

UiO : Department of Informatics
University of Oslo

Does Limit on Work-In-Progress (WIP) in Software Development Matter?

Truls Skeie
Master's Thesis Spring 2014



Summary

Background: In software engineering there are several principles with impact on a software project. If these principles are applied the wrong way, or not considered, 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 WIP-limit 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 meta data about each tasks the software company worked on from 2008 to 2013. The data set was analyzed using an application developed for this work, described later on. From the data set, the application measured variables such as *WIP*, *throughput*, *bugs*, *lead time* and *churn* for each team. The data produced by the application was interpreted with correlation and case summaries in SPSS.

Results: The results showed a mean correlation value of 0.4 between *WIP* and *throughput*, 0.2 for *bugs* and *lead time* and -0.1 for *churn* across the teams. The correlation table when all the teams data have been combined showed a significant positive correlation value between *WIP* and the variables; *throughput*, *bugs*, *lead time* and *churn*. The result also showed that team size has an impact on both *WIP* and *throughput*, the result also showed the impact both *lead time* and *throughput* has on a development process.

Conclusion:

Based on the data from this work, the conclusion is that WIP-limits matter in software development.

Contents

1	Introduction	1
1.1	Motivation	1
1.2	Research Question	2
1.3	Approach	2
1.4	Chapter overview	3
2	Background	5
2.1	Waterfall	5
2.2	Scrum	6
2.3	Lean	7
2.4	Kanban	9
2.4.1	Kanban Board	10
2.4.2	WIP-limit	11
2.5	Lead time	14
2.6	Just-In-Time	14
2.7	Throughput	16

2.8	Code churn	16
2.9	Software Innovation	17
3	Research Methods	19
3.1	Case study	19
3.2	Choice of case	20
3.2.1	Software Innovation's development process	22
3.3	Correlation	23
4	Data collected and calculations	25
4.1	SPSS	26
4.2	WIP per day	26
4.2.1	Step 1: Gather all unique dates into a ArrayList	26
4.2.2	Step 2: Gather the remaining dates	27
4.2.3	Step 3 Measure WIP	27
4.2.4	Example	28
4.3	Rest of the variables	31
4.3.1	Throughput	32
4.3.2	Churn	32
4.3.3	Lead time	33
4.3.4	Lead time and churn	34
4.3.5	Sub variables	34
4.3.6	Bugs finished, quarter	34

4.3.7	Mean days backlog, bug	35
4.4	Summary	35
5	Results	37
5.1	Correlation result for WIP	37
5.2	Correlation result for lead time	41
5.3	Correlation result for bugs	44
5.4	Correlation result for throughput	48
5.5	Correlation result for churn	51
5.6	Correlation result for team size	55
5.7	Correlation result for all teams combined	56
5.8	WIP-limit per team	59
6	Discussion	61
6.1	WIP and throughput	61
6.2	WIP and lead time	63
6.3	WIP and bugs	64
6.4	WIP and Churn	65
6.5	WIP-limit	66
6.6	Team size	66
6.7	Discussion of the sub variables	67
6.7.1	Throughput	67
6.7.2	Churn	72

7 Conclusion	77
7.1 Future work	78
Appendices	79
A Descriptive statistics (DS) for the ten teams	81
A.1 Team 1 - Descriptive Statistics	81
A.2 Team 2 - Descriptive Statistics	84
A.3 Team 3 - Descriptive Statistics	86
A.4 Team 4 - Descriptive Statistics	89
A.5 Team 5 - Descriptive Statistics	91
A.6 Team 6 - Descriptive Statistics	93
A.7 Team 7 - Descriptive Statistics	96
A.8 Team 8 - Descriptive Statistics	98
A.9 Team 9 - Descriptive Statistics	100
A.10 Team 10 - Descriptive Statistics	103

List of Figures

2.1	Waterfall model	6
2.2	Example of a Kanban board	11
2.3	JIT example	15
2.4	Optional caption for list of figures	18
4.1	Illustrating the WIP timeline for example stated in section 4.2.4	29
5.1	Optional caption for list of figures	59
6.1	Correlation graphs between throughput (X-axis) and the throughput sub variables (Y-axis) for team one.	68
6.2	Correlation graphs between throughput (X-axis) and the sub variables (Y-axis) for team two.	68
6.3	Correlation graphs between throughput (X-axis) and the sub variables (Y-axis) for team four.	69
6.4	Correlation graphs between throughput (X-axis) and the sub variables (Y-axis) for team eight.	71
6.5	Correlation graphs between throughput (X-axis) and the sub variables (Y-axis) for team ten.	72
6.6	Correlation graphs between the churn (X-axis) and the sub variables (Y-axis) for team seven.	74

6.7	Correlation graphs between the churn (X-axis) and the sub variables (Y-axis) for team eight.	75
6.8	Correlation graphs between the churn (X-axis) and the sub variables (Y-axis) for team nine.	76

List of Tables

2.1	Throughput	16
3.1	Excerpt from the data set	20
3.2	Variables from the SI dataset	21
3.3	Relationship between variable and columns from SI	22
4.1	The standard of the data set	25
4.2	Variables of the WIP objects	26
4.3	Showing Task ID, Date From and Date to	29
4.4	How churn is presented in the excel document	33
4.5	How lead time is recorded in the excel document	33
4.6	A excerpt from the result data produced by the program	34
5.1	Correlation with WIP. Team size is not taken into account	38
5.2	Descriptive Statistic table shows correlation with WIP. Team size is not taken into account	39
5.3	Correlation with WIP. Team size is taken into account	40
5.4	Descriptive Statistic for WIP correlation. Team size is taken into account	41

5.5	Correlation with Lead time. Team size is not taken into account	42
5.6	Descriptive Statistic for lead time Correlation. When team size is not taken into account	43
5.7	Correlation with Lead time. Team size taken into account	43
5.8	Descriptive Statistic - Correlation - Lead time - With team size taken into account	44
5.9	Correlation with Bugs. Team size is not taken into account	45
5.10	Descriptive Statistic for bugs Correlation. Team size is not taken into account	46
5.11	Correlation with Bugs - Team size is taken into account	47
5.12	Descriptive Statistic for bugs Correlation. Team size is taken into account	48
5.13	Correlation with Throughput. When team size is not taken into account	49
5.14	Descriptive Statistic for throughput correlation. Time size is taken into account	49
5.15	Correlation with throughput. Time size is taken into account.	50
5.16	Descriptive Statistic for throughput correlation. Time size is taken into account	51
5.17	Correlation with churn. When team size is not taken into account.	52
5.18	Descriptive Statistic for churn correlation. Team size is not taken into account	53
5.19	Correlation with churn. Team size taken into account	54
5.20	Descriptive Statistic for churn correlation. Team size taken into account	54
5.21	Correlation with Team size	55
5.22	Descriptive Statistic for team size correlation.	56
5.23	Correlation with all teams combined. Team size is not taken into account	56

5.24 Correlation with all teams combined. Team size taken into account	57
A.1 Optional caption for list of figures	81
A.2 Optional caption for list of figures	82
A.3 Optional caption for list of figures	82
A.4 Optional caption for list of figures	83
A.5 Optional caption for list of figures	83
A.6 Optional caption for list of figures	84
A.7 Optional caption for list of figures	84
A.8 Optional caption for list of figures	85
A.9 Optional caption for list of figures	85
A.10 Optional caption for list of figures	86
A.11 Optional caption for list of figures	86
A.12 Optional caption for list of figures	87
A.13 Optional caption for list of figures	87
A.14 Optional caption for list of figures	88
A.15 Optional caption for list of figures	88
A.16 Optional caption for list of figures	89
A.17 Optional caption for list of figures	89
A.18 Optional caption for list of figures	90
A.19 Optional caption for list of figures	90
A.20 Optional caption for list of figures	90

A.21 Optional caption for list of figures	91
A.22 Optional caption for list of figures	91
A.23 Optional caption for list of figures	92
A.24 Optional caption for list of figures	92
A.25 Optional caption for list of figures	93
A.26 Optional caption for list of figures	93
A.27 Optional caption for list of figures	94
A.28 Optional caption for list of figures	94
A.29 Optional caption for list of figures	95
A.30 Optional caption for list of figures	95
A.31 Optional caption for list of figures	96
A.32 Optional caption for list of figures	96
A.33 Optional caption for list of figures	97
A.34 Optional caption for list of figures	97
A.35 Optional caption for list of figures	97
A.36 Optional caption for list of figures	98
A.37 Optional caption for list of figures	98
A.38 Optional caption for list of figures	99
A.39 Optional caption for list of figures	99
A.40 Optional caption for list of figures	100
A.41 Optional caption for list of figures	100
A.42 Optional caption for list of figures	101

A.43 Optional caption for list of figures	101
A.44 Optional caption for list of figures	102
A.45 Optional caption for list of figures	102
A.46 Optional caption for list of figures	103
A.47 Optional caption for list of figures	103
A.48 Optional caption for list of figures	104
A.49 Optional caption for list of figures	104
A.50 Optional caption for list of figures	105

Listings

4.1	Gather all unique dates into ArrayList	26
4.2	Gather WIP object to the right data structure	27
4.3	Gather the remaining dates.	27
4.4	WIP measurement	28
4.5	Creating WIP-object	30
4.6	Pseudocode example of how throughput objects are added	31
4.7	Pseudocode example of how throughput is measured	32
4.8	Pseudocode example of how throughput is measured	32
4.9	Pseudocode example of lead time is measured	33

Preface

First of all I would like to thank my advisor, *Dag Sjøberg*, for valuable discussions and great guidance throughout this work as well as Software Innovation for providing the data set. I would also like to thank my dad, *Nils-Olav Skeie* and my good friend *Michael Gunnulfsen* for helping me correct countless spelling errors and for giving me useful tips. I would also like to thank *Henrik Skifeld* for helping me with Python. Most of all I would like to thank my girlfriend *Vilde Fjeldstad*, my mom, *Eva Solesvik*, my sister *Hilde* and all my friends for your love, support and friendship.

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 the reason 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 WIP-limit. In Kanban is the WIP-limit 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 literatures, 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, the motivation of this work will be to investigate WIP-limit in software development.

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.

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

1.4 Chapter overview

Chapter 2: Background:

Chapter 2 introduces background information and 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, 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 software program and SPSS, with descriptive statistics and correlation tables.

Chapter 6: Discussion:

Chapter 6 presents a discussion on the results from the case study and a discussion of the results from this work against the finding from prior research.

