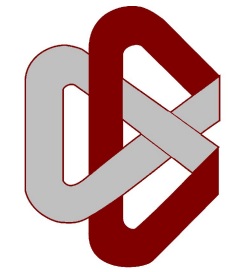

Centro de Investigación en Matemáticas, A.C.

CIMAT

Master Thesis

BINARY PRIORITY BACKLOG

"Improving Scrum prioritization using the Binary Priority Backlog method"

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Abstract

Prioritization and estimation are crucial activities for developing a software project. In this thesis a new method is proposed: Binary Priority Backlog (BPB).

Binary Priority Backlog (BPB) combines the flexibility of Scrum's prioritization (value and risk) with the precision of Hierarchical Analytic Hierarchy Process and the speed of Binary Priority List (BPL). To form a fast, flexible and unambiguous prioritized list of tasks.

The focus is on the following research questions: 1) How can we better prioritize and estimate software projects? 2) How can we define business value more precisely using Scrum and at the same time keep the flexibility of the metric to sort different products? 3) How can we help humans to make better time estimates using Scrum? 4) Using Scrum, is it possible to define the concepts of business value and improve time estimates? 5) Is it possible to use BPL to speed up and better serve in Scrum?

The Binary Priority Backlog (BPB) method is validated in a retrospective study with a real-world software development company and professional developers.

This thesis demonstrates after the experimentation that Binary Priority Backlog (BPB) can be successfully used to prioritize requirements in base to a defined business value and is suitable for a large number of requirements.

Keywords: Binary Priority List, BPL, Binary Search Algorithm, AHP, Requirements Prioritization, Scrum, Agile Project Management, Software Product Management, Prioritization Method, Scalability, Accuracy, Experimental Evaluation, Engineering

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Chapter 1. Introduction

> *"It is very difficult to make a vigorous, plausible, and job-risking defense of an estimate that is derived by no quantitative method, supported by little data, and certified chiefly by the hunches of the managers."*
>
> *-Fred Brooks*

Prioritization and estimation are different things (Stott & Newkirk, 2007). Prioritization is to decide which features should be developed first and estimation is answering "How long it will take?". The prioritization in Scrum, one of the most used agile software development methodologies worldwide, is a Product Owner[1] responsibility and the estimation is responsibility of the Development team (Koova, 2009).

According to the CHAOS Report 2011 we know that software applications developed with the traditional waterfall method have 86% of challenged and failed rate but a much higher rate with agile process that have 58% (Cohn, 2012). It looks like Figure 1-1. Therefore the success rate using agile process is still low.

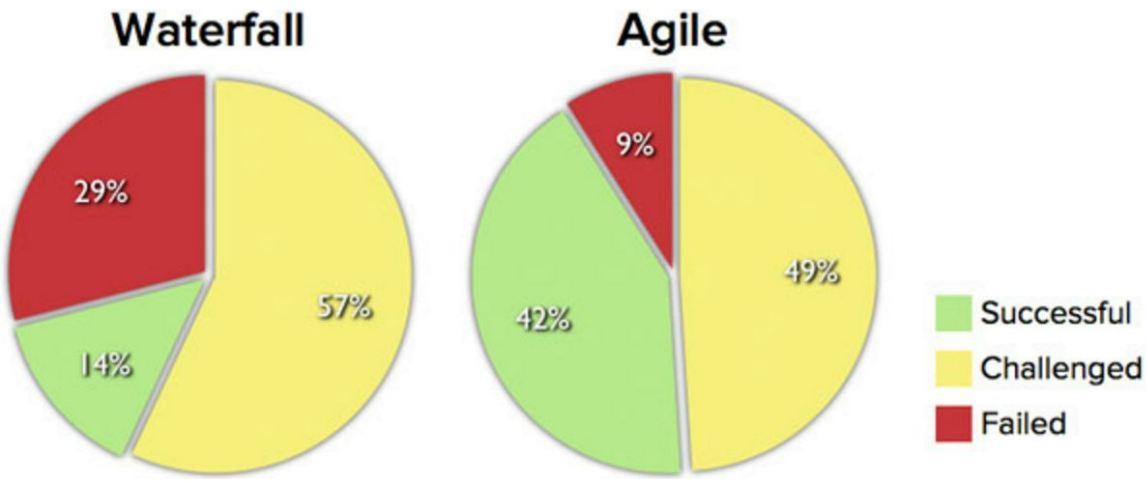


Figure 1-1. The CHAOS Manifesto (The Standish Group, 2012).

[1] The product owner responsibilities is to have a vision of what he or she wishes to build, and convey that vision to the scrum team.

Which leads us to the fundamental problem:

1.1. Research Question 1

How can we better prioritize and estimate software projects?

The Scrum Agile Methodology proposes to prioritize the Product Backlog[2] using two dimensions: Business value and time estimates (Koova, 2009). However this leads to other two problems:

A. Business Value isn't precisely defined and it is multidimensional i.e. different products may have different dimensions for value. Chapter 2 will discuss the problem.
B. Time estimates are affected by a myriad of problems that make them less reliable. Chapter 2 will talk about project chaos.

Which leads us to these questions:

1.2. Research Question 2.A

How can we define business value more precisely using Scrum and at the same time keep the flexibility of the metric to sort different products?

1.3. Research Question 2.B

How can we help humans to make better time estimates using Scrum?

Since 1970's the "Analytic Hierarchy Process" (AHP) presented by Saaty (1980) had been proposed as a way to analyze and take multidimensional decisions. Those multidimensional decisions are precisely the problems with lack of definition of Business Value in Research Question 2.A and 2.B. This leads us to the next research question:

1.4. Research Question 3

Using Scrum, is it possible to define the concepts of business value and improve time estimates?

However, previous attempts by Karlsson, Wohlin and Regnell (1997) and Ahl (2005) to use AHP to prioritize software projects has resulted in the next observation: Karlsson et al. (1997) concluded that "AHP is too slow and suitable only for small

[2] The product backlog in Scrum is a prioritized features list, containing short descriptions of all functionality desired in the product.

projects” since it requires to take too many decisions. Ahl (2005) claims that “AHP is difficult to handle” because is difficult to learn. Karlsson et al. (1997) has proposed “Binary Search Trees” (BST) and “Binary Priority List” (BPL) in order to speed up the AHP methodology. This generates the following question:

1.5. Research Question 4

Is it possible to use BPL to speed up and better serve in Scrum?

Finally a lot of research has been done about different techniques for software estimation. These studies have the following weak points (Ahl, 2005):

- They were performed with students and not with professional software developers.
- The studies did not analyze what really happened after the project was prioritized.

In this research we intend to avoid those concerns.

In this thesis we will cover the following topics, in Chapter 2 we establish some definitions and previous works in the area, such as prioritization, Scrum, AHP, BPL, etc. In Chapter 3 we propose a Software tool and a method to enhance Scrum using a combination between BPL and AHP by improving prioritization and software estimation. In Chapter 4 we present the design of the observational study we performed trying to answer the research questions. In Chapter 5, we show the observed results of the observational study. Chapter 6 includes our interpretation of the results. In Chapter 7 conclusions are presented, and finally Chapter 8 includes future work and some ideas to improve the Binary Priority Backlog (BPB) method.

Chapter 2. State of the Art

2.1. Fundamental Concepts

2.1.1. Prioritization

The priorities of user stories[3] determine the order in which you should implement them. Deciding priority is primarily a job of the customers, because they are ultimately responsible for deciding when and what should be delivered to the business (Stott & Newkirk, 2007).

Cohn (2006) claims that four factors must be considered when prioritizing the development of new features:

1. The financial value of having the features.
2. The cost of developing the new features.
3. The amount and significance of learning and the new knowledge created by developing the features.
4. The amount of risk removed by developing the features.

2.1.2. Estimation

The American Heritage Dictionary (2015) defines estimate as:

1. To calculate approximately (the amount, extent, magnitude, position, or value of something).
2. A tentative evaluation or rough calculation, as of worth, quantity or size.
3. A statement of the approximate cost of work to be done.
4. A judgment based on one's impressions.

McConnell (2006) claims that these definitions are similar to the ones you are asked for when you're requested for an estimate and for a tentative or preliminary calculation. But when executives ask for an estimate, they're really asking for a plan to meet a target or a commitment:

A. **A target** is a statement of a desirable business objective. For example: "We need to have version 2.1 ready to show it at the trade show in may".

[3] User stories are part of an agile approach that helps shift the focus from writing about requirements to talking about them.

B. **Commitment** is a promise to deliver defined functionality at a specific level of quality by certain date. For example: “The reports module will be implemented in 2 months”.

Therefore Conte, Dunsmore and Shen (1986) proposed that a good estimation approach should provide estimates that are within 25% of the actual results 75% of the time.

As McConnell (2006) concluded a good estimate is an estimate that provides a clear enough view of the project reality to allow the project leadership to make good decisions about how to control the project to hit its targets.

2.1.3. Cone of uncertainty

“The best we can do is size up the chances, calculate the risks involved, estimate our ability to deal with them, and then make our plans with confidence.”
-Henry Ford

The Cone of Uncertainty shows how estimates become more accurate as a project progresses (McConnelll, 2006).

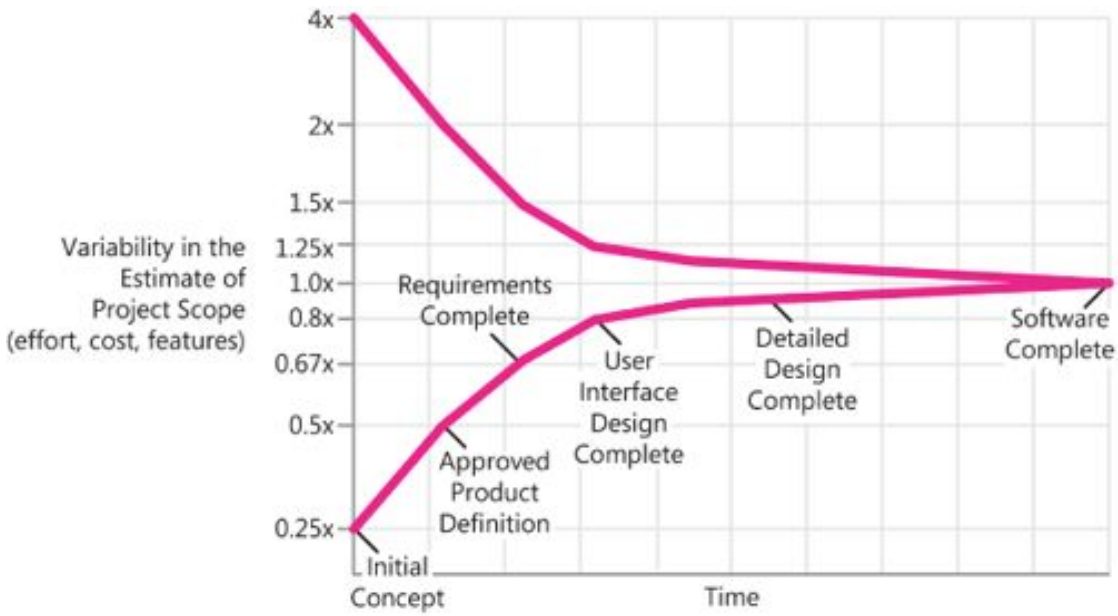


Figure 2-1. The Cone of Uncertainty based on common project milestones (McConnelll, 2006).

