.8	17.5	48.3	313	3
2013-1	26	19.5	10.5	19.1	67	2
2013-2	13	28.1	31	14.1	52	11
2013-3	24	24.4	19.5	18	62	2
2013-4	17	19.7	15	21.6	96	2
Total	361	22.7	15	24.8	313	2

(a) DS - Lead time

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	1	5	5	-	5	5
2010-4	30	58	15	106.2	469	1
2011-1	26	41	17.5	56.8	266	0
2011-2	18	14	3.5	19.1	59	0
2011-3	7	70	1	131.8	358	0
2011-4	37	24.2	7	53.9	309	0
2012-1	20	43.6	13.5	103	441	0
2012-2	69	39.3	11	85	438	0
2012-3	27	38.3	12	60.7	267	0
2012-4	46	52.2	17	88.1	373	0
2013-1	26	71.7	26	110.7	406	0
2013-2	13	37.1	24	45.9	123	0
2013-3	24	64.2	16.5	113.9	469	0
2013-4	17	61.6	10	112.8	321	0
Total	361	45.4	14	86.2	469	0

(b) DS - Churn

Table A.48: Caption of Descriptive Statistic for Lead time and Churn a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-4	1	219	219	-	219	219
2011-1	4	77	21	126.5	266	0
2011-2	3	29.3	25	27.8	59	4
2011-3	2	47.5	47.5	67.2	95	0
2011-4	10	35.3	0	97	309	0
2012-1	1	441	441	-	441	441
2012-2	25	66	5	131.9	438	0
2012-3	4	79	24.5	127.4	267	0
2012-4	8	95.5	16	133.9	310	0
2013-1	3	45.7	13	68.1	124	0
2013-2	2	48	48	67.9	96	0
2013-3	3	168.3	219	149.6	286	0
2013-4	3	78.3	0	135.7	235	0
Total	69	75.5	5	123.6	441	0

(a) DS - Churn feature

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	1	5	5	-	5	5
2010-4	29	52.5	15	103.6	469	1
2011-1	22	34.4	17.5	35.6	125	0
2011-2	15	10.9	1	16.5	54	0
2011-3	5	79	1	156.7	358	0
2011-4	27	20.1	14	26.4	128	0
2012-1	19	22.7	13	44.3	195	0
2012-2	44	24.1	14.5	32.5	141	0
2012-3	23	31.2	12	42.3	151	0
2012-4	38	43.1	17	74.6	373	0
2013-1	23	75.1	27	115.8	406	0
2013-2	11	35.1	24	45.2	123	0
2013-3	21	49.3	14	104	469	0
2013-4	14	58	11	113	321	0
Total	292	38.3	15	73.2	469	0

(b) DS - Churn bug

Table A.49: Caption of Descriptive Statistic for Churn feature and Churn bug a, b

Quarter	N	Mean	Median	Std.Dev	Max	Min
2010-3	11	2.3	1	3	11	1
2010-4	32	2.6	2	1.7	8	1
2011-1	29	2.1	2	1.3	6	1
2011-2	24	1.3	1	0.7	4	1
2011-3	15	1.5	1	0.6	3	1
2011-4	37	2.5	2	2.1	9	1
2012-1	26	1.6	1	0.9	4	1
2012-2	34	2	2	1.5	8	1
2012-3	29	1.6	1	0.9	4	1
2012-4	35	2	1	1.5	7	1
2013-1	29	2.3	1	2.7	13	1
2013-2	16	1.5	1	0.6	3	1
2013-3	22	2.3	2	1.8	7	1
2013-4	19	1.4	1	0.6	3	1
Total	370	1.9	1	1.6	13	1

(a) DS - Bugs

Quarter	Finished	Not finished	Total	Finished	Not finished
2010-3	8	17	25	32	68
2010-4	65	17	82	79.3	20.7
2011-1	49	11	60	81.7	18.3
2011-2	29	2	31	93.5	6.5
2011-3	9	13	22	40.9	59.1
2011-4	72	22	94	76.6	23.4
2012-1	23	19	42	54.8	45.2
2012-2	53	16	69	76.8	23.2
2012-3	30	15	45	66.7	33.3
2012-4	65	6	71	91.5	8.5
2013-1	62	6	68	91.2	8.8
2013-2	16	8	24	66.7	33.3
2013-3	45	5	50	90	10
2013-4	26	0	26	100	0
Mean	30.8	9.3	40.13	67.0	33.0

(b) DS - Bugs per quarter

Table A.50: Caption of Descriptive Statistic for Bugs and Bugs finished within quarter
a, b