Chapter 7: Conclusion:

Chapter 7 provides the conclusion 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), Kanban (Section 2.4) with affiliated tools and the software development company Software Innovation (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)

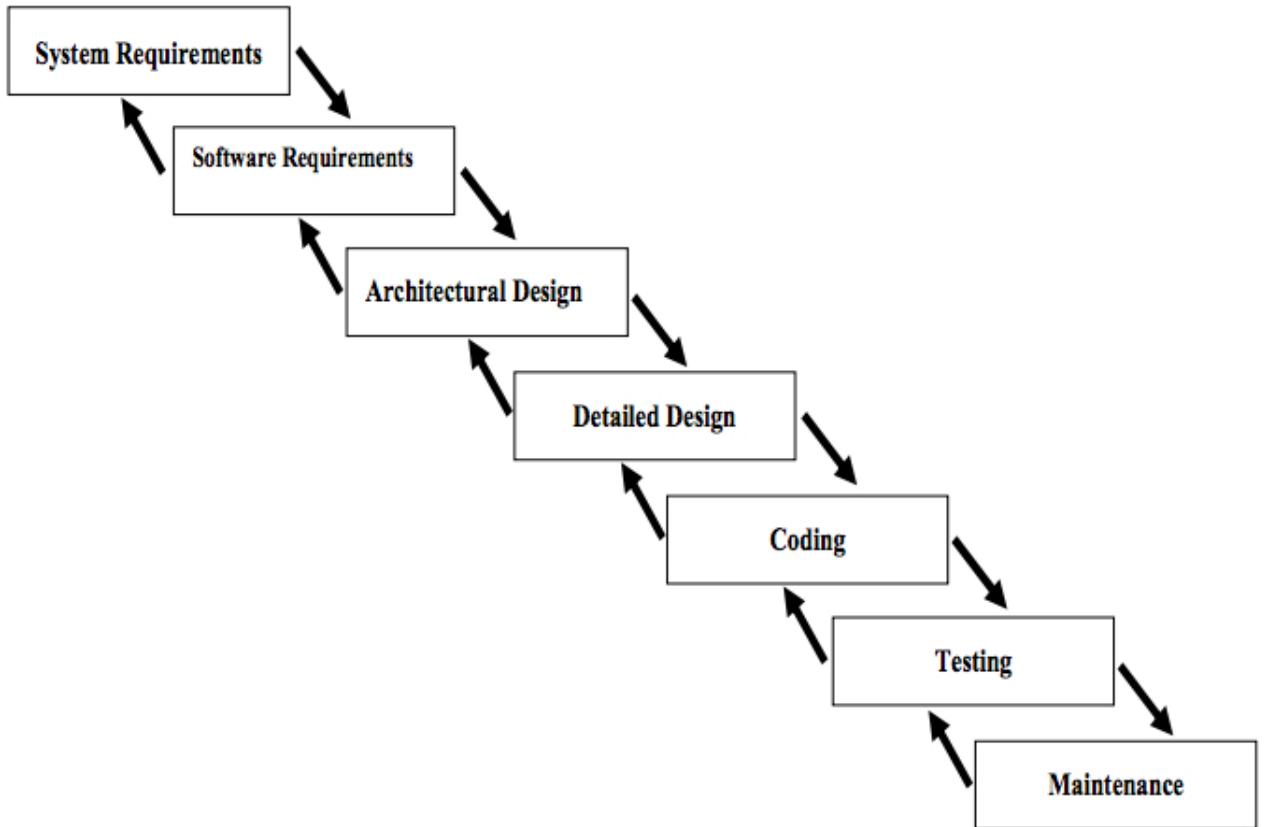


Figure 2.1: Waterfall model

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 (Alliance, 2012):

Individuals and interactions over processes and tools
Working software over comprehensive documentation
Customer collaboration over contract negotiation
Responding to change over following a plan

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 for Toyota. In 1975 was Toyota 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 eliminating 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 with a book called "Lean Software Development: An Agile Toolkit" (M. Poppendieck and T. Poppendieck, 2003). In the book, Poppendieck stated that an important tool to manage workflow is the concept of pull-systems, which means that 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:** Do not wait for details. As soon as enough information is gathered start the development activity. Get everyone involved in figuring out the details. Do not 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 is 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).

"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 is 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 not be 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 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 is 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*. The columns 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* does not 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 using one color for feature and another color for bug. In the paper "Kanban Implementation in a Telecom Product Maintenance" (Seikola, Loisa and Jagos, 2011), 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 . In another project, they used yellow sticky notes for scenarios, blue for bugs, pink for issues (Shinkle, 2009).

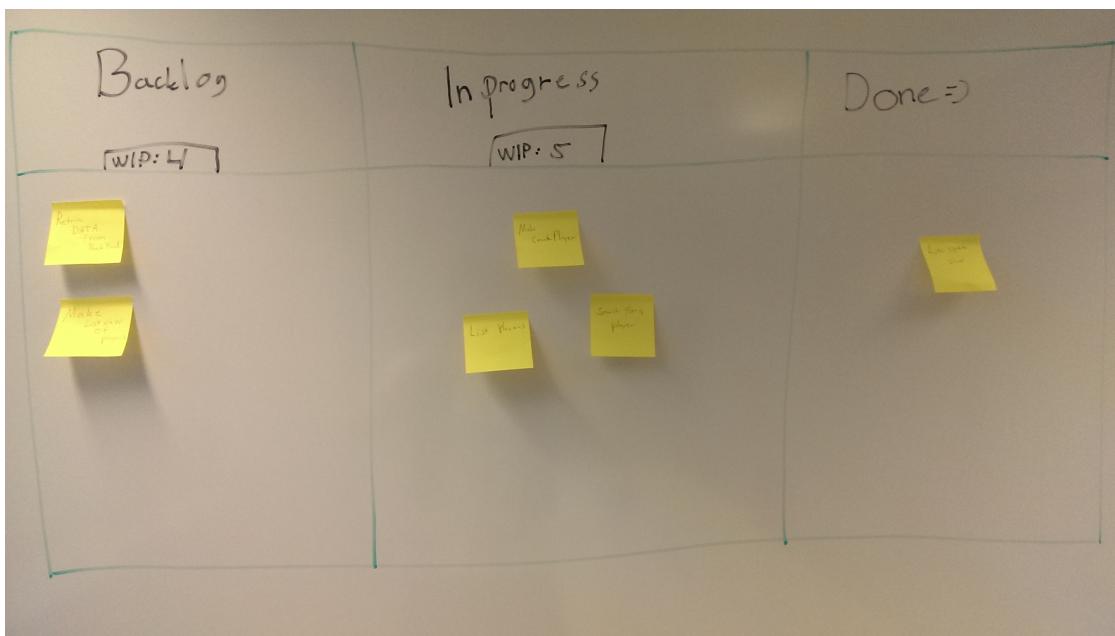


Figure 2.2: Example of a Kanban board

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 explained that the users often do not 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). Both the papers "Lean Software Management" (Kniberg, 2010) and the "Impact of Kanban on Software Project Work" (M. Ikonen et al., 2011) 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 a good one.

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)

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

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 WIP-limit and unlimited WIP. Section 2.4.2.2 shows the importance of WIP-limit, stated by various researches.

2.4.2.1 WIP-limit vs. Unlimited WIP

In the 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 mean 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 prevented task switching. The paper did a simulation of a process that was originally without WIP-limits, with WIP-limits. The study showed 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 a 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 WIP-limit, 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 WIP-limits 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 is 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 is 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 increase 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 are the rocks located in different sizes. The rocks illustrate 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 its 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 lowers the stream (inventory), problems and waste will become visible. Lean wants to lower inventory in order to make problems and waste occur, because when problems and waste occurs, one is 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 it is 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.

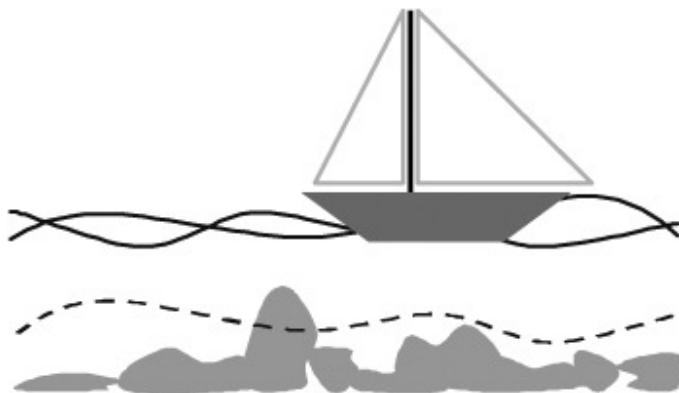


Figure 2.3: JIT example

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:

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 development. Churn is a term used as surrogates for effort in software engineering. Many studies in software development 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 presented in Chapter 5. 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 - (b) Team size - (c) Team size - (d) Team size - (e) Team
team one team two team three team four size - five

Year	Quarter	Team Size
2010	3	5
2010	4	6
2011	1	6
2011	2	6
2011	3	5
2011	4	5
2012	1	4
2012	2	6
2012	3	6
2012	4	9
2013	1	9
2013	2	9
2013	3	9
2013	4	14
Total		99

Year	Quarter	Team Size
2010	3	10
2010	4	8
2011	1	8
2011	2	8
2011	3	13
2011	4	9
2012	1	10
2012	2	5
2012	3	9
2012	4	3
Total		76

Year	Quarter	Team Size
2010	4	2
2011	1	8
2011	2	8
2011	3	13
2011	4	10
2012	1	10
2012	2	2
2012	3	25
2012	4	11
2013	1	22
2013	2	21
2013	3	23
2013	4	8
Total		162

(f) Team size - team six (g) Team size - team seven (h) Team size - team eight

Year	Quarter	Team Size
2010	4	5
2011	1	8
2011	2	7
2011	3	7
2011	4	9
2012	1	10
2012	2	8
2012	3	10
2012	4	12
2013	1	8
2013	2	9
2013	3	8
2013	4	8
Total		109

Year	Quarter	Team Size
2010	3	3
2010	4	11
2011	1	12
2011	2	9
2011	3	4
2011	4	17
2012	1	20
2012	2	17
2012	3	18
2012	4	13
2013	1	17
2013	2	9
2013	3	10
2013	4	10
Total		170

(i) Team size - team nine

(j) Team size - team ten

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 is explained. 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-limits 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 from 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 and Dag Sjøberg is the supervisor of this work and he had access to the data set, so 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 these columns are irrelevant for this study, but the important columns are 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.
Lines added	Number of lines added to a task
Lines modified	Number of lines modified when working on a task
Lines deleted	Number of lines deleted from a task
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 were created. The **Date from** column contains date from the tasks was pulled from the backlog. The **Date to** column consists of all of the dates when tasks were marked as finished. The **Lines added**, **Lines Modified** and **Lines Deleted** column 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 consists of which team the task belongs to.