Research by Laranjeira (1990) suggests that the accuracy of the software estimate depends on the level of refinement of the software's definition.

McConnell (2006) affirms that software organizations routinely sabotage their own projects by making commitments too early in the Cone of Uncertainty.

2.1.4. Problems for estimation and prioritization in software projects

"There's no point in being exact about something if you don't even know what you're talking about."
-John von Neumann

One of the most common sources of estimation error is forgetting to include necessary tasks in the project estimates (Lederer et al., 1992).

McConnell (2006) claims that one of the great ironies in software development is that after a project team creates an estimate, managers, and sales staff take the estimate and turn it into an optimistic business target over the objections of the project team.

Numerous researchers have found that guessing, intuition, unstructured expert judgment use of informal analogies, and similar techniques are the dominant strategies used for about 60% to 85% of all estimates (Hihn & Habib-Agahi, 1991) (heemstra & Kusters, 1991) (Paynter, 1996) (Jørgensen, 2004) (kitchenham, Pfleeger, Mccoll & Eagan, 2002).

- Genuchten (1991) claims that developers estimates tend to contain an optimism factor of 20% to 30%.
- Excessive schedule pressure occurs in 75% to 100% of large projects (Jones, 1994).
- Off-the-cuff estimation is one of the most common errors that project teams make (Lederer et al., 1992) (Jørgensen, 2004) (kitchenham et al., 2002).

McConnell (2006) lists some other ways to introduce errors into an estimate such as:

- Unfamiliar business area.
- Unfamiliar technology area.
- Incorrect conversion from estimated time to project time or, as an example, assuming the project team will focus on the project eight hours per day, five days per week.
- Misunderstanding of statistical concepts. For example, especially adding together a set of "best case" estimates or a set of "worst case" estimates.
- Budgeting processes that undermine effective estimation, especially those that require final budget approval in the wide part of the Cone of Uncertainty.

- Having an accurate size estimate, but introducing errors when converting the size estimate to an effort estimation.
- Having accurate size and effort estimates, but introducing errors when converting those to a schedule estimate.
- Overstated savings from new development tools or methods.
- Simplification of the estimate as it is reported to up layers of management, fed into the budgeting process, and so on.

2.2. What is Scrum?

Scrum is an iterative and incremental agile software development methodology for managing product development. Scrum enables teams to self-organize by encouraging physical co-location or close online collaboration of all team members, as well as daily face-to-face communication among all team members and disciplines in the project (Koova, 2009).

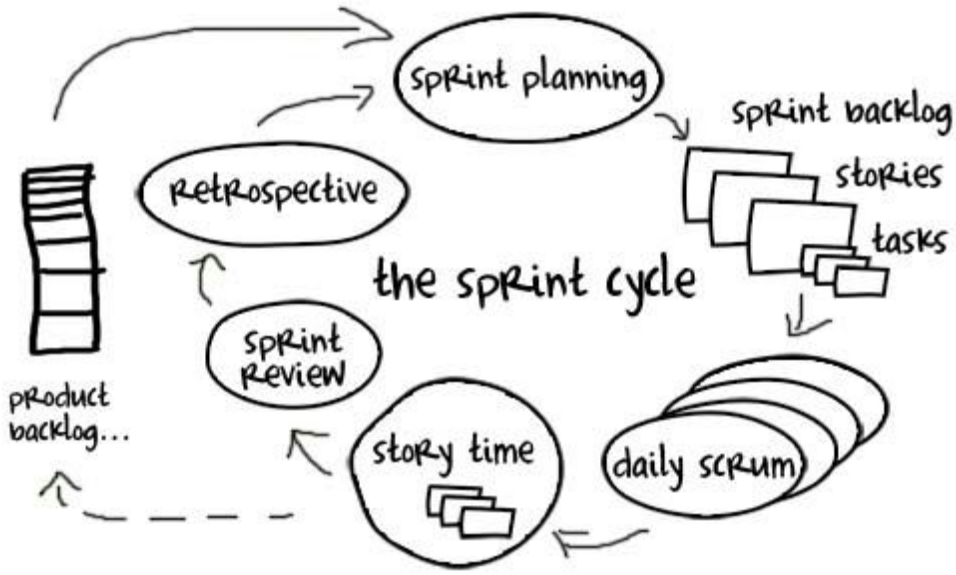


Figure 2-2. Sprint Cycle Life in Scrum (Sims & Johnson, 2012).

According the blog Scrum Study (2013) the Product Owner has to translate the inputs and needs of the project stakeholders to create the Prioritized Product Backlog. Hence, Value, Risk or Uncertainty and Dependencies are the three factors considered while prioritizing the user stories in the Prioritized Product Backlog.

Scrum has an abstract definition of business value. Nil (2014) claims that Business Value is a nebulous catch-all for any and all types of economic benefit a business will conceivably derive from an information technology (IT) solution. Also Nil (2014) said that any given IT investment will be expected to yield a hodge-podge of benefits

as diverse as revenue increases, efficiency gains and improved customer satisfaction. Nil (2014) states that it is appealing to combine these into a single measure of business value because it makes it easier to compare costs with benefits. An agile business case includes:

- High level scope.
- Value of the initiative.
- Timeline.
- Cost and Funding.
- Objectives related to strategy, risks, and assumptions.

2.2.1. Scrum Process

Rawsthorne and Shimp (2009) claims that the fundamental process flow of Scrum is the Sprint, which is a relatively short period of time in which Backlog Items are converted into Results. Also they show the following summary of the Scrum process:

1. Team of 7±2 does the work.
2. Product owner provides the work requests.
3. Scrum master provides care for the whole team (Product owner/Team).
4. Team swarms on the work.
5. Team is cross-functional.
6. Team owns its process.
7. Product owner provides validation for each work request.
8. Work is done in short bursts < 30 days each (Sprints).
9. Work starts and stops with planning and review.
10. Review demo for product; Review retro for process.
11. Daily Scrum detects any adjustments needed.
12. Product owner determines priority as a flow of work requests.
13. Scrum master observes and helps the whole team adjust.
14. Scrum master tunes the whole team for maximum performance.

2.2.2. Business Value

“You have to be very careful if you don't know where you're going, because you might not get there”
-Yogi Berra

There are several definitions of Value in the literature:

- The Institute of Value Management defines that value is based on the relationship between satisfying needs and expectations and the resources required to achieve them.
- Marvin (1992) claims that quality is value to someone.
- Wikipedia defines business value as an informal term that includes all forms of value that determine the health and well-being of the firm in the long-run.

When you use the words “business value” it is implied that someone is really talking about a whole bunch of things (Little, 2008):

- A definition of what value means; and one or more specific operational definitions of business value for the effort (project) at hand.
- A bunch of ideas that surround and pervade business value, that are key to the way we use it.
- A recognition that communication and motivation are key.
- A very practical down-to-earth subject, that is at the same time difficult and slippery.
- A bunch of practices that make business value useful. I want to call these the business value engineering practices.

2.2.3. Problems with Business Value

We have many definitions of Value, Larry Cooper claims that value is an interesting word and one that generates a lot of different opinions. Also Milton Friedman said that return on investment was the primary measure of value (Cooper & Stone, 2015).

Jen Stone claims that agile practices do not define value either, only that we should prioritize according to highest business value, which is apparently achieved by prioritizing features in a product (Cooper & Stone, 2015).

Karlsson et al (1997) claims that one of the greatest problems for software developers is that they might develop a product that does not satisfy their customer's needs and expectations.

2.2.4. Risk Prioritization

Cohn (2006) claims that a risk is anything that has not yet happened but might and that would jeopardize or limit the success of the project. Also there are many different types of risk on projects, including:

- Schedule risk ("We might not be done by October").
- Cost risk ("We might not be able to buy hardware for the right price").
- Functionality risks ("We might not be able to get that to work").

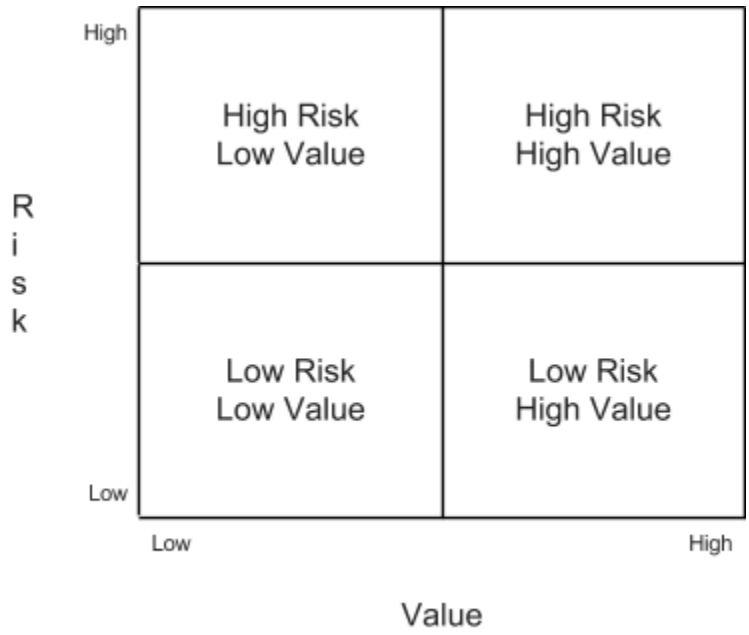


Figure 2-3. The four quadrants of the risk–value relationship (Cohn, 2006).

Cohn (2006) also remarks that the appropriate development sequence for the features is the following:

1. **First the high-value, high-risk features.** These features deliver the most value and working on them eliminates significant risks.
2. **Then the high-value, low-risk features**. These features offer as much value as the first set but they are less risky.
3. **Next the low-value, low-risk features.** These are sequenced third because they will have less impact on the total value of the product if they are dropped and because they are low risk.
4. **The low value but are high-risk are best avoided**. Defer work on all low-value features, especially those that are also high-risk. Try to defer

low-value, high-risk items right out of the project. There is no reason to take on a high degree of risk for a feature of limited value.