Bibliography

- Adams, M. and B. Smoak (1990). 'Managing manufacturing improvement using computer integrated manufacturing methods'. In: *Semiconductor Manufacturing Science Symposium, 1990. ISMSS 1990., IEEE/SEMI International*, pp. 9–13. DOI: 10.1109/ISMSS.1990.66111.
- Alliance, Scrum (2012). 'Scrum, A description'. In:
- Anderson, David J. (2010). *Kanban: Successful Evolutionary Change for Your Technology Business*. Blue Hole Press. ISBN: 0984521402.
- Anderson, David et al. (2011). 'Studying Lean-Kanban Approach Using Software Process Simulation'. In: *Agile Processes in Software Engineering and Extreme Programming*. Ed. by Alberto Sillitti et al. Vol. 77. Lecture Notes in Business Information Processing. Springer Berlin Heidelberg, pp. 12–26. ISBN: 978-3-642-20676-4. DOI: 10.1007/978-3-642-20677-1_2.
- Beedle, Mike et al. (1999). 'SCRUM: An extension pattern language for hyperproductive software development'. In: *Pattern Languages of Program Design 4*, pp. 637–651.
- Birkeland, JørnOla (2010). 'From a Timebox Tangle to a More Flexible Flow'. In: *Agile Processes in Software Engineering and Extreme Programming*. Ed. by Alberto Sillitti et al. Vol. 48. Lecture Notes in Business Information Processing. Springer Berlin Heidelberg, pp. 325–334. ISBN: 978-3-642-13053-3. DOI: 10.1007/978-3-642-13054-0_35.
- Brekkan, Elin and Eystein Mathisen (2010). 'Introducing Scrum in Companies in Norway: A Case Study'. In:
- Cocco, Luisanna et al. (2011). 'Simulating Kanban and Scrum vs. Waterfall with System Dynamics'. In: *Agile Processes in Software Engineering and Extreme Programming*. Springer, pp. 117–131.
- Conboy, Kieran (2009). 'Agility from First Principles: Reconstructing the Concept of Agility in Information Systems Development'. In: *Information Systems Research* 20.3, pp. 329–354. DOI: 10.1287/isre.1090.0236.
- Concas, Giulio et al. (2013). 'Simulation of software maintenance process, with and without a work-in-process limit'. In: *Journal of Software: Evolution and Process* 25.12, pp. 1225–1248. ISSN: 2047-7481. DOI: 10.1002/smrv.1599.

- D. Sjøberg Yamashita, A, B Anda, A Mockus et al. (2012). 'Quantifying the effect of code smells on maintenance effort'. In:
- El-Emam, Khaled (2000). 'A methodology for validating software product metrics'. In: Gandomani, TAGHI JAVDANI et al. (2013). 'Important considerations for agile software development methods governance.' In: *Journal of Theoretical & Applied Information Technology* 55.3.
- Gerring, John (2006). *Case Study Research: Principles and Practices*. Cambridge University Press. ISBN: 0521676568.
- Gupta, Vikram (May 2013). *InfoQ Interviews David J. Anderson at Lean Kanban 2013 Conference*. URL: http://www.infoq.com/articles/David_Anderson_Lean_Kanban_2013_Conference_Interview (visited on 01/10/2013).
- IBM (Jan. 2014). *IBM SPSS Statistics 21 Core System User's Guide*. URL: http://www.sussex.ac.uk/its/pdfs/SPSS_Core_System_Users_Guide_21.pdf (visited on 30/01/2014).
- Ikonen, Marko et al. (2010). 'Exploring the sources of waste in Kanban software development projects'. In: *Software Engineering and Advanced Applications (SEAA), 2010 36th EUROMICRO Conference on*. IEEE, pp. 376–381.
- Ikonen, M. et al. (2011). 'On the Impact of Kanban on Software Project Work: An Empirical Case Study Investigation'. In: *Engineering of Complex Computer Systems (ICECCS), 2011 16th IEEE International Conference on*, pp. 305–314. DOI: 10.1109/ICECCS.2011.37.
- Investopedia (30th Nov. 2013). *Quarter - Q1, Q2, Q3, Q4*. URL: <http://www.investopedia.com/terms/q/quarter.asp> (visited on 30/11/2013).
- Javadian Kootanaee, Akbar, K Babu and Hamid Talari (2013). 'Just-in-Time Manufacturing System: From Introduction to Implement'. In: Available at SSRN 2253243.
- Kniberg, Henrik (2010). *Kanban and Scrum - making the most of both*. lulu.com. ISBN: 0557138329.
- Lai, C.L., W.B. Lee and W.H. Ip (2003). 'A study of system dynamics in just-in-time logistics'. In: 138, pp. 265–269.
- Leonardo Campos Rafael Buzon, Eric Fer (Mar. 2013). *Kanban Pioneer: Interview with David J. Anderson*. URL: <http://www.infoq.com/articles/David-J.-Anderson-Kanban/> (visited on 30/09/2013).
- Manning, James (2013). 'Lean Software Development'. In:
- Middleton, P. and D. Joyce (2012). 'Lean Software Management: BBC Worldwide Case Study'. In: *Engineering Management, IEEE Transactions on* 59.1, pp. 20–32. ISSN: 0018-9391. DOI: 10.1109/TEM.2010.2081675.
- Munassar, Nabil Mohammed Ali and A Govardhan (2010). 'A Comparison Between Five Models Of Software Engineering.' In: *International Journal of Computer Science Issues (IJCSCI)* 7.5.
- Ohno, Taiichi (2001). *Toyota Production System on Compact Disc: Beyond Large-Scale Production*. Productivity Press. ISBN: 1563272679.
- Oracle (2013). 'ArrayList'. In:
- Poppendieck, Mary (2003). 'Lean Development and the Predictability Paradox'. In:

- Poppendieck, Mary and Tom Poppendieck (2003). *Lean Software Development: An Agile Toolkit*. Addison-Wesley Professional. ISBN: 0321150783.
- (2006). *Implementing Lean Software Development: From Concept to Cash*. Addison-Wesley Professional. ISBN: 0321437381.
 - (2009). *Leading Lean Software Development: Results Are not the Point*. Addison-Wesley Professional. ISBN: 0321620704.
- Raman, S. (Oct. 1998). 'Lean software development: is it feasible?' In: *Digital Avionics Systems Conference, 1998. Proceedings., 17th DASC. The AIAA/IEEE/SAE*. Vol. 1, C13/1–C13/8 vol.1. DOI: 10.1109/DASC.1998.741480.
- Rouse, Margaret (2005). *Throughput*. URL: <http://searchnetworking.techtarget.com/definition/throughput> (visited on 04/03/2014).
- Seikola, M., H. Loisa and A. Jagos (Aug. 2011). 'Kanban Implementation in a Telecom Product Maintenance'. In: *Software Engineering and Advanced Applications (SEAA), 2011 37th EUROMICRO Conference on*, pp. 321–329. DOI: 10.1109/SEAA.2011.56.
- Shepard, Jon M. and Robert W. Greene (2002). *Sociology and You*. Glencoe/McGraw-Hill. ISBN: 0078285763.
- Shinkle, C.M. (2009). 'Applying the Dreyfus Model of Skill Acquisition to the Adoption of Kanban Systems at Software Engineering Professionals (SEP)'. In: *Agile Conference, 2009. AGILE '09*. Pp. 186–191. DOI: 10.1109/AGILE.2009.25.
- Sienkiewicz, Lukasz (2012). 'Scrumban - the Kanban as an addition to Scrum software development method in a Network Organization'. In:
- Sjøberg, D.I.K., A. Johnsen and J. Solberg (2012). 'Quantifying the Effect of Using Kanban versus Scrum: A Case Study'. In: *Software, IEEE* 29.5, pp. 47–53. ISSN: 0740-7459. DOI: 10.1109/MS.2012.110.
- Software Innovation* (Dec. 2013). URL: <http://www.software-innovation.com/EN/COMPANY/pages/default.aspx> (visited on 12/12/2013).
- Srinivasan, Mandyam M., Steven J. Ebbing and Alan T. Swearingen (2003). 'Woodward Aircraft Engine Systems Sets Work-in-Process Levels for High-Variety, Low-Volume Products'. In: *Interfaces* 33.4, pp. 61–69. DOI: 10.1287/inte.33.4.61.16377.
- The-Kanban-Way (2011). *Importance of Kanban work-in-progress (WIP) limits*. URL: <http://www.kanbanway.com/importance-of-kanban-work-in-progress-wip-limits#.U0Pmzq2Swkc> (visited on 14/10/2013).
- Vesaliusstraat, Andreas (n.d.). 'The Non-Transitivity of Pearson's Correlation Coefficient: An Educational Perspective'. In:
- Yin, Liangfang, Yuanqing Xiao and Zhenyu Xu (June 2013). 'A new principle based on Pearson correlation coefficient to avoid mal-operation of the restricted earth fault protection'. In: *Electricity Distribution (CIRED 2013), 22nd International Conference and Exhibition on*, pp. 1–4. DOI: 10.1049/cp.2013.0799.
- Yin, Robert K. (2008). *Case Study Research: Design and Methods (Applied Social Research Methods)*. SAGE Publications, Inc. ISBN: 1412960991.