The data from SI was analyzed on team level. The data was analyzed using the software program and SPSS. The software program 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 created labeled as bug	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	Mean 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 variables churn and throughput are 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 mean 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 and 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 did not 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 that 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 is 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, therefore I have choose to use Pearson correlation.

Chapter 4

Data collected and calculations

This chapter introduces how the software program's algorithm 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), the sub variables (Section 4.3.5), number of bugs finished per quarter (Section 4.3.6) and mean 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). SPSS will be used to analyze the derived data from the software program 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, which is shown by 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

```
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

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 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 were some dates missing from the data set. The software program has to create those. In order to create the remaining dates, the program takes the first date and the last date from each of the teams' ArrayList, as shown in line 1 and 2 of Listing 4.3. Each of the ArrayLists are sorted by date. Then the program checks if all the dates between the first date and the last date are in the team's ArrayList. If the date is not in the ArrayList, the program will generate the date and put it into the ArrayList, which is done by the method addToArrayList showed in the lines 10-13. In order to keep the pseudocode simple, the generateWIP method stated in line 12 was omitted. The generateWIP method creates a new WIP object and returns it.

```

1 WIP first = ArrayList.get(0)
2 WIP last = ArrayList.get(ArrayList.size() - 1)
3 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 in Listing 4.4, 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 that 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
17 int Nr_of_finished_dates(Date date)
18     Nr_of_dates_to_decrement = 0
19     for WIP in ArrayList
20         if date AFTER WIP.getEndDate() DO
21             if date not picked
22                 Nr_of_dates_to_decrement++
23                 dateIsPicked(WIP)
24     return Nr_of_dates_to_decrement
25

```

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.

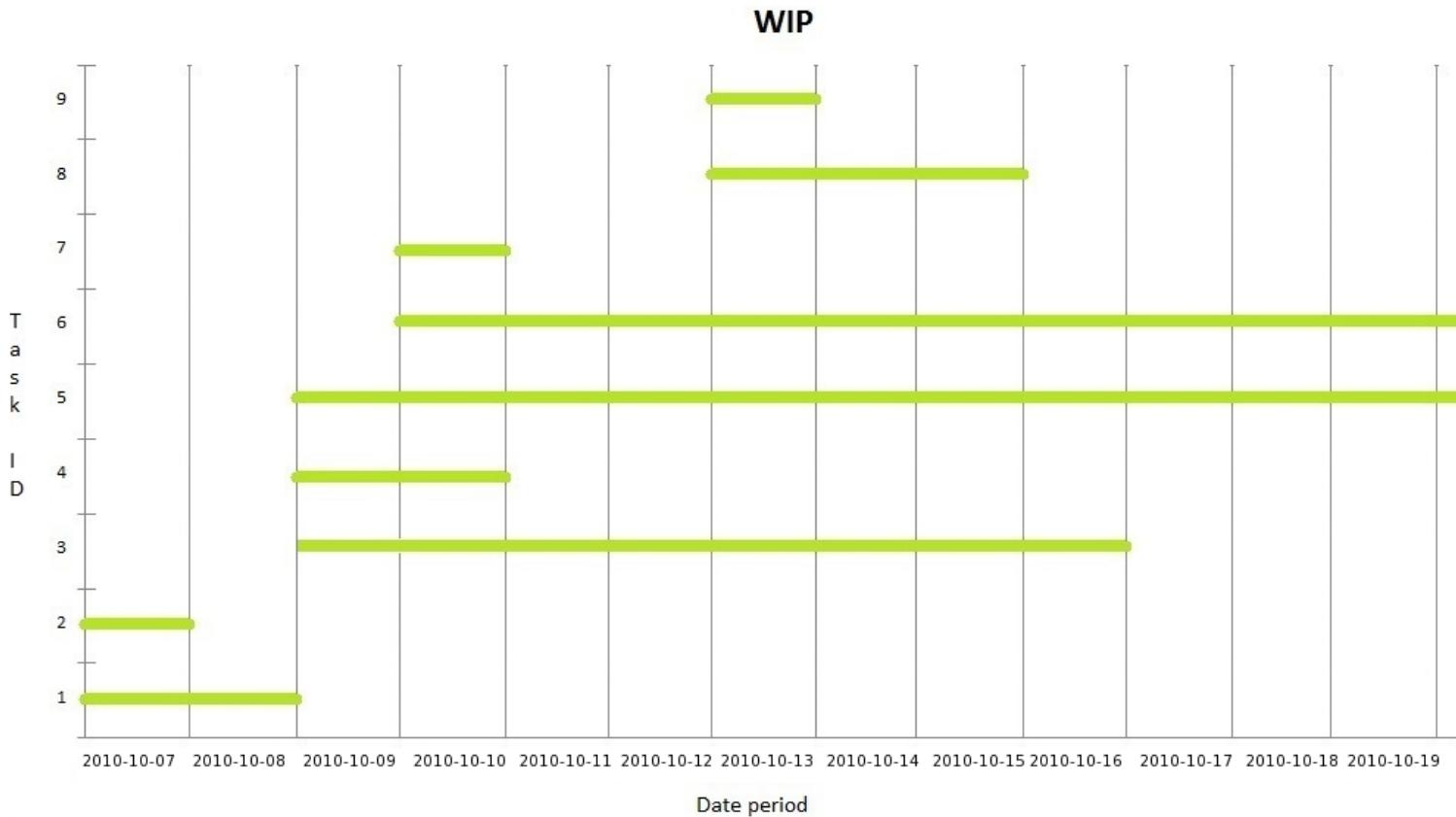


Figure 4.1: Illustrating the WIP timeline for example stated in section 4.2.4

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 labeled with task id one. The program creates the WIP-object for line 1, shown by 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. After the date is created, the program will see if the date 2008-10-09 exists and will do so for the rest of the dates.

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 9 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 17 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 5 is 1 ($0 - 1 + 2 = 1$), therefore WIP at date 2010-10-08 is 1, 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 identical. 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 4.6. After all the lines has been read and all objects has been put in the right data structure the algorithms differ in respect of what is going to be measured.

```

1 void addBug(Bug b)
2   if b.team EQUALS "TeamOne"
3     if dateExists(b.date, TeamOne) EQUALS false
4       // if date does not 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 does not 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 does not 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 does not exists, then add the bug
20      TeamFour.add(b)
21
22  /* And so on for the rest of the teams */
23
24
25

```

Listing 4.6: 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 4.7 does the actual computation. The method is called for each throughput object from the data set. The method starts off 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 4.7: 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*. For example; for task id 1 the churn is 2028 ($352 + 307 + 1369 = 2028$). Some tasks have zero churn, for example task with id 6, these tasks do not need code in order to be finished such tasks need technical support to be finished. The churn algorithm is shown in Listing 4.8

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

Listing 4.8: Pseudocode example of how throughput is measured

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

4.3.3 Lead time

The program does not need to compute 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 called *lead time* 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 4.9.

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 = t.date
4       lead_time.value = t.value
5       return
6   structure.add(t)
7 
```

Listing 4.9: 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, the output from the software program 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 group the variables *churn* and *throughput*. The result from case summaries provides the sub variables for each quarter.

Team name	Churn	Throughput	Date	Quarter	Type
Team one	25	10	2011-12-20	2011-4	Feature
Team two	3	5	2012-04-19	2012-2	bug
Team one	7	2	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 extracts the *created date* and the *date to* values from each task and checks if their quarter and year match. If they do, a boolean value is set to true, otherwise it is set to false. The output produced by the software program is used by SPSS, where the boolean value will be grouped by *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 Mean days backlog, bug

To get the statistics on the mean number of days bugs are in backlog per quarter, the software 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 mean days for bugs per quarter.

The sub variables, bugs finished, quarter and mean days backlog, bug is used as help variables. A correlation tables for these variables will not be provided in Chapter 5.

4.4 Summary

This chapter presented the algorithm and an example of how WIP is computed in this work as well as how the other variables are computed.

Chapter 5

Results

The first result from when team size was **not** taken into account showed an mean correlation value of 0.6 between *team size* and *WIP* and 0.5 between *team size* and *throughput*. Five of the ten teams also had a significant positive correlation between these variables. Based on the correlation values, it was hard to find any evidence that 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.

The result from when team size was taken into account showed nine out of ten teams have a positive correlation between *throughput* and *WIP*. The correlation tables for *throughput*, *churn*, *lead time* and *bugs* are showed in order to figure out why the correlation between these variables is positive.

Each section except Sections 5.6 and Section 5.7 are 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 analysis. Section 5.6 is presented with one correlation table and one descriptive statistic table. Section 5.7 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 result for 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 the correlation when team size is **not** taken into account. In the table one can see **team one** has a positive correlation between *WIP* and *throughput*, *throughput feature*, *bugs*, *lead time*, *churn feature* and *team size*. **Team two** has a significant negative correlation between *WIP* and *churn* and *churn bug*. **Team three** has a positive correlation between *WIP* and all *throughput* variables, *bugs* and *team size*. **Team four** has significant positive correlation between *WIP* and all variables except *team size*. **Team five** has a positive correlation between *WIP* and *throughput bug*, *lead time* and *team size*.

Table 5.1: Correlation with WIP. 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).

	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**	0.56*	0.54*	0.07	0.55	0.15	0.88**	0.63*
Bugs	0.72**	0.20	0.60*	0.74**	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**

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

Throughput feature, *throughput bug*, *churn feature* and *churn bug* are subset of respectively *throughput* and *churn*. It is natural that these sub variables have a significant positive correlation to *WIP*, when either *throughput* or *churn* 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 by Table 5.1. The relationship between these variables is explained in Section 6.7.

The descriptive statistics tables in each section are based on correlation. 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 between *WIP* and both *throughput* and *team size* are 0.6. The mean correlation between *WIP* and *lead time*, *throughput feature*, *throughput bug and bugs* are 0.5 and *bugs finished, quarter* have a mean correlation of 0.3 between *WIP*. Rest of the values has a mean value of ± 0.2 or less.