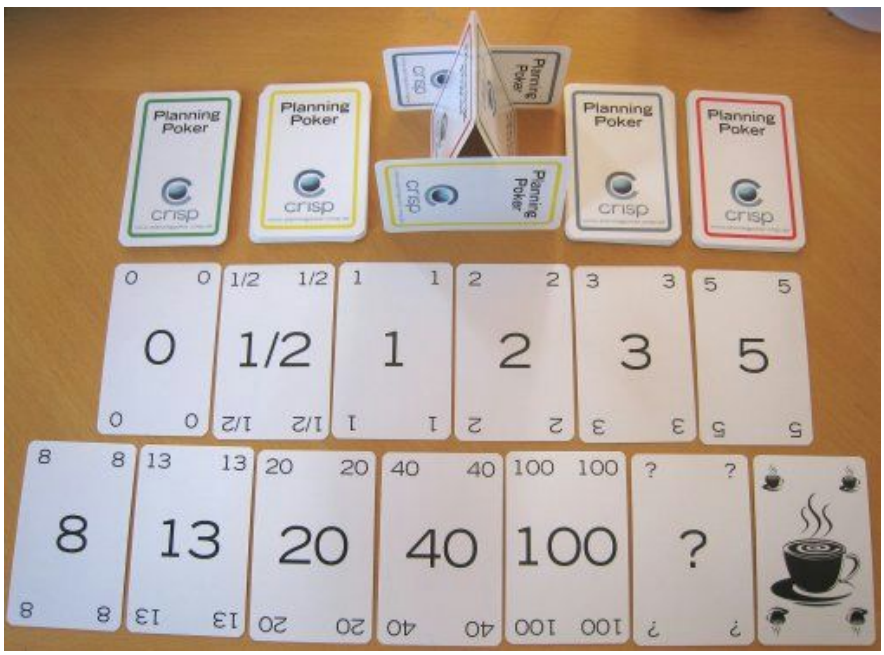
2.2.4. Story Points

Cohn (2004) proposes that a nice feature of story points is that each team defines them as a meaningful unit to estimate effort according to each team's working culture. One team may decide to define a story point as an ideal day of work. Another team may define a story point as an ideal week of work. Yet another team may define a story point as a measure of complexity of the story.

Because the wide variety of meanings for story points, Joshua kerievsky has suggested that story points represent Nebulous Unit of Time, or NUTs[4]. Cohn (2004) affirm that prioritizing the stories is difficult if they have not written to express business value, or if the stories are too large.

2.2.5. Planning Poker

Bourdeaux (2009) defines planning poker as an incredibly useful consensus based estimation tool that has become a household word in agile shops around the world. Cohn (2004) claims that planning poker combines expert opinion, analogy, and disaggregation into an enjoyable approach to estimating that results in quick but reliable estimates.



[4] Joshua Kerievsky on extremeprogramming@yahoogroups.com. August 5, 2003

Figure 2-4. Planning poker cards. (Wikipedia, 2007)

At the start of planning poker, each estimator is given a deck of cards. Each card has written on it one of the valid estimates. Each estimator may, for example, be given a deck of cards that read 0, 1, 2, 3, 5, 8, 13, 20, 40, and 100. The cards should be prepared prior to the planning poker meeting and the numbers should be large enough to see across a table. Cards can be saved and used for the next planning poker session (Cohn, 2004).

Ariely (2008) claims that humans rarely choose things in absolute terms. We don't have an internal value meter that tells us how much things are worth. Rather, we focus on the relative advantage of one thing over another, and estimate value accordingly. Also Ariely (2008) affirm that in the ordinal scale the only decision that has to be taken is if the requirements are more or less important that each other, not to which extent as in the ratio scale.

2.2.6. Problems with Time Estimation

Jones (1996) claims that excessive or irrational schedules are probably the single most destructive in all of software. McConnell (2006) lists common examples of project chaos such as:

- Requirements that weren't investigated very well in the first place.
- Lack of end-user involvement in requirements validation.
- Poor designs that lead to numerous errors in the code.
- Poor coding practices that give rise to extensive bug fixing.
- Unexperienced personnel.
- Incomplete or unskilled project planning.
- Prima donna team members.
- Abandoning planning under pressure.
- Developer gold-plating.
- Lack of automated source code control.

Our method helps with the problem of requirements prioritization, because Product Owners and Developers are involved in the prioritization tasks and help to obtain better results.

2.2.7. Advantages of Scrum

According to Adell (2013) these are the advantages of using Scrum in a software development project:

- Scrum methodology enables projects where the business requirements documentation is hard to quantify to be successfully developed.
- Fast moving, cutting edge developments can be quickly coded and tested using this method, and mistakes can be easily rectified.
- It is a lightly controlled method which insists on frequent updating of the progress in work through regular meetings. Thus there is clear visibility of the project development.
- Like any other agile methodology, this is also iterative in nature. It requires continuous feedback from the user.
- Due to short sprints and constant feedback, it becomes easier to cope with the changes.
- Daily meetings make it possible to measure individual productivity. This leads to the improvement in the productivity of each of the team members.
- Issues are identified well in advance through the daily meetings and hence can be resolved in speedily.
- It is easier to deliver a quality product in a scheduled time.
- Agile Scrum can work with any technology and programming language but is particularly useful for fast moving web 2.0 or new media projects.
- The overhead cost in terms of process and management is minimal thus leading to a quicker, cheaper result.

Scrum helps out method with the process of prioritize requirements in base of business value. Also Scrums claims that Product Owner define requirements and helps with the prioritization task.

2.3. Analytic Hierarchy Process (AHP)

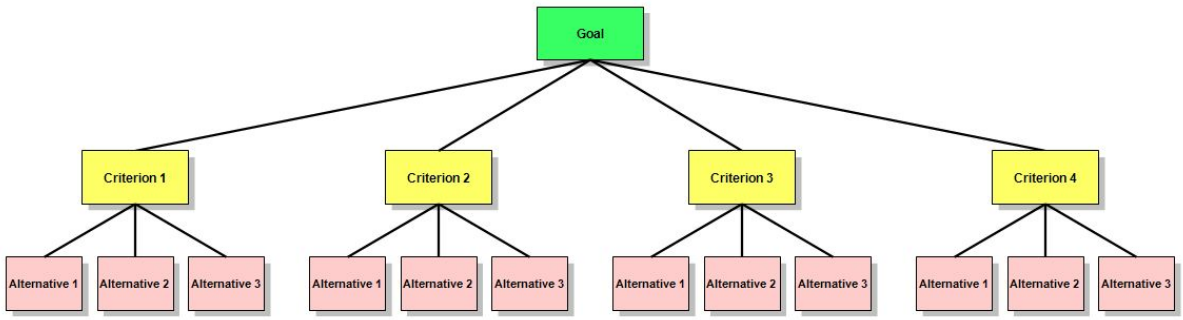


Figure 2-5. A simple AHP. In this figure there are three alternatives for reaching the goal, and four criteria to be used in deciding among them (“Analytic hierarchy process”, 2015).

The “Analytic Hierarchy Process” (AHP) presented by Saaty (1980) has been proposed as a way to analyse and take multidimensional decisions. Saaty and Hu (1998) published an article about using eigenvector versus other methods in AHP. Saaty and Hu (1998) conclude that even though the eigenvector method is not an accurate method, it has a simpler mathematical formula, this method is also relatively faster than the other methods that have been suggested to use with AHP. According to Saaty and Hu (1998) the largest source of errors is the human judgment assessment which is inclined to make error decisions.

Davis (1993) claims that AHP in large-scale development projects the requirements are often structured in a hierarchy of interrelated requirements. The most generalized requirements are placed at the top of the hierarchy and the more specific requirements on levels below.

Karsten and Garvin (1996) claims that decisions support tools, in particular the AHP, can provide the necessary and valuable assistance in the identification and selection of telecommunication pilot project participants.

Hartwich (1999) concluded that in overall AHP presents a powerful tool to use for weighting and prioritizing research output. It is suitable to structure complex problems, especially with discrete alternatives. Also said that some interviewees may find it somewhat tedious to go through that amount of pairwise comparisons. Related to this critique is the argument that after a certain time, experts may lose interest in the interviews.

Regnell, Höst, Dag, Beremark and Hjelm (2001) claims that the technique itself is not adapted to distributed prioritization with multiple stakeholders.

2.3.1. AHP Process description

In AHP the candidate requirements are compared in pairs, and to which extent one of the requirements is more important than the other requirement. States that the intensity of importance should be according to the Table 2-1.

How important	Description
1	Equal importance
3	Moderate difference in importance
5	Essential difference in importance
7	Major difference in importance
9	Extreme difference in importance
Reciprocals	If requirement i has one of the above numbers assigned to it when compared with requirement j, then j has the reciprocal value when compared with i.

Table 2-1. Fundamental scale used for pairwise comparisons in AHP (Saaty, 1980).

Karlsson et al (1997) claims that to implement AHP it is necessary to follow these three steps:

1. **As preparation**, outline all unique pairs of requirements at the same level in the hierarchy. Note that not all requirements are pair-wise compared to each other, but only those at the same level.
2. **As execution**, compare all outlined pairs of requirements using the scale in Table 2-1.
3. **As presentation**, do the same as for AHP at each level of the hierarchy. The priorities are then propagated down the hierarchy.

Karlsson et al (1997) affirm that AHP possesses similar characteristics to AHP. Using a hierarchical structure reduces the required number of decisions, but also the amount of redundancy. Thus it is more sensitive to judgmental errors than AHP.

2.3.2. Mathematical foundation of AHP

The rationale behind AHP is explained by Ahl (2005) as follows: Take the requirements that should be prioritized (the total amount of requirement is n), and put them into a matrix, where the rows have the index of i and columns have the index of j. The matrix is called W and the elements in the matrix are called w. The requirement that is placed in row i and column j gets the index ij. Therefore the element wij has the row index = i and column index = j.

	Requirement 1	Requirement 2	...	Requirement n
Requirement 1	1	w_{12}	w_{1j}	w_{1n}
Requirement 2	w_{21}	1	w_{2j}	w_{2n}
...	w_{i1}	w_{i2}	1	w_{in}
Requirement n	w_{n1}	w_{n2}	w_{nj}	1

Table 2-2. Matrix of pairwise comparisons (Saaty, 1980).