Table 5.2: Descriptive Statistic table shows correlation with WIP. Team size is **not** taken into account

	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	0.5	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

The Table 5.3 shows the correlation from when team size was taken into account. **Team two** has a significant positive correlation between *WIP* and *throughput*, *throughput bug*, *bugs finished, quarter* and *lead time*. **Team three** has a significant correlation between *WIP* and *throughput*, *throughput feature* and *bugs finished, quarter*. **Team four** has a positive correlation between *WIP* and all variables except *throughput bug*, *bugs*, *avg days in backlog*, *bugs* and *churn bug*.

Table 5.3: Correlation with WIP. Team size is taken into account

	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	0.27	0.11	0.07	0.57	0.37	0.58*	-0.22
Bugs	0.10	0.49	0.25	0.25	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

* 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 between *WIP* and *bugs, bugs, finished quarter* and *lead time*. **Team eight** has a significant correlation between *WIP* and *bugs finished, quarter* and *churn bug*. **Team nine** has a significant positive correlation between *WIP* and all *throughput* variables. **Team ten** has a significant negative correlation for *avg days in backlog, bugs*.

In Table 5.3, teams **two** and **three** have a significant correlation for two of the three *throughput* variables. **Team four** has a positive correlation for two of the three *churn* and *throughput* 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 6.7. The descriptive statistic Table 5.4 shows *throughput* has an mean correlation of 0.4 between *WIP*. The rest of the variables except *throughputs* sub variables have a mean correlation of ± 0.2 or less.

Table 5.4: Descriptive Statistic for WIP correlation. Team size is taken into account

	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	0.3	0.4	0.3	0.7	-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

5.2 Correlation result for lead time

Table 5.5 displays the first correlation table for *lead time*, which shows the correlation between *lead time* and the variables when team size is **not** taken into account. **Team one** has a positive correlation between *lead time* and all variables except *throughput bug*, *avg days in backlog, bugs* and *churn bug*. **Team two** has a positive correlation between *lead time* and *throughput* and *throughput bug*. **Team three** has a significant correlation between *lead time*, *bugs* and *churn bug*. **Team four** has a significant positive correlation between *lead time* and *WIP, throughput, throughput feature, churn* and *churn feature*. **Team five** has a significant correlation between *lead time* and *WIP*.

Table 5.5: Correlation with Lead time. 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).

	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	0.31	0.42	-0.01	0.61	-0.17	0.28	0.37
Bugs	0.77**	0.50	0.54*	0.22	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

Team seven has a significant positive correlation between *lead time* and *WIP*, *bugs* and *bugs finished, quarter*. **Team eight** has a significant correlation between *lead time* and *throughput feature*, *churn* and *churn feature*. **Team ten** has a significant correlation between *lead time* and *WIP*.

Table 5.5 displays the variances between the *throughput* variables for team **one**, **two**, **four** 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 6.7. Table 5.6 shows the mean correlation between *lead time* and both *WIP* and *throughput* are 0.5. *Throughput feature* has the mean correlation of 0.4 between *lead time* and *throughput bug*, *bugs*, *churn feature* and *team size* have the mean correlation of 0.3 between *lead time*. The rest of the values have a correlation of ± 0.2 or less between *lead time*.

Table 5.6: Descriptive Statistic for lead time Correlation. When team size is **not** taken into account

	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 5.7 shows the correlation between *lead time* and the variables when team size is taken into account. The table shows **team one** has significant positive correlation between *lead time* and *bugs*, *bugs finished, quarter*, *churn* and *churn bug*. **Team two** has a significant positive correlation between *lead time* and all values except *avg days in backlog*, *bugs*, *churn* and *churn feature*. **Team four** has a significant positive correlation between *lead time* and *WIP*, *throughput*, *throughput feature*, *churn* and *churn feature*. **Team five** has significant correlation between *lead time* and all values except *WIP*, *throughput feature* and *churn feature*.

Table 5.7: Correlation with Lead time. 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).

	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	0.22	0.84**	0.41	0.56	-0.27	0.25	0.91**
Bugs	0.83**	0.72**	0.48	0.44	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

Team six has a significant correlation between *lead time* and both *throughput* and *throughput feature*. **Team seven** has a significant correlation between *lead time* and *WIP*, *bugs* and *bugs finished, quarter*. **Team eight** has a significant correlation between *lead time* and *throughput feature, churn* and *churn feature*. **Team ten** has a significant positive correlation between *lead time* and *throughput, throughput bug, bugs* and *bugs finished, quarter*.

The *throughput* relationship for team **four, 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 6.7. The Table 5.8 displays a mean correlation of 0.5 between *lead time* and *throughput, throughput bug, bugs* and *bugs finished, quarter*. *Churn* and *throughput feature* have the mean correlation of 0.4 between *lead time*. The rest of the values have a mean correlation of ± 0.2 or less between *lead time*.

	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 result for bugs

This section contains information about the correlation tables between the variables and *bugs*. In the first correlation Table 5.9 the correlation between *lead time* and the variables, when team size is **not** taken into account is presented. In the table one can see **team one** has a significant correlation between *bugs* and with all the variables except *throughput bug, bugs finished, quarter, avg days in backlog, bugs*, and *churn bug*. **Team two** has a significant correlation between *bugs* and *throughput* and *throughput bug*. **Team three** has a significant correlation between *bugs* and *WIP*, the *throughput* variables and *lead time*. **Team four** has a significant correlation between *bugs* and *WIP, throughput bug, bugs finished, quarter, avg days in backlog, bugs* and *churn bug*. **Team five** has a significant

correlation between *bugs* and *throughput* variables and *team size*.

Table 5.9: Correlation with Bugs. 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).

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
WIP	0.72**	0.20	0.60*	0.74*	0.50	0.46	0.62	0.04	0.58*	0.18
Throughput	0.69**	0.81**	0.88**	0.51	0.97**	0.27	0.53	0.41	0.70**	0.56*
Throughput Feature	0.74**	0.01	0.82**	0.53	0.88**	0.30	0.56	0.22	0.60*	-0.14
Throughput bug	-0.17	0.83**	0.87**	0.54*	0.96**	0.69**	0.50	0.92**	0.65*	0.59*
Bugs finished, quarter	0.50	-0.18	0.12	0.87**	0.17	0.76**	0.79**	0.18	0.70**	0.05
Avg days in backlog, bugs	0.52	0.38	0.43	0.53*	0.18	0.24	0.23	0.28	0.21	0.13
Lead time	0.77**	0.50	0.54*	0.22	0.32	-0.23	0.69*	-0.13	0.44	0.04
Churn	0.62*	-0.27	0.10	0.12	-0.06	-0.12	0.11	-0.16	-0.48	0.04
Churn feature	0.77**	0.01	0.09	0.22	0.43	-0.10	0.11	-0.25	-0.62*	0.07
Churn bug	0.42	-0.19	-0.19	0.71*	-0.11	0.42	0.12	0.65*	-0.04	0
Team size	0.80**	0.26	0.27	0.06	0.71**	0.41	0.41	0.42	0.41	0.16

Team six has a significant correlation with *throughput bug* and *bugs finished, quarter*. **Team seven** has a significant correlation 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**, **four** and **eight** have variances in both the *throughput* and *churn* variables according to Table 5.9. Teams **two**, **six** 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 6.7. In Table 5.10, one can see that *throughput* and *throughput bug* have the mean correlation of 0.6 between *bugs*, *throughput feature* has the correlation of 0.5 between *bugs*, *WIP* has an mean correlation of 0.4 between *bugs*, *bugs finished, quarter, avg days backlog, bugs, lead time* and *team size* have the mean correlation of 0.3 between *bugs*. The *churn* variables have the mean values of ± 0.2 or less between *bugs*.

Table 5.10: Descriptive Statistic for bugs Correlation. Team size is **not** taken into account

	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	0.9	-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	0.7	-0
Team size	10	0.3	0.4	0.3	0.6	-0.3

The second correlation table for bugs, displayed in Table 5.11 shows correlation when team size is taken into account. In the table one can see **team one** has a significant correlation between *bugs* and *throughput bug*, *bugs finished*, *quarter*, *avg days in backlog*, *bugs* and *lead time*. **Team two** has a significant correlation between *bugs* and all the *throughput* variable and *lead time*. **Team three** has a significant correlation between *bugs* and all the *throughput* variables and all the *churn variables*. **Team five** has a significant correlation between *bugs* and all variables except *WIP*, *throughput feature*, *bugs finished*, *quarter* and *churn feature*.

Table 5.11: Correlation with Bugs - 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).

	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**	0.29	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

Team six has significant correlation between *bugs* and *throughput bug* and *bugs finished*, *quarter*. **Team seven** has a significant relationship between *bugs* and *WIP*, *bugs finished*, *quarter* and *lead time*. **Team eight** has a significant correlation between *bugs* and *throughput*, *throughput bug*, *bugs finished*, *quarter* and *churn bug*. **Team nine** has a significant correlation between *bugs* and *throughput* and *throughput bug*. **Team ten** has a significant correlation between *bugs* and *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. Teams **one**, **six** and **nine** shows variance between the *throughput variables*. The variables relationship is explained in Section 6.7. Table 5.12 displays a mean correlation of 0.8 for *throughput bug* between *bugs*, 0.6 for *throughput* between *bugs*, 0.5 for *bugs finished*, *quarter* and *lead time* between *bugs*, 0.4 for *avg days backlog*, *days* and *churn bug* between *bugs*. *Churn* has the correlation of 0.3 between *bugs*, while the rest has a mean correlation of ± 0.2 or less between *bugs*.

Table 5.12: Descriptive Statistic for bugs Correlation. Team size is taken into account

	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

5.4 Correlation result for 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 6.7.

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

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

Table 5.13: Correlation with Throughput. 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).

	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**	0.59*	0.99**	0.04	0.91**	0.44	0.96**	0.98**
Bugs	0.69**	0.81**	0.88**	0.51	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*

For teams **one, four, six and eight** are there a variance between the *churn* variables; the relationship between these variables is explained in Section 6.7. The Table 5.14 displays *throughput feature* has a mean correlation of 0.8 between *throughput*, *throughput bug* has a mean correlation of 0.7 between *throughput*, *WIP* and *bugs* have a mean correlation of 0.6 between *throughput*, *lead time* and *team size* have the correlation of 0.5 between *throughput* and *bugs finished, quarter* has an mean mean of 0.3 between *throughput*. The rest of the values have an mean correlation of ± 0.2 or less between *throughput*.