Each matrix would require n (the total amount of requirement) squared comparisons.

$$n^2$$

The amount of matrixes require n squared multiplied by d (the number of matrixes).

$$d \times n^2$$

Each matrix element consists of the comparison between two requirements (i and j), which gives us the following relationship:

$$(1)\ w_{ij} = \frac{w_i}{w_j}$$

That leads us to another important relationship, which is that for every index of i, j, k has the following relationship:

$$(2)\ w_{ij} = w_{ji}^{-1}, w_{ij} = w_{ik}w_{kj}$$

We only need to do half the comparison, since the formulae (2) say that wij = 1/wji .This leaves us to the diagonal, with the comparison with requirement wi and wi they will always be equal. This led us to the formulae:

$$(3)\ \frac{n(n-1)}{2}$$

The next step according to Saaty (1980) is to calculate the eigenvector vs Gass and Rapcsák (2004) describe it in the following way: If W is a consistent matrix then W is of rank one and λmax= n . If the relationship λmax= n is true, W is a positive reciprocal matrix.

$$(4)\ Wv = \lambda v$$

This means that v must be the eigenvector of W that correspond to the maximum eigenvalue λ.

$$(5)\ w_{11} + w_{21} + w_{i1} + w_{(n-1)1} + w_{n1} = z$$

Then you divide each element in the column with the sum, z, you calculated with formula (5). The next step is to add up the element in row i.

The final step is to divide each row sum with the amount of requirements n.

2.3.3. Psychological foundation of AHP

Ahl (2005) claims that the problem with human perception and judgments are subject to change if the human becomes tired or something changes the human psychological state. To solve this problem, AHP propose that we should only compare aij, j >i.

Whyte, Wilson and Wilson (1969) claims that the immense scope of hierarchical classification is clear. It is the most powerful method of classification used by the human brain-mind in ordering experience, observations, entities and information. Though not yet definitely established as such by neurophysiology and psychology, hierarchical classification probably represents the prime mode of coordination or organization (i) of cortical processes, (ii) of their mental correlates, and (iii) of the expression of these in symbolisms and languages. The use of hierarchical ordering must be as old as human thought, conscious and unconscious.

2.3.4. Advantages of AHP

Karlsson et al. (1997) comment these advantages of AHP:

- AHP is very trustworthy since the huge amount of redundancy in the pairwise comparisons makes the process fairly insensitive to judgmental errors.
- The resulting priorities are relative (element-1 is "extreme difference in importance" than element-2) and based on a ratio scale (compare the elements in pairs to obtain a ratio scale ranking by solving the eigenvalue problem) which allows for useful assessments of requirements.

Saaty (1980) claims that we do not expect "cardinal" consistency to hold everywhere in the matrix because people's feelings do not conform to an exact formula. Nor do we expect "ordinal" consistency, as people's judgments may not be transitive.
AHP may help our method with the hierarchical classification because is a powerful method of classification, and help to propagate requirements´s priorities down the hierarchy.

2.4. What is BPL?

Bebensee, Van de Weerd and Brinkkeper (2010) define Binary Priority List (BPL) as a requirements prioritization technique. Karlsson (1997) claims that BPL is basically the same as the Binary Search Tree (BST) approach which was introduced to the requirements prioritization area.

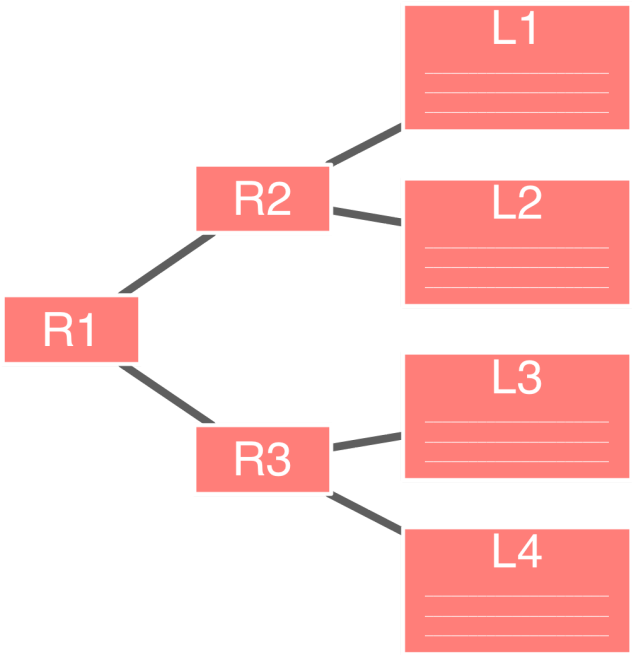


Figure 2-6. Structure of Binary Priority List. For example, requirement R2 is more important than R1, R3, L3 and L4 (Bebensee et al., 2010).

Each list would require log of n (the total amount of requirement) comparisons.

$$n \times log_2(n)$$

The amount of lists require n squared multiplied by d (the number of lists).

$$d \times n \times log_2(n)$$

2.4.1. BPL Process

In order to use the BPL technique Babense et al. (2010) propose the following steps to prioritize requirements:

1. Collect all requirements to a single pile.
2. Take any one of the requirements from the pile and put it as a root requirement.
3. Take another requirement and compare it to the root requirement.
4. If the requirement has a lower priority than the root requirement, compare it to the requirement below the root requirement. If the requirement has higher priority than the root requirement, compare it to the requirement above the root. This is continued until a place where there is no sub-requirement to compare with is encountered and the requirement can be finally placed to this position.
5. Steps 3 to 4 are repeated for all requirements.
6. At the end, travel through the list in top-down order to get the prioritized order of the requirements.

BPL may help our method with the requirements prioritization because this method require low number of comparisons and is a powerful technique.

2.4.2. Previous Researcher Works

There is only little notion of BPL in literature. Only four papers deal with it in more detail presenting this algorithm as an option to prioritize software requirements.

Karlsson et al (1997) compared BPL to five other prioritization techniques. In their research, BPL scored relatively weak in terms of time consumptions, easy of use, reliability and fault tolerance.

On the other hand, Ahl (2005) conducted an experiment in which he compared BPL with four other prioritization techniques in terms of reliability of results, ease of use, time consumption and scalability. In this experiment BPL was considered the best out of the five techniques. Ahl (2005) comes to the conclusion that BPL scales up very well and is therefore especially interesting for prioritizing large amounts of requirements.

Bebensee et al (2010) developed a tool for product managers to use BPL as a prioritization technique for their software requirements, they validated the application

in two product software companies. The goal of these case studies was to test whether BPL can be applied as a requirements prioritization technique and how it is perceived by experience software product managers. Bebensee et al (2010) concluded that BPL is a suitable technique for prioritizing medium amounts of requirements and could especially help smaller software product companies to formalize their requirements prioritization process.

Vestola (2010) conducted an experiment in which he compared BLP with eight other prioritization techniques in terms of empirical studies, result scale, speed, and best suited for number of requirements. In this experiment BPL obtain an average speed and be suited for small and medium number of requirements. In their research, concluded that is impossible to say, which of the methods is the best one. It really depends on the situation.

Chapter 3. Proposed Solution

"Prediction is very difficult, especially about the future"
-Niels Bohr, Danish physicist

Let's start by restating the desirable characteristics of our solution.

Given Research Question	Desirable Requirements
RQ1: How can we better prioritize and estimate software projects?	● Prioritize better ● Estimate better
RQ2.A: How can we define business value more precisely using Scrum and at the same time keep the flexibility of the metric to sort different products?	● Define Business value more precisely ● Be flexible enough to accommodate different definitions of value
RQ2.B: How can we help humans to make better time estimates using Scrum?	● Produce better time estimates
RQ3: Using Scrum, is it possible to define the concepts of business value and improve time estimates?	● Combine Scrum and the comparison matrix of AHP to specify better Business Value and Time estimates.
RQ4: Is it possible to use BPL to speed up and better serve in Scrum?	● Speed up the time to take prioritize requirements.
Finally it should consider the following weak points (Ahl, 2005): ● They were performed with students and not with professional software developers. ● The studies didn't analyze what really happened after the project was prioritized.	● Tested with professional software developers. ● Analyze if the prioritization was right after the finalization of the project.
Prioritize real-world project requirements	● Tested with a software company ● Analyze the correlation between requirements prioritized by the software company and the Binary Priority Backlog

Table 3-1. Given Research Question vs Desirable requirements.

With all the previous “Desirable Requirements” we present our Proposed Solution below.

3.1 Proposed method

Scrum does not have a definition of business value and needs to improve the way it makes time estimation. This problem is discussed in Chapter 2. There is no record of a combination between BPL and the comparison matrix of AHP being used in any experiment, and as a conclusion of having a better understanding of their benefits, it is worth to have this combination as candidate technique to prioritize requirements.

The proposed method was tested in a real-world project on a private Software Development company. Previous researchers used BPL and AHP prioritization techniques. Chapter 2 discussed these topics.

The aim of the experiment presented in this thesis is to evaluate if Binary Priority Backlog (BPB) is fast, easy to use, accurate and scalable when there are more requirements. The main purpose of this thesis is to define business value in terms of risk-value relationship.

3.2 Binary Priority Backlog method

Creating a great value proposition is a critical step in building good marketing messages but writing effective value propositions isn’t easy. Geoff Moore suggests a specific template for outlining the value proposition (Moore, 1999) and we used it to define the value of our proposal:

- **For**: Agile Developers.
- **Who are dissatisfied with**: The lack of definition of business value in Scrum and the lack of documentation in BPL.
- **Our product:** Binary Priority Backlog.
- **Is a:** Prioritization technique and software tool.
- **That provides**:
    - Fast prioritization.
    - Unambiguous ordering.
    - Precision and flexibility in the definition of value.
    - Ordered results.
    - Implemented in an easy to use tool.
- **Unlike**:
    - Plain Scrum that does not really provide order with planning poker.

- AHP that has been branded only for small projects.
- BPL that is not documented.