Table 5.14: Descriptive Statistic for throughput correlation. Time size is taken into account

	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

The second correlation table, Table 5.15 shows the correlation between *throughput* and the variables when team size is taken into account. In the table one can see *throughput* has a significant correlation to either *throughput feature* or *throughput bug* for each of the teams. The teams **two**, **three** 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**, **four**, **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 6.7.

Table 5.15: Correlation with throughput. 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).

	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**	0.32	0.99**	0.31	0.56	0.82**	0.95**	1**
Bugs	0.05	0.90**	0.81**	0.50	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

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

Team six has positive correlation between *throughput* and *lead time*. **Team eight** has a correlation with *bugs*, *bugs finished*, *quarter*, *churn* and *churn bug*. **Team nine** has a significant correlation between *throughput* and *WIP* and *bugs*. **Team ten** has a significant correlation between *throughput* and *bugs*, *bugs finished*, *quarter* and *lead time*. The *churn* variables for teams **four**, **five** and **eight** have a variance, according to Table 5.15. The *churn* relationship is explained in Section 6.7.

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

Table 5.16: Descriptive Statistic for throughput correlation. Time size is taken into account

	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

5.5 Correlation result for 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 6.7.

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 between *churn* and *bugs*, *bugs finished*, *quarter* and *lead time*. **Team two** has a significant correlation between *churn* and *WIP*. **Team four** has a significant correlation between *churn* and all variables except *bugs*, *bugs finished*, *quarter*, *avg days in backlog*, *bugs*, *team size* and *throughput bugs*, but not *throughput*. The *throughput* relationship is explained in Section 6.7. Team five has a negative correlation between *churn* and *team size*.

Table 5.17: Correlation with churn. 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).

	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	0.27	-0.03	-0.03	0.54	-0.17	-0.20	0.07
Bugs	0.62*	-0.27	0.10	0.12	-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

Team six has significant correlation between *churn* and *avg days in backlog*, *bugs*. **Team eight** has a significant correlation between *churn* and *throughput*, *throughput feature* and *lead time*, but not *throughput bug*. The *throughput* relationship for **team eight** is explained in Section 6.7. The Table 5.18 shows that there do not exists variables with a mean correlation of ± 0.2 between *churn* without the *churn* sub variables

Table 5.18: Descriptive Statistic for churn correlation. Team size is **not** taken into account

	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	-0.1	-0.1	0.4	0.5	-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

The second correlation table for *churn*, Table 5.19 shows the *churn* correlation table when team size is taken into account. The table also 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 6.7.

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

Table 5.19: Correlation with churn. 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).

	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	0.22	0.83**	0.28	0.08	0.34	-0.10	0.07
Bugs	0.47	0.29	0.67**	0.27	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**

Team six has a significant positive correlation between *churn* and *avg days in backlog, bugs*. **Team eight** has a significant positive correlation between *churn* and *throughput, bugs finished, quarter* and *lead time*. **Team ten** has a significant positive correlation between *churn* and *avg days in backlog, bugs*. Teams **two, four, five** and **eight** have a variance in their *throughput* relationship, according to Table 5.19. The relationship between these variables is explained in Section 6.7. The Table 5.20 displays a mean correlation of 0.6 for both *churn* sub variables between *churn*, 0.5 for *bugs finished, quarter* between *churn*, 0.4 for *lead time* between *churn* and 0.3 for *throughput, throughput bug* and *bugs* between *churn*. The rest of the values have a correlation of ± 0.2 or less between *churn*.

Table 5.20: Descriptive Statistic for churn correlation. Team size taken into account

	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	0.8	-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

5.6 Correlation result for team size

The team size correlation Table 5.21 displays that **team one** has a significant correlation between *team size* and *WIP, throughput, throughput feature, bugs, lead time* and *churn feature*. **Team two** has a correlation between *team size* and *avg days in backlog, bugs*. **Team three** has a significant correlation between *team size* and *WIP* and *churn bug*. **Team five** has a significant correlation between *team size* and *WIP, throughput, throughput bug, bugs, churn* and *churn bug*.

Table 5.21: Correlation with Team size

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

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

	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	0.17	0.67**	0	0.71*	0.40	0.48	0.64*
Bugs	0.80**	0.26	0.27	0.06	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

Team six has significant correlation between *team size* and *WIP, throughput, throughput feature* and *churn bug*. **Team seven** has a significant correlation between *team size* and *throughput bug* and *bugs finished, quarter*. **Team eight** has significant correlation between *team size* and *WIP, throughput* and *throughput feature*. **Team ten** has a significant positive correlation between *team size* and *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, eight** 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 6.7. The Table 5.22 displays a mean correlation of 0.6 for *WIP* between *team size*, 0.5 for *throughput* between *team size*, 0.4 between *team size* and the *throughput* sub variables and *bugs*. *Lead time* has the mean correlation of 0.3 between *team size*. Rest of the variables has a correlation of ± 0.2 or less between *team size*.

Table 5.22: Descriptive Statistic for team size correlation.

	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

5.7 Correlation result for all teams combined

The Tables 5.23 and 5.24 shows the correlation 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*.

Table 5.23: Correlation with all teams combined. 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).

	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

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

significant correlation 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 feature, bugs* and *churn bug*. *Avg days in backlog, bugs* has a significant correlation 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 correlation with *WIP, bugs finished, quarter, avg days in backlog, bugs, churn and churn feature*. *Team size* has a significant correlation to *WIP, throughput, throughput feature, throughput bug, bugs, avg days in backlog, bugs, lead time and churn*.

Table 5.24 shows the correlation when team size is taken into account, one can see *WIP* has a significant correlation to all variables except *throughput bug, avg days in backlog, bugs, churn feature* and *churn bug*. *Throughput* has significant correlation to all variables except *churn* and *churn feature*. *Throughput feature* has significant correlation to all variables except *bugs, churn, and churn feature*. *Throughput bug* has significant value to *throughput, throughput feature, bugs* and *bugs finished, quarter*.

Table 5.24: Correlation with all teams combined. 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).

	WIP	TP	TP ft	TP bug	Bugs	Bugs, qrt	Avg backlog b	Lead time	Churn	Churn ft	Churn bug
WIP	1	0.55**	0.51**	0.13	0.29**	0.40**	-0.14	0.36**	0.17*	0.15	0
Throughput	0.55**	1	0.95**	0.24**	0.25**	0.56**	-	-0.20*	0.38**	-0.01	-0.11
Throughput Feature	0.51**	0.95**	1	0.20*	0.09	0.47**	-	-0.27**	0.34**	-0.03	-0.10
Throughput bug	0.13	0.24**	0.20*	1	0.38**	0.19*	0.06	0.16	0.03	0	-0.04
Bugs	0.29**	0.25**	0.09	0.38**	1	0.57**	0.30**	0.32**	0.21*	0.16	0.28**
Bugs finished, quarter	0.40**	0.56**	0.47**	0.19*	0.57**	1	-0.13	0.39**	0.18*	0.07	0.08
Avg days in backlog, bugs	-0.14	-0.20*	-0.27**	0.06	0.30**	-0.13	1	0.03	0.15	0.08	0.42**
Lead time	0.36**	0.38**	0.34**	0.16	0.32**	0.39**	0.03	1	0.38**	0.26**	0.13
Churn	0.17*	-0.01	-0.03	0.03	0.21*	0.18*	0.15	0.38**	1	0.87**	0.49**
Churn feature	0.15	-0.11	-0.10	0	0.16	0.07	0.08	0.26**	0.87**	1	0.43**
Churn bug	0	-0.19*	-0.23**	-0.04	0.28**	0.08	0.42**	0.13	0.49**	0.43**	1

Bugs has a significant correlation to all variables except *throughput feature* and *churn feature*. *Bugs finished, quarter* has a significant correlation to all variables except *avg days in backlog, bugs, churn feature* and *churn bug*. *Avg days in backlog, bugs* has a significant correlation to *throughput, throughput feature, bugs* and *churn bug*. *Lead time* has a significant correlation to all variables except *throughput bug, avg days in backlog, bugs* and *churn bug*. *Churn* has a significant correlation to *WIP, bugs, bugs finished, quarter, lead time* and both the *churn* sub variables. *Churn feature* has a significant correlation to *lead time, churn* and *churn bug*. *Churn bug* has significant correlation to all variables except *WIP, throughput bug, bugs finished, quarter* and *lead time*.

5.8 WIP-limit per team

To try to explain the positive correlation between *WIP* and *throughput* the mean WIP-limit for each of the teams were measured. *Team one* has an mean WIP-limit of 0.73. *Team two* has an mean WIP-limit of 2.31. *Team three* has an mean WIP-limit of 1.78. *Team four* has an mean WIP-limit of 3.21. *Team five* has an mean WIP-limit of 1.93. *Team six* has an mean WIP-limit of 3.02. *Team seven* has an mean WIP-limit of 2.03. *Team eight* has an mean WIP-limit of 0.71. *Team nine* has an mean WIP-limit of 2.19 and *team ten* has an mean WIP-limit of 1.08. This gives an mean WIP-limit of 1.9.