The following diagram illustrates our approach:

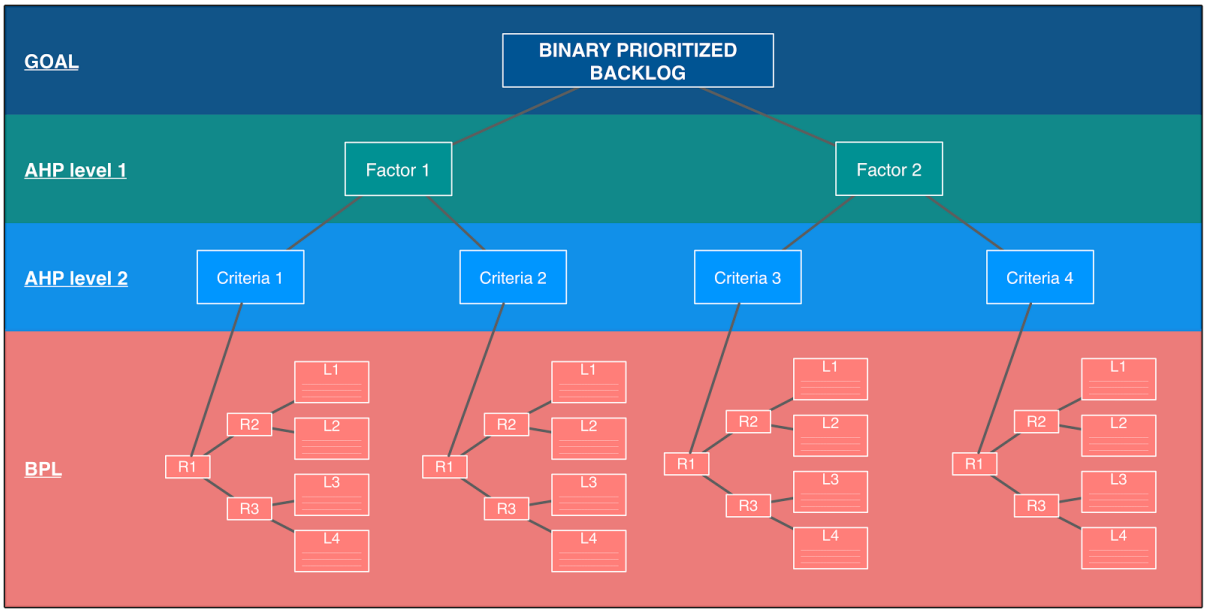


Figure 3-1. Structure proposed of Binary Priority Backlog.

3.3 Experimental Binary Priority Backlog

In order to validate the author's proposal a tool was developed to handle requirements stored on Trello[5]. This tool is an open source website, that allows to access to a specific board and then prioritize the requirements. See appendix 2.

3.3.1 Instrumentation

The technology used to develop the tool for Binary Priority Backlog is the following:

- **Vagrant.** Vagrant provides easy to configure, reproducible, and portable work environments built on top of industry-standard technology and controlled by a single consistent workflow to help maximize the productivity and flexibility of you and your team.[6]
- **Puppet.** Open source Puppet helps you describe machine configurations in a declarative language, bring them to a desired state, and keep them there through automation.[7]

[5] Trello keeps track of everything, from the big picture to the minute details https://trello.com/.
[6] https://docs.vagrantup.com/v2/why-vagrant/index.html
[7] http://docs.puppetlabs.com/

- **Trello.** Trello is an online tool for managing projects and personal tasks.[8]
- **Git.** Git is a free and open source distributed version control system designed to handle everything from small to very large projects with speed and efficiency.[9]
- **Javascript.** Is a high-level, dynamic, untyped, and interpreted programming language.
- **HTML5.** Markup language used for structuring and presenting content on the World Wide Web
- **CSS3.** Stylesheet language that describes the presentation of an HTML document.

[8] https://trello.com/about
[9] https://git-scm.com/

3.3.2 The Appearance of Binary Priority Backlog

First of all, the requirements are in a Trello's account. Then, to be able to get access to Trello, the test subject first had to login. After a user had successfully logged in into the system, the system show all the boards and their lists. Next, the test subject selects the list of requirements. After that, the system randomize the order in which the user should prioritize the requirements. And at the end the system runs the Binary Priority Backlog engine and uploads the requirements prioritized in a new list.

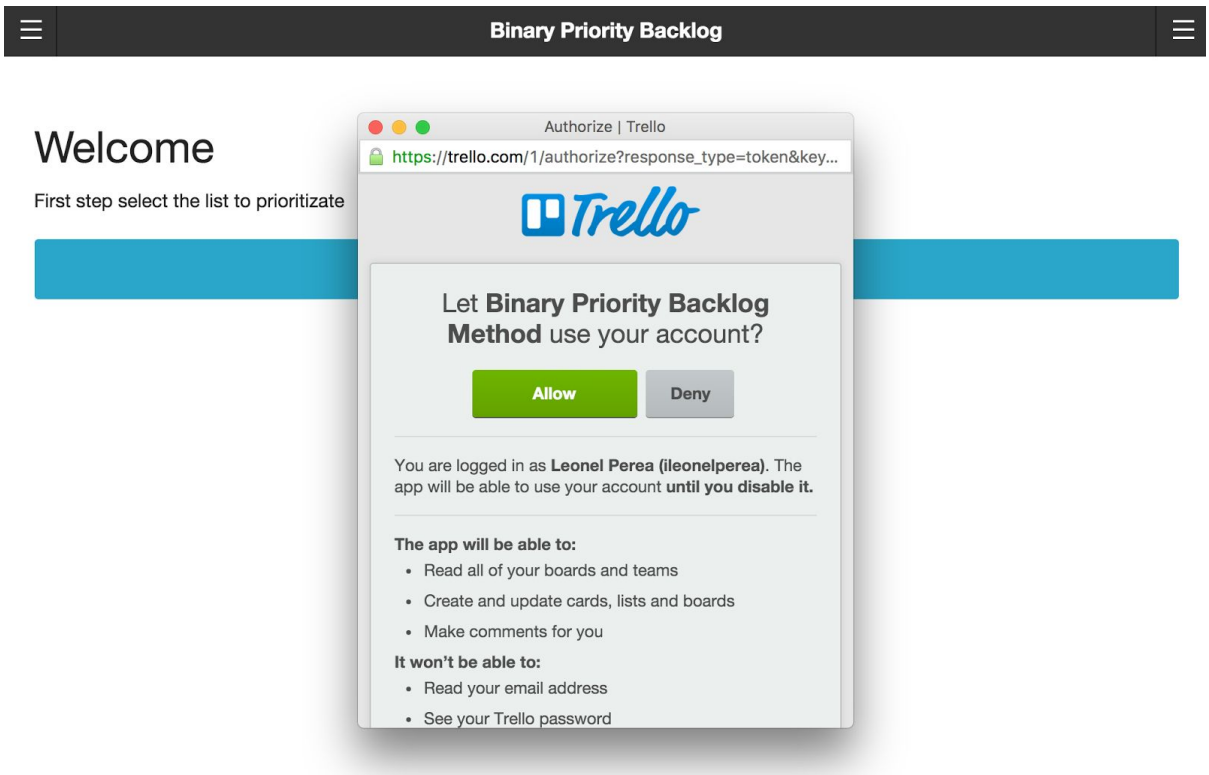


Figure 3-2. Login interface to Trello.

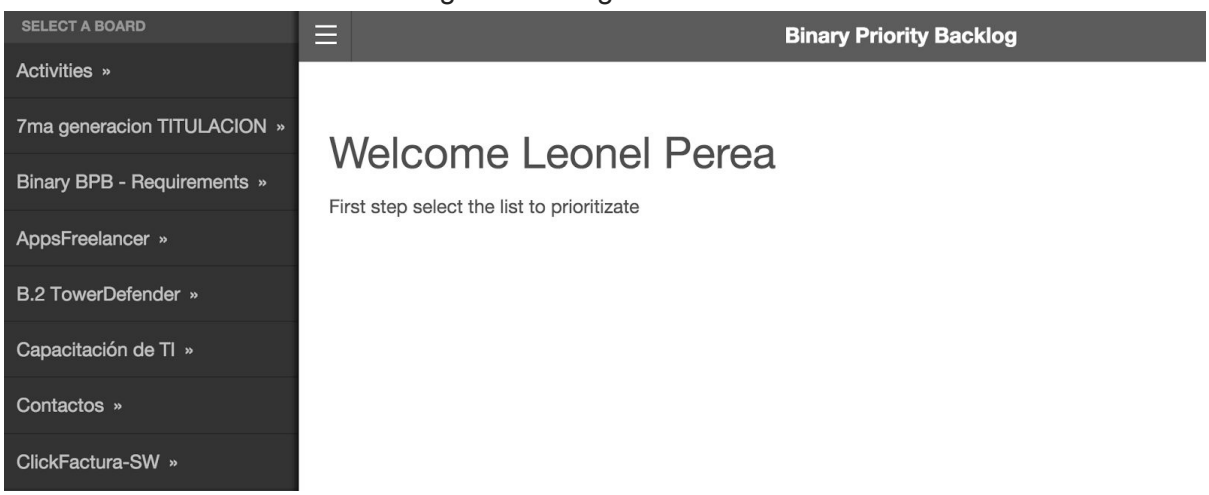


Figure 3-3. Boards and lists of requirements.

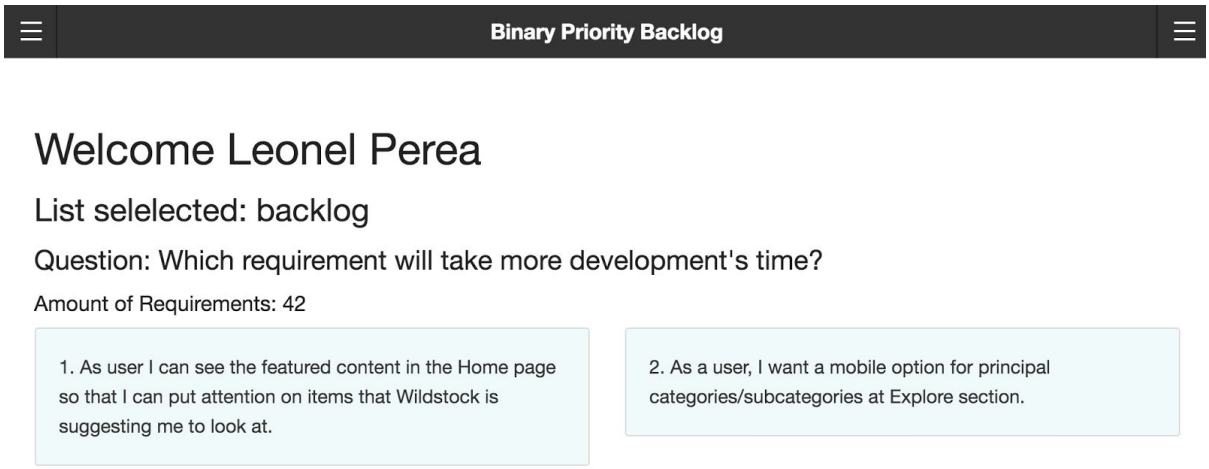


Figure 3-4. Interface for prioritization of requirements.

3.3.3 Introduction of the experimental tool

Since every pre-test subject need to have the information about the method, we create an introduction, the introduction have information regarding the theory about the Binary Priority Backlog method. See appendix 3.

Chapter 4. Experiment

In order to test the proposed solution (Binary Priority Backlog), we devised the following two experiments:

1) **Artificial Project**
   Along three iterations of a software project with a team of 10 developers, two project owners will prioritize and estimate the requirements that appear in the book “Backlog e-commerce using Laravel and stripe” by Gilmore and Eric (2015). We will able to test how the Binary Priority Backlog method works and compare the correlation between the three iterations and the order chosen in the book. The main conditions for the experiment are:
   a) In order to test the experiment we executed three iteration:
      i) We applied the same project with one product owner and two developers
      ii) We applied the same experiment with a second group of people with one product owner and two developers
      iii) And finally mathematically combined the previous two iterations in a third plus added the opinion of other six developers. The equivalent of having two product owners and 10 developers in one team.
   b) Before the execution and at the end of the the experiment each participant will answer a survey.
   c) Use the same requirements.
2) **Real-world project**
   A group of two professional developers and one project owner from a software company will prioritize and estimate a software project that was already developed using our method. In this way we will be able to compare what really happened versus what a new team would have predicted. The main conditions for the experiment are:
   a) Should be professional developers.
   b) Before the execution and at the end of the the experiment each participant will answer a poll.
   c) Use the same requirements.

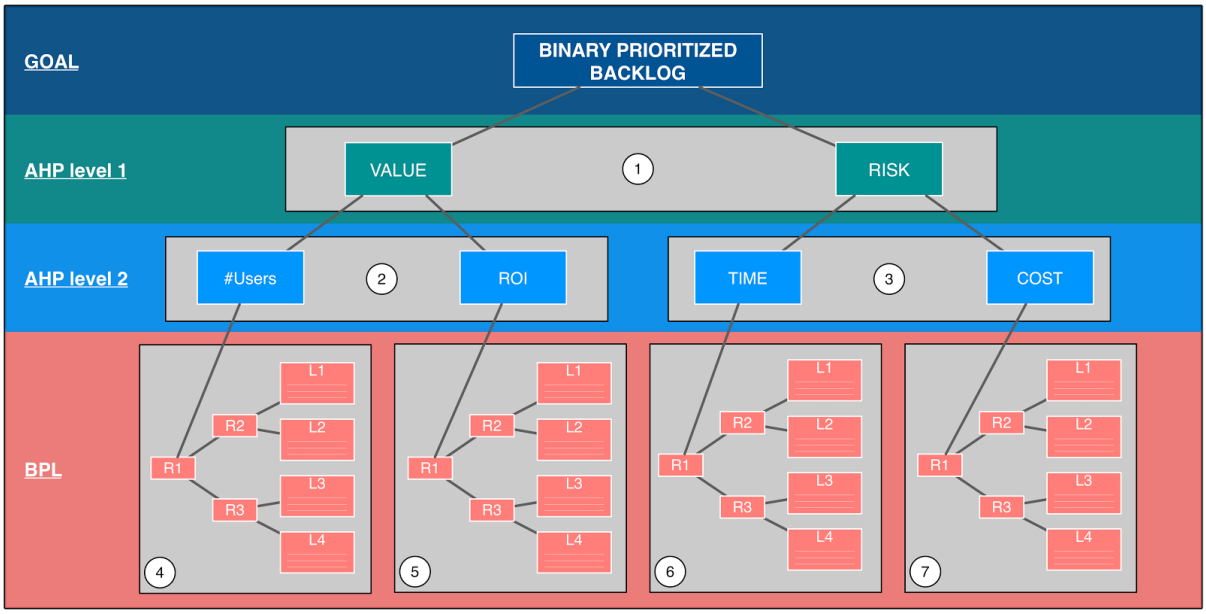


Figure 4-1. Seven phases to implement Binary Priority Backlog.

The experiment was divided into seven phases, those phases were:

1. **In Phase 1.** the Product Owner prioritizes in base to Value and Risk using AHP method.
2. **In Phase 2.** The Product Owner prioritizes in base to #Users and ROI using AHP method.
3. **In Phase 3.** the Product Owner prioritizes in base to Time and Cost using AHP method.
4. **In Phase 4.** the Product Owner prioritizes the requirements in base to #Users using BPL method.
5. **In Phase 5.** the Product Owner prioritizes the requirements in base to ROI using BPL method.
6. **In Phase 6.** the Developers prioritize the requirements in base to Time using BPL method.
7. **In Phase 7.** the Developers prioritize the requirements in base to Cost using BPL method.

4.1 Participants

This experiment was conducted with a developers team of the selected private software company.

4.2 Execution of the experiment

This experiment was conducted in a computer room during one meeting. The Product Owner and the developers were in the same room, then the Product Owner can answer the developer's questions and monitor the process.

Before the execution and at the end of the the experiment each Developer answered a survey. This would increase the scope of this thesis and make it more complex. The questions asked for this method were the following:

4.2.1 Survey before applying the proposed method Binary Priority Backlog

- How many years have you been programming?
- How many projects have you finished?
- What development languages do you know?
- Which development methodology do you use?
- What criteria do you use to prioritize requirements?
- How much time do you spend in prioritization task?

4.2.2 Survey after the execution of the method Binary Priority Backlog

- How much time did the prioritization take?
- How easy was the Binary Priority Backlog method?
- How easy to understand was the Binary Priority Backlog method?
- How scalable was the method?
- The results match your intuition?

Data collection: In this experiment the data is stored in Trello.

Environment: This experiment is done in an artificial project and in a real-world software development company.

Time plan: The time of presentation will be 15 min and execution of the experiment will be between 15 to 40 min.

Sampling: This will be a convenience sample since we are looking for software developers that already work at the company and also weren't involved in the original project.

Pause: During the experiment, each test subject should be given the opportunity to take a break.

Chapter 5. Results

This section shows the results of the two experiments.

5.1 Experiment 1 - Artificial project

5.1.1 Iteration 1

In this iteration took part one Product Owner and two Developers. Steps did in this iteration:

1. Product owner define the weight of Value as 60% and Risk as 40%.
2. Product owner define the weight of #Users as 40% and ROI as 60%.
3. Product owner define the weight of Time as 60% and Cost as 40%.
4. Calculate the weight of #Users, ROI, Time and Cost.
5. Calculate the compose weight multiplicand #Users, ROI, Time and Cost by the weight defined by the Product Owner.

To know what represents each column see the appendix 3.

Choice	Value		Risk		Compose Weight
	#Users	ROI	Time	Cost	
Priority Vector	60.00%		40.00%		
	40.00%	60.00%	60.00%	40.00%	
As a customer, I need to see the Home Page so that I can see the company's offer	0.74%	7.89%	7.89%	7.89%	6.17%
As a company owner, I need to create a website so that I need a way for customers to see my website	0.97%	8.68%	6.00%	6.00%	5.76%
As a company owner, I need to have an online website so that customers can contact us	1.15%	9.62%	5.04%	5.04%	5.75%
As a company owner, I need implement a payment processing service so that customers could pay online	9.62%	5.50%	0.61%	0.61%	4.53%
As a company owner, I need to have a layout that suit my own needs so that I need to customers see my services	1.28%	6.55%	4.56%	4.56%	4.49%
As a customer, I need to have a responsive website so that I need to navigate with deferents device's resolutions	1.55%	7.18%	3.78%	3.78%	4.47%

As a company owner, I need to create the About Us Page so that customers can see company's information	0.61%	0.97%	9.62%	9.62%	4.34%
As a customer, I need to see the sign out option so that I can sign out of my account	0.67%	0.67%	8.68%	8.68%	3.88%
As a company owner, I need to automate manual task so that I need to have a modern web development	4.15%	6.00%	1.41%	1.41%	3.72%
As a customer, I need to see the buy button so that I can buy a product	7.18%	4.56%	0.82%	0.82%	3.69%
As a costumer, I need to see the tax information	0.82%	1.72%	7.18%	7.18%	3.69%
As a customer, I need to have the Contact Form so that I can ask a question	0.90%	1.90%	6.55%	6.55%	3.52%
As a company owner, I need to sell products so that customers could buy products online	3.10%	5.04%	1.90%	1.90%	3.32%
As a customer, I need to see the shipping's form so that I could inject my shipping address	1.90%	4.15%	3.10%	3.10%	3.19%
As a customer, I need to see the order information's form so that I could inject the information	5.04%	3.41%	1.15%	1.15%	2.90%
As a customer, I need to do checkout so that I could purchase the order´s products	2.82%	3.78%	2.09%	2.09%	2.87%
As a company owner I need a email delivery service so that I can send emails from my website	8.68%	1.28%	0.67%	0.67%	2.81%
As a company owner, I need to Add Team Members to the payment processing system so that customer service teams be able to issue refunds	6.55%	2.30%	0.90%	0.90%	2.76%
As a company owner, I need to have a admin console so that I can add/update products	7.89%	1.55%	0.74%	0.74%	2.75%
As a customer, I need to download current and past invoices	1.06%	0.61%	5.50%	5.50%	2.67%
As a customer, I need to upgrade or downgrade my subscription so that I can change my current subscription plan	2.56%	3.10%	2.30%	2.30%	2.65%
As a customer, I need to cancel my subscription plan	2.09%	2.56%	2.82%	2.82%	2.55%
As a customer, I need to subscribe to plan so that I can have multi-seasonal services	3.41%	2.82%	1.72%	1.72%	2.52%
As a customer, I need to receive an email receipt so that I could see the summary of my purchase	5.50%	2.09%	1.06%	1.06%	2.50%
As a company owner, I need to create coupons so that I can encourage visitor registration	1.41%	0.90%	4.15%	4.15%	2.32%

As a company owner, I need to Integrate User Account Registration so that I can have the customers information	6.00%	1.15%	0.97%	0.97%	2.24%
As a company owner, I need to create coupons so that I could generate interest in the new subscriptions	2.30%	1.41%	2.56%	2.56%	2.08%
As a customer, I need to recover my password so that I can login again	1.72%	0.74%	3.41%	3.41%	2.04%
As a customer, I need to see my orders so that I could see the information of each order	3.78%	1.06%	1.55%	1.55%	1.91%
As a customer, I need to see the sign in option so that I can sign in with my user and password	4.56%	0.82%	1.28%	1.28%	1.90%

Table 5-1. Exp 1 Artificial project Iteration 1.

5.1.2 Iteration 2

In this iteration took part one Product Owner and two Developers. Steps did in this iteration:

1. Product owner define the weight of Value as 60% and Risk as 40%.
2. Product owner define the weight of #Users as 60% and ROI as 40%.
3. Product owner define the weight of Time as 60% and Cost as 40%.
4. Calculate the weight of #Users, ROI, Time and Cost.
5. Calculate the compose weight multiplicand #Users, ROI, Time and Cost by the weight defined by the Product Owner.