Year - Quarter	WIP-limit
2010-3	0.61
2010-4	0.23
2011-1	0.21
2011-2	0.47
2011-3	0.89
2011-4	0.38
2012-1	0.63
2012-2	0.89
2012-3	1.12
2012-4	1.2
2013-1	1.37
2013-2	1.81
2013-3	0.32
2013-4	0.22
Mean	0.73

Year - Quarter	WIP-limit
2010-3	1.44
2010-4	1.43
2011-1	2.09
2011-2	2.48
2011-3	2.18
2011-4	2.15
2012-1	1.34
2012-2	3.62
2012-3	3.03
2012-4	2.4
2013-1	1.97
2013-2	4.0
2013-3	2.68
2013-4	1.66
Mean	2.31

Year - Quarter	WIP-limit
2010-3	1.55
2010-4	1.55
2011-1	2.19
2011-2	2.35
2011-3	2.3
2011-4	2.33
2012-1	2.26
2012-2	2.18
2012-3	2.16
2012-4	2.28
2013-1	1.24
2013-2	0.99
2013-3	0.88
2013-4	0.7
Mean	1.78

Year - Quarter	WIP-limit
2010-3	0.89
2010-4	0.56
2011-1	2.61
2011-2	3.45
2011-3	3.51
2011-4	4.11
2012-1	4.0
2012-2	5.84
2012-3	4.67
2012-4	4.12
2013-1	2.78
2013-2	3.2
2013-3	3.09
2013-4	2.11
Mean	3.21

Year - Quarter	WIP-limit
2010-3	1.68
2010-4	1.44
2011-1	0.56
2011-2	0.85
2011-3	1.28
2011-4	1.21
2012-1	1.78
2012-2	2.7
2012-3	0.82
2012-4	1.11
2013-1	4.03
2013-2	7.97
2013-3	0.78
2013-4	0.87
Mean	1.93

(a) Team size - (b) Team size - (c) Team size - (d) Team size - (e) Team
team one team two team three team four size - five

Year - Quarter	WIP-limit
2010-3	1.9
2010-4	1.72
2011-1	1.63
2011-2	1.73
2011-3	3.9
2011-4	4.58
2012-1	3.91
2012-2	2.92
2012-3	2.54
2012-4	2.92
2013-1	3.62
2013-2	4.86
2013-3	3.4
2013-4	2.67
Mean	3.02

Year - Quarter	WIP-limit
2010-3	1.41
2010-4	2.88
2011-1	1.85
2011-2	2.13
2011-3	2.15
2011-4	1.94
2012-1	1.44
2012-2	3.31
2012-3	2.65
2012-4	0.56
Mean	2.03

Year - Quarter	WIP-limit
2010-4	0.19
2011-1	0.46
2011-2	0.74
2011-3	0.86
2011-4	0.88
2012-1	0.97
2012-2	2.14
2012-3	0.36
2012-4	0.51
2013-1	0.38
2013-2	0.94
2013-3	0.36
2013-4	0.5
Mean	0.71

(f) Team size - team six (g) Team size - team seven (h) Team size - team eight

Year - Quarter	WIP-limit
2010-4	0.9
2011-1	1.48
2011-2	1.61
2011-3	1.82
2011-4	1.78
2012-1	1.62
2012-2	4.43
2012-3	3.26
2012-4	1.82
2013-1	2.68
2013-2	2.95
2013-3	1.99
2013-4	2.14
Mean	2.19

Year - Quarter	WIP-limit
2010-3	0.9
2010-4	1.19
2011-1	0.68
2011-2	0.66
2011-3	0.22
2011-4	0.98
2012-1	1.23
2012-2	2.03
2012-3	0.7
2012-4	1.84
2013-1	0.96
2013-2	0.98
2013-3	1.25
2013-4	1.54
Mean	1.08

(i) Team size - team nine (j) Team size - team ten

Figure 5.1: Caption of team size for teams in SI

Chapter 6

Discussion

The first sections contain discussion based on the research questions, the different results from this study and what other literature has stated. The last Section 6.7, 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.

6.1 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 days when WIP was not limit. 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 process without WIP-limit.

The Tables 5.14 and 5.16 from this result show no evidence towards the fact that lowering WIP-limit will increase *throughput*. *Throughput* has the mean correlation of 0.6 when team size is **not** taken into account and 0.4 otherwise. One can argue that the throughput correlation 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 mean correlation 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, 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 a low correlation, team one and seven has a low-medium correlation and team two, three, four and nine has a medium-high significant correlation 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 at least a medium positive correlation relationship between *WIP* and *throughput*.

The combined Table 5.23 shows a significant correlation of 0.41 when team size is **not** taking into account and Table 5.24 shows an overall significant correlation of 0.55 when team size is taken into account. The values presented in this section point towards the fact that when *WIP* increases, so does *throughput*. The *WIP-limit* for SI could be too low which explains why *WIP* and *throughput* has a positive correlation relationship.

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 of 0.8, *bugs*, *throughput feature* has an mean correlation of 0.6, *lead time* has the mean correlation of 0.5, *bugs finished quarter*, *bugs* and *WIP* has the mean correlation of 0.4, *churn* has a mean correlation of 0.3 and the rest of the variables has a mean correlation of ± 0.2 . The combine Table 5.24 shows *throughput* has significant correlation to all variables except *churn* 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 of 0.8, *throughput bug* has a mean correlation of 0.7, *bugs* and *WIP* has a correlation of 0.6 and both *lead time* and *team size* has an mean correlation of 0.5, *bugs finished*, *quarter* has the mean correlation of 0.3 and the rest of the variables has a mean correlation of ± 0.2 . The combined Table 5.23 shows *throughput* has a significant correlation relationship to *WIP*, *throughput feature*, *throughput bug*, *bugs*, *bugs finished*, *quarter* and *team size*.

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

extent.

6.2 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 a mean correlation relationship of 0.5 between *WIP* and *lead time*, as shown in Table 5.2. The correlation Table 5.1 shows teams one, four, five, seven and ten have a significant positive correlation relationship, both team two and three has a medium correlation relationship and team six, eight and nine has a low positive correlation relationship.

The result from when team size was taken into account shows an mean correlation relationship of 0.2, which is a weaker correlation relationship. Three of the ten teams have a significant positive correlation, while the rest of teams' correlation vary from 0.32 to -0.18, 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, as shown by Table 5.2. The standard deviation when team size is taken into account is 0.4 and the median is 0, as shown in Table 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 of 0.27, when team size is **not** taken into account. The correlation Table 5.24 shows a significant correlation of 0.36 when team size is taken into account. The value presented in this section shows when time size is taken into account, the mean correlation is 0.2, but the combine correlation is a significant one of 0.36. This shows a low to medium positive correlation relationship between *WIP* and *lead time*. When team size is **not** taken into account; there is a low significant correlation for all the teams combined and medium-high positive correlation when each team is measured independently. Based on these results, decreasing the WIP-limit will decrease *lead time*.

The *lead time*'s descriptive statistic Table 5.8 shows *throughput*, *throughput bug*, *bugs* and *bugs finished*, *quarter* have the mean correlation 0.5, while *churn* and *throughput feature* has the correlation of 0.4 and the rest has a mean correlation of ± 0.2 or less, when team size is taken into account. When team size is **not** taken into account, *WIP* and *throughput* has an mean correlation of 0.5 and *throughput feature* has the value 0.4, *throughput bug*,

bugs, churn feature and *team size* has the mean correlation of 0.3 and the rest variables has a correlation of ± 0.2 or less. The combine 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 all variables except *throughput bug, avg days in backlog, bugs* and *churn bug* 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 and the mean correlation between *lead time* and *throughput* is odd, these values should be further investigated.

6.3 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).

The result from this work shows when *team size* is **not** taken into account, the mean correlation between *WIP* and *bugs* is 0.5 and four of the teams have a significant positive correlation between *bugs* and *WIP*. All of the ten teams also have a positive correlation, as shown in Table 5.1. The two variable *bug finished, quarter* and *avg days backlog bugs* is used as a side measures. The two variables are used to see how long bugs are in backlog and the amount of bugs fixed vs. the amount of bugs recorded in system per quarter. The mean correlation 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 mean correlation relationship. The mean correlation of 0.1 for *avg days backlog bugs*, the combine correlation of 0.17 from Table 5.23 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 **not** taken into account. The *bugs finished, quarter* with the mean of 0.3, also has a significant positive correlation of 0.17. These values show a weak correlation relationship between *bugs finished, quarter* and *WIP*.

When *team size* is taken into account, the mean correlation 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 correlation. The *bug finished, quarter* and *avg days backlog, bugs* has the mean correlation 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 combine Table 5.24 shows *bugs finished, quarter* with a significant correlation of 0.40 and *avg days in backlog, bugs* with a negative correlation of -0.14. These values show a weak correlation relationship between *bugs* and *WIP* and a medium significant correlation

relationship between *WIP* and *bugs finished, quarter*.

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 0.2. The median numbers show significant impact of team size between the relationship of *WIP* and *bug*. The standard deviation values for the two cases is equal, as shown in 5.2 and 5.4

When team size is **not** taken into account, the overall correlation is significant with a value of 0.41, shown in Table 5.23. The correlation Table 5.24 shows the correlation from when time size is taken into account. The table shows an overall significant correlation of 0.29. The values from this section shows there is evidence that WIP-limit helps decrease bugs.

The descriptive statistic table for bugs in Section 5.3 shows *bugs* variable has a mean correlation of 0.6 to *throughput* and *throughput bug*, *throughput feature* has a mean correlation of 0.5, *WIP* has a mean correlation of 0.4 and *bugs finished, quarter avg days backlog, bugs, lead time* and *team size* has a mean correlation of 0.3 and rest of the variables have a mean correlation of ± 0.2 or less, as shown in Table 5.10. Table 5.23 shows *bugs* has an overall significant correlation to all variables except *lead time* and all the *churn* variables. All of this when team size is **not** taken into account. When team size is taken into account, *bugs* has a mean correlation of 0.8 for *throughput bug*, 0.6 for *throughput again, bugs finished quarter* and *lead time* has the mean correlation 0.5, *avg days in backlog, bugs* has the mean correlation of 0.4, *churn* 0.3 and the Table 5.24 shows that *bugs* has a significant correlation to all variables except *throughput feature* and *churn feature*. When team size is taken into account, the correlation relationship between the variables and *bugs* increases for almost each variable versus when team size was **not** taken into account.

6.4 WIP and Churn

Churn is used as surrogates for effort in this work. Based on the descriptive statistics tables, independently of team size; there is no relationship between *WIP* and *churn* or the sub variables of churn according to Tables 5.2 and 5.4. The results show a mean correlation of -0.1, 0 and 0.1 for the *churn* variables. 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.

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 -0.2 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 of 0.06 when team size is taken into account. The Table 5.24 shows a significant correlation of 0.17. These values show that *WIP-limit* has little impact on *churn*.

Section 5.5 shows *churn* correlation tables. The Table 5.18 shows when team size is **not** taken into account, *churn* has only low correlation relationship between any of the other variables, except the *churn's* sub variables. When team size is taken into account, *bugs finished*, *quarter* has a mean correlation relationship of 0.5, *lead time* has a correlation of 0.4 and *throughput*, *throughput bug* and *bugs* has a correlation of 0.3, as shown by Table 5.20. The combine Table 5.23 shows *churn* has a significant positive correlation 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 *WIP*, *bugs*, *bugs finished*, *quarter*, *lead time* and both the *churn* sub variables, as shown by Table 5.24.