To know what represents each column see the appendix 3.

Choice	Value		Risk		Compose Weight
	#Users	ROI	Time	Cost	
Priority Vector	60.00%		40.00%		
	60.00%	40.00%	60.00%	40.00%	
As a company owner I need a email delivery service so that I can send emails from my website	5.50%	2.09%	7.89%	2.09%	4.71%
As a company owner, I need implement a payment processing service so that customers could pay online	2.82%	7.89%	0.67%	0.61%	3.17%
As a company owner, I need to Add Team Members to the payment processing system so that customer service teams be able to issue refunds	1.41%	1.15%	5.50%	2.30%	2.47%
As a company owner, I need to automate manual task so that I need to have a modern web development	0.61%	1.41%	8.68%	0.90%	2.78%
As a company owner, I need to create a website so that I need a way for customers to see my website	8.68%	6.00%	0.90%	1.06%	4.95%
As a company owner, I need to create coupons so that I can encourage visitor registration	0.74%	1.55%	9.62%	4.56%	3.68%
As a company owner, I need to create coupons so that I could generate interest in the new subscriptions	1.72%	3.78%	1.90%	3.41%	2.53%
As a company owner, I need to create the About Us Page so that customers can see company's information	0.82%	0.97%	2.82%	8.68%	2.59%

As a company owner, I need to have a admin console so that I can add/update products	6.00%	4.56%	0.97%	1.28%	3.69%
As a company owner, I need to have a layout that suit my own needs so that I need to customers see my services	5.04%	0.90%	0.82%	1.41%	2.45%
As a company owner, I need to have an online website so that customers can contact us	7.89%	5.04%	6.00%	3.10%	5.99%
As a company owner, I need to Integrate User Account Registration so that I can have the customers information	4.56%	2.30%	3.41%	2.82%	3.46%
As a company owner, I need to sell products so that customers could buy products online	9.62%	9.62%	2.30%	0.67%	6.43%
As a costumer, I need to see the tax information	2.30%	1.28%	1.28%	5.50%	2.32%
As a customer, I need to have the Contact Form so that I can ask a question	0.90%	2.82%	3.10%	7.89%	3.00%
As a customer, I need to cancel my subscription plan	0.67%	0.67%	1.15%	6.55%	1.73%
As a customer, I need to do checkout so that I could purchase the order´s products	3.78%	7.18%	0.74%	1.15%	3.45%
As a customer, I need to download current and past invoices	1.55%	0.74%	0.61%	5.04%	1.69%
As a customer, I need to have a responsive website so that I need to navigate with deferents device's resolutions	6.55%	1.72%	6.55%	0.74%	4.46%
As a customer, I need to receive an email receipt so that I could see the summary of my purchase	2.56%	3.41%	2.09%	3.78%	2.85%
As a customer, I need to recover my password so that I can login again	1.06%	1.90%	7.18%	6.00%	3.52%
As a customer, I need to see my orders so that I could see the information of each order	1.90%	0.82%	1.06%	2.56%	1.54%
As a customer, I need to see the buy button so that I can buy a product	4.15%	8.68%	1.41%	0.82%	4.05%
As a customer, I need to see the Home Page so that I can see the company's offer	7.18%	5.50%	1.72%	0.97%	4.47%
As a customer, I need to see the order information's form so that I could inject the information	3.10%	2.56%	3.78%	1.90%	2.94%
As a customer, I need to see the shipping's form so that I could inject my shipping address	2.09%	3.10%	1.55%	4.15%	2.53%
As a customer, I need to see the sign in option so that I can sign in with my user and password	3.41%	1.06%	4.56%	7.18%	3.72%
As a customer, I need to see the sign out option so that I can sign out of my account	1.15%	0.61%	5.04%	9.62%	3.31%

As a customer, I need to subscribe to plan so that I can have multi-seasonal services	1.28%	4.15%	2.56%	1.55%	2.32%
As a customer, I need to upgrade or downgrade my subscription so that I can change my current subscription plan	0.97%	6.55%	4.15%	1.72%	3.19%

Table 5-2. Exp 1 Artificial project Iteration 2.

5.1.3 Iteration 3

In this iteration took part two Product Owner and ten Developers. Steps did in this iteration:

1. The first product owner define the weight of Value as 60% and Risk as 40% then the second product owner define the weight of Value as 60% and Risk as 40%. After that we calculate the weight between the two product owners.
2. The first product owner define the weight of #Users as 60% and ROI as 40% then the second product owner define the weight of #Users as 40% and ROI as 60%. After that we calculate the weight between the two product owners.
3. The first product owner define the weight of Time as 60% and Cost as 40% then the second product owner define the weight of Time as 60% and Cost as 60%. After that we calculate the weight between the two product owners.
4. Calculate the weight of #Users, ROI, Time and Cost obtained from the 5 developers.
5. Calculate the compose weight multiplicand #Users, ROI, Time and Cost by the weight obtained from the weight defined by the 2 Product Owners.

To know what represents each column see the appendix 3.

Choice	Value		Risk		Compose Weight
	#Users	ROI	Time	Cost	
Priority Vector	60.00%		40.00%		
	50.00%	50.00%	60.00%	40.00%	
As a company owner I need a email delivery service so that I can send emails from my website	3.39%	5.39%	2.96%	5.48%	4.22%
As a company owner, I need implement a payment processing service so that customers could pay online	4.16%	8.75%	1.06%	0.79%	4.25%
As a company owner, I need to Add Team Members to the payment processing system so that customer service teams be able to issue refunds	1.01%	3.85%	0.98%	2.01%	2.01%
As a company owner, I need to automate manual task so that I need to have a modern web development	0.83%	2.78%	4.59%	0.78%	2.31%
As a company owner, I need to create a website so that I need a way for customers to see my website	9.15%	3.49%	4.15%	0.78%	4.91%

As a company owner, I need to create coupons so that I can encourage visitor registration	0.86%	1.48%	2.33%	1.63%	1.52%
As a company owner, I need to create coupons so that I could generate interest in the new subscriptions	1.63%	3.04%	1.82%	1.38%	2.06%
As a company owner, I need to create the About Us Page so that customers can see company's information	0.98%	0.79%	9.62%	9.15%	4.30%
As a company owner, I need to have a admin console so that I can add/update products	3.34%	6.22%	1.22%	4.23%	3.84%
As a company owner, I need to have a layout that suit my own needs so that I need to customers see my services	3.80%	1.09%	4.32%	1.41%	2.73%
As a company owner, I need to have an online website so that customers can contact us	7.22%	3.10%	7.34%	2.36%	5.23%
As a company owner, I need to Integrate User Account Registration so that I can have the customers information	2.73%	4.15%	3.35%	3.38%	3.41%
As a company owner, I need to sell products so that customers could buy products online	7.33%	6.36%	1.26%	0.78%	4.53%
As a costumer, I need to see the tax information	1.85%	1.05%	1.52%	1.77%	1.52%
As a customer, I need to have the Contact Form so that I can ask a question	4.39%	1.86%	8.29%	7.34%	5.04%
As a customer, I need to cancel my subscription plan	1.20%	1.38%	2.97%	2.86%	1.94%
As a customer, I need to do checkout so that I could purchase the order´s products	3.96%	5.00%	1.08%	4.07%	3.60%
As a customer, I need to download current and past invoices	1.72%	0.90%	3.89%	1.22%	1.92%
As a customer, I need to have a responsive website so that I need to navigate with deferents device's resolutions	6.87%	1.63%	2.84%	3.83%	3.84%
As a customer, I need to receive an email receipt so that I could see the summary of my purchase	3.17%	4.45%	3.98%	1.86%	3.54%
As a customer, I need to recover my password so that I can login again	1.94%	1.81%	3.59%	4.41%	2.69%
As a customer, I need to see my orders so that I could see the information of each order	2.10%	2.30%	1.31%	3.23%	2.15%
As a customer, I need to see the buy button so that I can buy a product	4.35%	7.93%	5.50%	3.80%	5.61%
As a customer, I need to see the Home Page so that I can see the company's offer	7.93%	3.12%	5.14%	5.35%	5.41%

As a customer, I need to see the order information's form so that I could inject the information	3.25%	3.80%	1.44%	4.82%	3.23%
As a customer, I need to see the shipping's form so that I could inject my shipping address	2.09%	2.50%	0.71%	2.66%	1.97%
As a customer, I need to see the sign in option so that I can sign in with my user and password	2.11%	2.81%	3.14%	7.89%	3.49%
As a customer, I need to see the sign out option so that I can sign out of my account	0.95%	0.64%	6.22%	8.08%	3.26%
As a customer, I need to subscribe to plan so that I can have multi-seasonal services	3.64%	3.78%	1.04%	1.06%	2.65%
As a customer, I need to upgrade or downgrade my subscription so that I can change my current subscription plan	2.04%	4.55%	2.34%	1.60%	2.80%

Table 5-3. Exp 1 Artificial project Iteration 3.

5.2 Experiment 2 - Real Life Project

In this experiment took part one Product Owner and two Developers. Steps did in this iteration:

1. Product owner define the weight of Value as 60% and Risk as 40%.
2. Product owner define the weight of #Users as 60% and ROI as 40%.
3. Product owner define the weight of Time as 60% and Cost as 40%.
4. Calculate the weight of #Users, ROI, Time and Cost.
5. Calculate the compose weight multiplicand #Users, ROI, Time and Cost by the weight defined by the Product Owner.

The first column represent the requirement description, the second one represents the requirement weight obtained from the software company, the third represent the overall composite weight obtained from the Binary Priority Backlog method and the fourth represent the correlation between software company and Binary Priority Backlog of each 7 requirements.

The correlation between the two sets of requirements was 14.99.