6.5 WIP-limit

The previous research states that *WIP-limit* should be low, but not if one should start by limit one tasks per developer, or two or so on. The *WIP-limit* for SI is 1.9 per developer. In this case the *WIP-limit* could be too low and that's the reason *throughput* and *WIP* has a positive correlation relationship. Because if the *WIP-limit* is to low, the bottlenecks will not occur and the teams are able to produce more, but they are not allowed by the *WIP-limit*. One should try to increase the *WIP-limit* for SI and see if the *throughput* continues to increase. If the *WIP-limit* continues to increase then the *WIP-limits* are probably too low.

The mean correlation values between *WIP* and both *lead time* and *bugs* are 0.5 when team size is **not** taken into account and 0.2 when team size is taken into account. The values when team size is taken into account are low, which also can point towards the fact that *WIP-limit* is too low for SI.

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 mean correlation relationship of 0.6 with *throughput* and 0.5 with *bugs* and *lead time*. These three correlation are decreased by 0.2 and 0.3 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*. If team size were not taken into account the result from this work would have been biased.

6.7 Discussion of the sub variables

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

6.7.1 Throughput

Team one have a significant correlation for both *throughput* and *throughput feature*, but not for *throughput bug*, as showed in the WIP correlation Table 5.1. *Throughput* and *throughput feature* have correlation 0.74 and 0.73, while *throughput bug* has the correlation of 0.02. The possible cause *throughput bug* does not has a significant correlation with *WIP*, while *throughput* does, might be because *throughput bug* consist of 37% (108/290) of the *throughput* dates, as shown in the total rows in Tables A.1b and A.2b. 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 of 0.96 for *throughput feature* and 0.03 for *throughput bug*.

Team two's throughput feature differ from *throughput* based on the correlation 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 correlation graphs in Figure 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*.

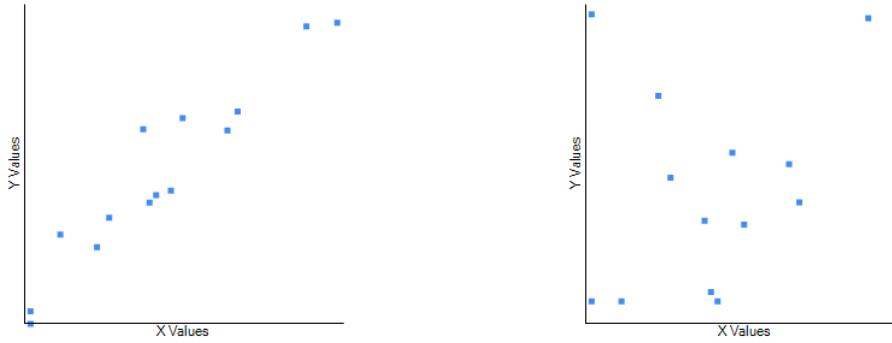


Figure 6.1: Correlation graphs between throughput (X-axis) and the throughput sub variables (Y-axis) for team one.

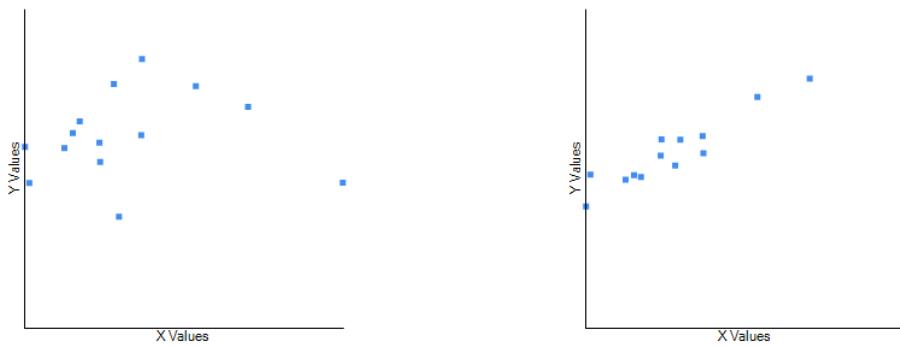


Figure 6.2: Correlation graphs between throughput (X-axis) and the sub variables (Y-axis) for team two.

Team three has the correlation 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, 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 of 0.98, while *throughput feature* has a correlation of 0.90.

Team four has the correlation 0.86 for *throughput*, 0.85 for *throughput feature* and 0.27 for *throughput bug*, showed in WIP correlation Table 5.3. These values indicate that *throughput feature* represents the majority of *throughput*. The dates in the descriptive

statistic Tables A.16b, A.17a and A.17b empower this assumption. The dates show that *throughput* consists of 674 dates of which *throughput feature* represents 644 and *throughput bug* represents 30. The mean values on the other hand are 6.2 for *throughput*, 6.2 for *throughput feature* and 5.6 for *throughput bug*. The mean values indicate that *throughput feature* represents the most of *throughput*, but *throughput bug* contributes. The correlation graphs in Figure 6.3 and the correlation of 1 for *throughput feature* and 0.32 for *throughput bug* showed by *throughput* correlation Table 5.15 show otherwise. The correlation table and the graphs show *throughput feature* represents most of the *throughput* variable.

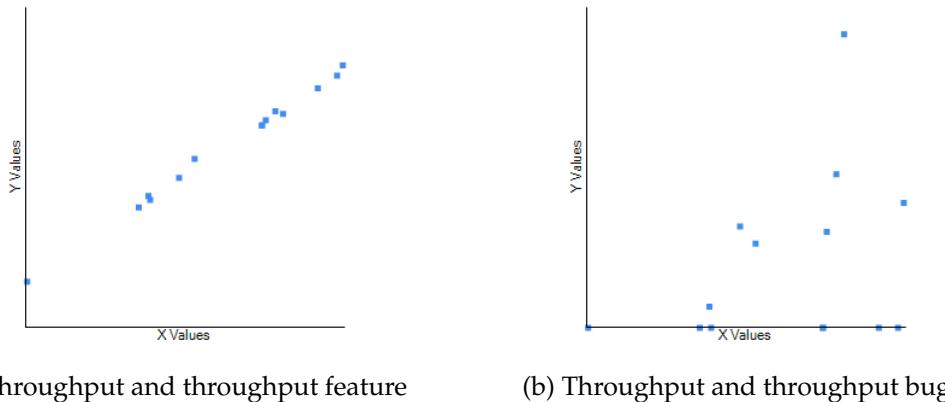


Figure 6.3: Correlation graphs between throughput (X-axis) and the sub variables (Y-axis) for team four.

Team five has a significant correlation for *throughput bug* with a correlation of 0.54, *throughput* with a correlation of 0.52, but not *throughput feature*. *Throughput feature* has a correlation 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* have the correlation 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 of 0.99 and *throughput bugs* value of 0.04.

Team seven has a significant correlation for *throughput*, *throughput feature*, but not *throughput bug*, as showed in WIP correlation Table 5.1. The table showed a correlation of 0.67 for *throughput*, 0.63 for *throughput feature* and 0.55 for *throughput bug*. The difference between the correlation 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 correlation of 2.8 and *throughput bug* has a mean correlation 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 correlation of .91 for both *throughput feature* and *bug*.

Team eight has a significant correlation for *throughput bug*, but not *throughput*, as showed in bugs correlation Table 5.9. The descriptive statistic Tables A.36b, A.37a and A.37b show *throughput bug* consist of 99 dates and has a total mean of 1.5, while *throughput feature* consist of 92 dates and a total mean of 3.2 and *throughput* has mean of 2.3 and contains of 191 dates. 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*. The correlation graphs in Figure 6.4 shows otherwise. The Figure 6.4a

shows dots in an upward direction, hence positive correlation, while in Figure 6.4b almost all the dots are all gathered around the low values of Y. The Figures in 6.4 reflects the correlation of 0.94 for *throughput feature* and 0.44 for *throughput bug*. This shows that total dates and total mean can be used as an indicator of the relationship between variables, but it cannot prove it.

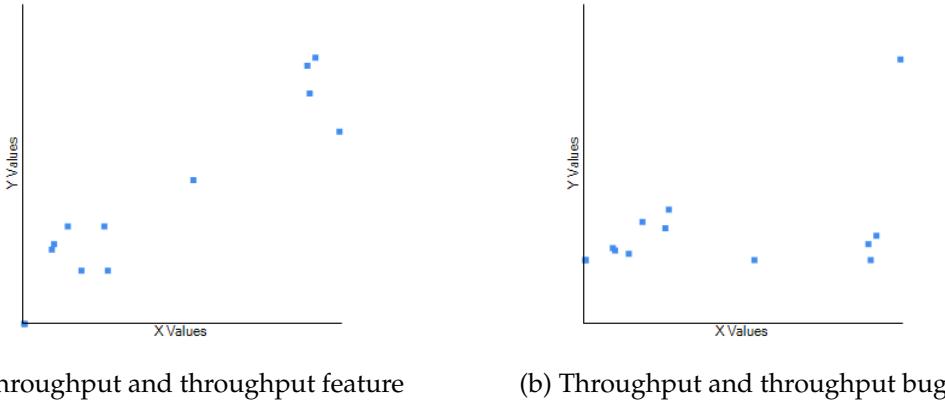


Figure 6.4: Correlation graphs between throughput (X-axis) and the sub variables (Y-axis) for team eight.

Team nine has a significant positive correlation for *throughput* and *throughput bug*. The reason *throughput feature* does not have 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 correlation 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 of 0.95, while *throughput feature* has a correlation 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* are 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 Figure 6.5 disproves that assumption. The Figure 6.5a shows a vague significant positive correlation, while Figure 6.5b 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*.

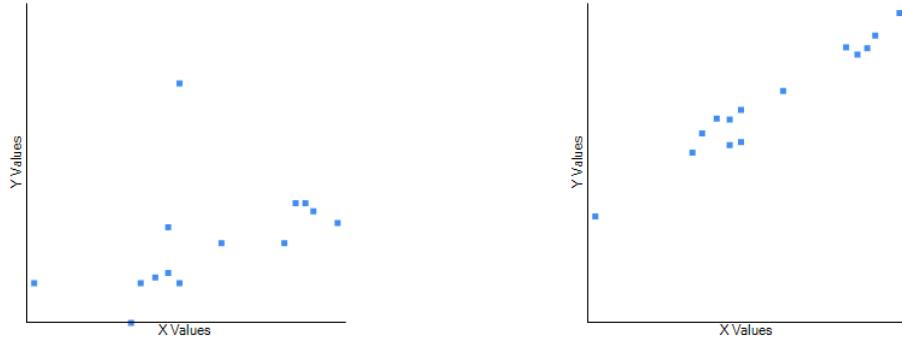


Figure 6.5: Correlation graphs between throughput (X-axis) and the sub variables (Y-axis) for team ten.

6.7.2 Churn

In WIP correlation Table 5.1 have the three churn variables for **team one** scattered correlation. *Churn* has a correlation of 0.47, *churn feature* has a correlation 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* have a significant negative correlation for **team two**. *Churn feature* on the other hand has a correlation of -0.25, showed in WIP correlation Table 5.1. According to the correlation, 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 correlation 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 of 0.7 for *churn bug* and 0.58 for *churn feature*.

The three *churn* variables for **team three** have the correlation 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 between *churn feature* and *churn* is 0.90.

Churn for **team four** has the correlation of 0.97, *churn feature* has the correlation of 0.96 and *churn bug* has the correlation 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 of 0.99 and *churn bug* has the correlation of 0.13.

Churn bug for **team five** has a significant positive correlation of .94, while *churn feature* has the correlation 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 is 29.4.

Team six has a significant correlation of 0.77 for *churn bug*, while both *churn* and *churn feature* has the correlation 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 of 0.91 while *churn bug* has the correlation 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 6.6 disproves that.

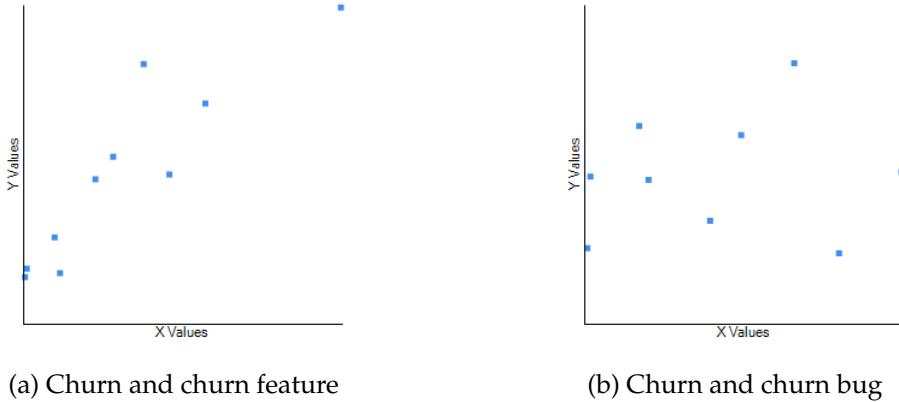


Figure 6.6: Correlation graphs between the churn (X-axis) and the sub variables (Y-axis) for team seven.

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 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 6.7 and correlation Table 5.17 disproves 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 6.7a shows a clear positive correlation, while Figure 6.7b shows no pattern and shows a correlation close to 0.

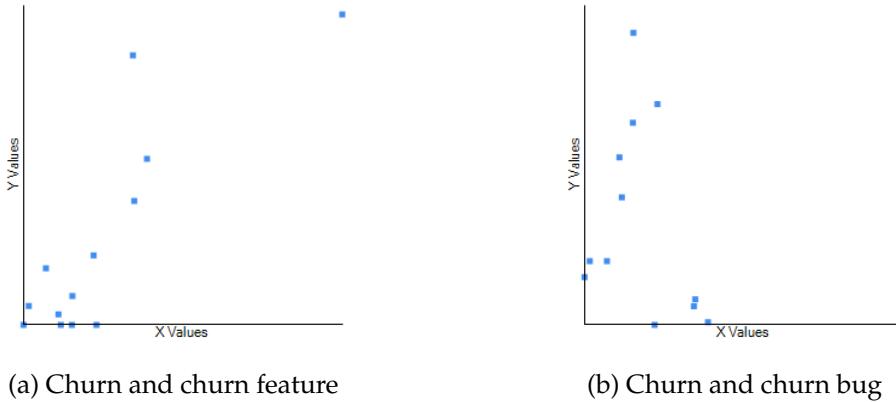
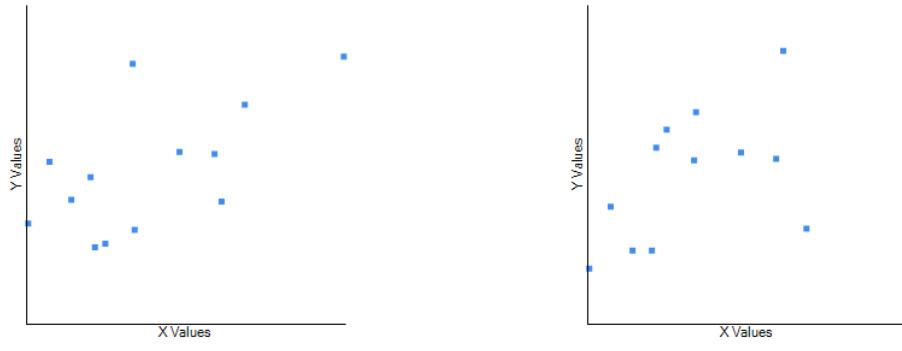


Figure 6.7: Correlation graphs between the churn (X-axis) and the sub variables (Y-axis) for team eight.

Team nine has a significant correlation of -0.62 to *churn feature*, while *churn* has the correlation of -0.48 and *churn bug* has the value -0.04, as showed in bugs correlation Table 5.9. Based on the correlation, 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 6.8, one can see Figure 6.8a show a positive correlation. The Figure 6.8b represents a positive correlation, but not as high as Figure 6.8a. The *churn* correlation states the same, Table 5.17 shows *churn feature* correlation is 0.60 and *churn bug* correlation is 0.39. This proves that *churn feature* represents most of *churn*.



(a) Churn and churn feature

(b) Churn and churn bug

Figure 6.8: Correlation graphs between the churn (X-axis) and the sub variables (Y-axis) for team nine.

Team ten has a significant correlation of 0.94 for *churn bug* and *churn feature* has the correlation 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*.

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 result from Chapter 5, 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 and possible gave bias results.

If WIP-limit matters in software development some of its benefits should be to reduce bugs, increase throughput, decrease lead time without compromising. Based on the results from this work, *WIP* has a mean correlation of 0.4 with *throughput* on team level and a significant positive correlation of 0.55 when all teams are combined. Previous research has stated to lower *WIP* to decrease throughput, which this case study disapproves. The possible reason *WIP* and *throughput* have a positive correlation, could be because their WIP-limit is too low. There is also stated that WIP-limit decrease *lead time*, the mean correlation between these two variables is 0.2 and the overall correlation between these two is a significant correlation of 0.36. This shows evidence towards the fact that WIP-limit decrease *lead time* in a weak manner. There is also stated that WIP-limit decreases number of *bugs*. The mean correlation between *bugs* and *WIP* is 0.2 and the overall correlation is a significant value of 0.29, which shows that WIP-limit does decrease *bugs* in a weak manner. According to the combine Table 5.24, *WIP* had seven significant positive correlation. Based on these values *throughput*, *bugs* and *lead time* decreases when *WIP* does. It is positive that both *bugs* and *lead time* decreases, but *throughput* should increase. WIP-limits matter, but the result of this work shows that one need to comprise. The result show also that *throughput* positive correlation is

a moderate, while the two others is a weak correlation relationship. The conclusion of this work is that *WIP*-limit matters and one needs to take *lead time*, *throughput* and *bugs* into account when one would like to find the optimal *WIP*-limit and if one would like to optimize they *WIP*-limits.

7.1 Future work

The conclusion from this work is made on one case study. It is recommend doing the same calculation as in this work with another data set and comparing the outcome. It is also suggested a different approach as looking more deeply into the relationship between *WIP* and *team size*. 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.

It is also suggested to look the values up against release dates. There is also done another research on the data from SI, I would suggest comparing the result from this work against the other research. I will also suggest trying to higher the *WIP*-limit to see if their current *WIP*-limit is too low. I will also suggest to check the cycle time for SI against the *lead time* and *WIP* correlation.

Appendices

Appendix A

Descriptive statistics (DS) for the ten teams

The following tables show the descriptive statistics for the ten teams before team size was taken into account.

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

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

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

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

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.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

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

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

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

Quarter	N	Mean	Median	Std.Dev	Max	Min	Quarter	Finished	Not finished	Total	Finished	Not finished
2010-3	20	2.6	2	3.5	17	1	2010-3	30	23	53	56.6	43.4
2010-4	40	2.5	2	1.7	9	1	2010-4	65	34	99	65.7	34.3
2011-1	47	2.4	2	1.8	8	1	2011-1	101	13	114	88.6	11.4
2011-2	40	3.8	3	2.5	13	1	2011-2	142	8	150	94.7	5.3
2011-3	43	2.6	2	2.4	13	1	2011-3	87	24	111	78.4	21.6
2011-4	47	2.5	2	1.6	8	1	2011-4	90	29	119	75.6	24.4
2012-1	35	3.3	3	3	16	1	2012-1	94	23	117	80.3	19.7
2012-2	34	2.3	2	1.5	7	1	2012-2	70	9	79	88.6	11.4
2012-3	43	3.6	2	2.6	10	1	2012-3	146	7	153	95.4	4.6
2012-4	33	3.9	3	3.1	14	1	2012-4	101	27	128	78.9	21.1
2013-1	38	2.2	2	1.2	6	1	2013-1	78	5	83	94.0	6.0
2013-2	32	1.9	1.5	1.2	5	1	2013-2	58	3	61	95.1	4.9
2013-3	35	1.8	1	1.1	5	1	2013-3	62	2	64	96.9	3.1
2013-4	37	1.9	1	1.3	7	1	2013-4	69	0	69	100	0
Total	536	2.7	2	2.2	17	1	Mean	66.4	12.3	78.8	74.4	25.6

(a) DS - Bugs

(b) DS - Bugs per quarter

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

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

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

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

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

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.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

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

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

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

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.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

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

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

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

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.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

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

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

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

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.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

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

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

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

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
2010-4	47		1	48	97.9
2011-1	119		2	121	98.3
2011-2	45		8	53	84.9
2011-3	35		6	41	85.4
2011-4	45		7	52	86.5
2012-1	46		2	48	95.8
2012-2	36		12	48	75
2012-3	67		0	67	100
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.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

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

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

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
2013-1	15	5.5	4	5.7	17	0
2013-2	10	31.2	6.5	48.4	149	0
2013-3	15	23.3	7	40.2	145	0
2013-4	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

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.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

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

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

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

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.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

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

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

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

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

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 (IJCSI)* 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.