Requirement	Software Company	Binary Priority List	Correlation
As user I can see the featured content in the Home page so that I can put attention on items that Wildstock is suggesting me to look at.	6.94%	5.62%	82.09%
As a user I can see how Wildstock works in the Home page.	6.45%	6.94%	
As a user I wan start exploring Wildstock from the Home page.	6.02%	6.45%	
As a user I want recover my password because I forget it.	5.62%	2.38%	
As a logged-in user I want to log out so that I can finish my Wildstock session.	5.26%	1.03%	
As a user when seeing the images gallery I can clicking an image tile so that I can see a popup with the enlarged image and its full details.	4.92%	1.46%	
As a logged-in user I can add an image to my shopping cart from the Categories page.	4.61%	1.93%	
As a logged-in user when seeing an image pop up I can add the image to my shopping cart so that I can buy it later.	4.33%	0.90%	
As a user I can change my password.	4.07%	2.07%	

As a user I can delete purchased images.	3.82%	1.27%	34.55%
As a user I can download my purchased images.	3.59%	2.22%	
As a logged-in user I want to have a dashboard so that I can get a summary of my actions.	3.34%	0.69%	
As a logged-in user I want to update my Profile so that I can show an accurate Profile to other users interested in buying my images.	3.13%	0.61%	
As a logged-in user I want to manage my Payment Methods so that I can purchase images.	2.92%	0.83%	
As a logged-in user I want to manage my Payout Methods so I can get paid for images that I sell.	2.74%	0.96%	
As a user I can upload a photo in batch.	2.56%	1.56%	
As a user I want to edit details of selected uploaded images.	2.38%	0.74%	
As a user I want to delete selected uploaded images.	2.22%	0.78%	-70.95%
As an admin I want to manage images.	2.07%	0.47%	
As an admin I can setup featured content so that I can suggest new content to the user.	1.93%	0.50%	
As an admin I can setup the Categories/Sub-Categories in the Admin Categories page.	1.80%	0.65%	
As an admin I can see all the users so I can manage them.	1.67%	0.43%	
As a user, I want to be able to go to the secondary action on the bottom of the site (see the footer).	1.56%	3.34%	
As a user, I want to be able to go to the main actions at the top across the site so that I can access easily whenever I want.	1.46%	4.07%	
As a user, I want to see featured community in the Homepage.	1.36%	1.17%	
As a new user I want to join to Wildstock so that I can start to make transactions at Wildstock.	1.27%	5.26%	
As a new user I want login to Wildstock so that I can start to make transactions at Wildstock.	1.17%	3.13%	56.53%
As a user, I want to explore media at Wildstock so that I can get whatever I need.	1.10%	4.61%	
As a user, I want to filter explore content according to selected filters so that I can look for a specific field easily.	1.03%	2.92%	
As a user, I want a mobile option for principal categories/subcategories at Explore section.	0.96%	4.33%	
As a user, I want to search content in Wildstock so that I can get easily what I'm looking for..	0.90%	6.02%	

As a logged-in user I can favorite an image so that it gets added to my "saved" images.	0.83%	3.82%	
As a logged-in user, I want to view artist's profile.	0.78%	1.10%	
As a user I can view my uploaded images in gallery view.	0.74%	1.36%	
As a user I set my uploaded images as active/inactive.	0.69%	0.53%	
As a user I can view details in a popup of my uploaded images when I click in the image.	0.65%	4.92%	55.11%
As a user I can view all my saved images in gallery view.	0.61%	2.56%	
As a user I can unlike my favorites images.	0.57%	2.74%	
As a user, I want to download selected uploaded images.	0.53%	1.67%	
As a user, when I upload a image I want to be crop it as square so that it could fit with the site.	0.50%	0.57%	
As a user I can view all the images I want to buy in my shopping cart so that I can manage my shop.	0.47%	3.59%	
As a user I can complete the checkout process	0.43%	1.80%	

Table 5-4. Experiment 2 Real-world project.

5.3 Survey results

In this section the results from the experiment executed in the software development company are presented.

5.3.1 Survey **before** the experiment

The results from the survey before the execution of the method were the following:

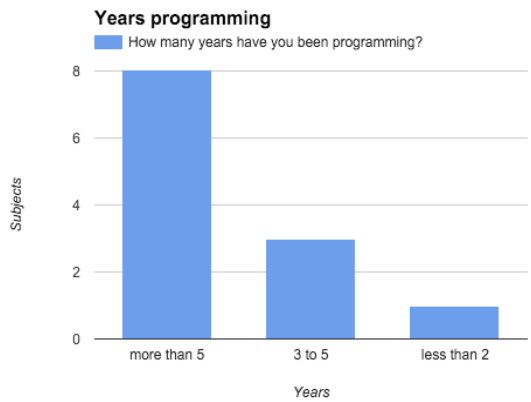


Figure 5-1. Years programming.

Figure 5-1 shows that most of the developers that participated in the experiment have 5 or more years of experience, which means that are no rockies in the field.

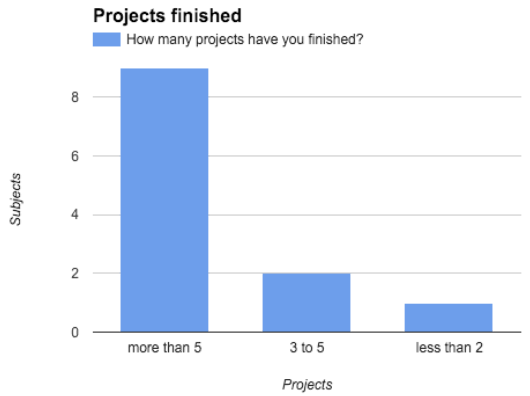


Figure 5-2. Projects finished.

Figure 5-2 Once again the table shows that these developers have delivered real software since nine subjects finished more than five projects.

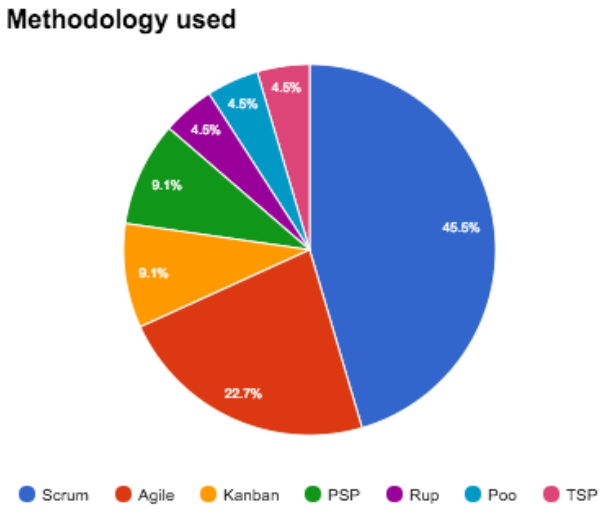


Figure 5-3. Methodology used.

Figure 5-3 shows that 77.3% of the subjects use agile methodologies (Scrum + Kanban + Agile) and only 22.7% of the subjects uses traditional methodologies.

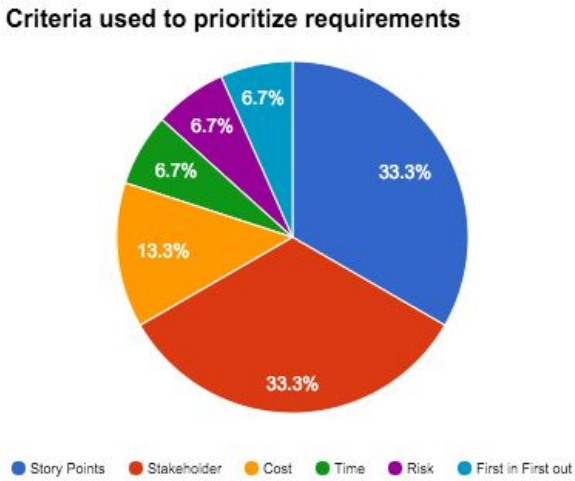


Figure 5-4. Criteria used to prioritize requirements.

Figure 5-4 In 60% of the cases the subjects use risk like criteria to prioritize the requirements as we defined in Binary Priority Backlog (Cost + Time + Risk + Story Points).
In one third of the cases stakeholders define the criteria to prioritize requirements.

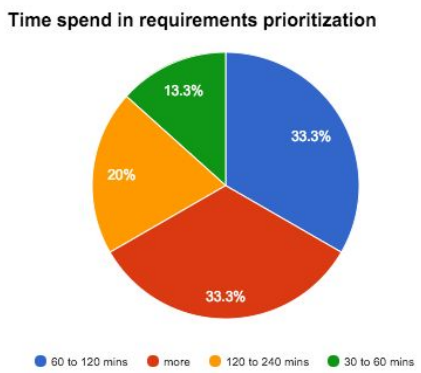


Figure 5-5. Time spent prioritizing requirements.

The figure 5-5 shows that 86.7% of the subjects spend more than 60 mins in requirements prioritization task, also only 13.3% of the subjects spend less than 60 mins in the prioritization task, that is more time that Binary Priority Backlog (BPB) takes, also 33.3% of the subjects spend more than 120 mins in in the requirements prioritization task.

5.3.2 Survey results **after** the experiment

The results from the survey after the execution of the method were the following.

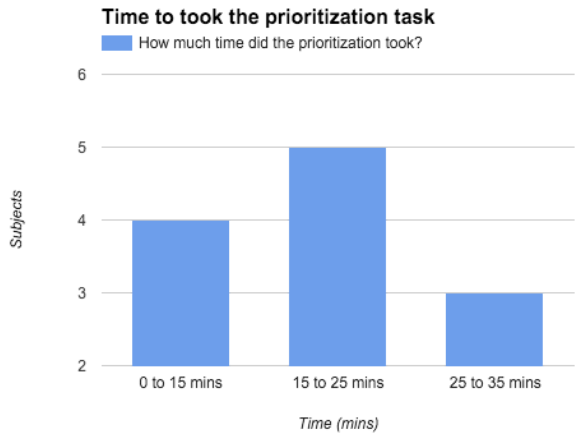


Figure 5-6. Time to took the prioritization task.

Figure 5-6 shows that with Binary Prioritization Backlog (BPB) the subjects spend less than 30 mins in requirements prioritization task, only 3 developers spent between 25 to 35 mins in requirements prioritization task.

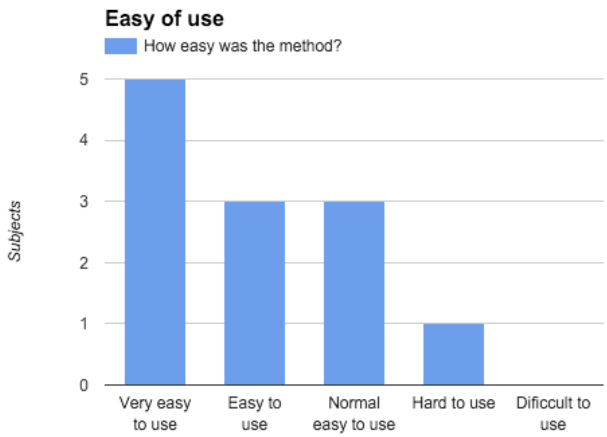


Figure 5-7. Easy of use.

Figure 5-7 shows that 91% of the subjects affirm that Binary Prioritization Backlog tool was easy to use, also only 1 subject claims that it was hard to use.

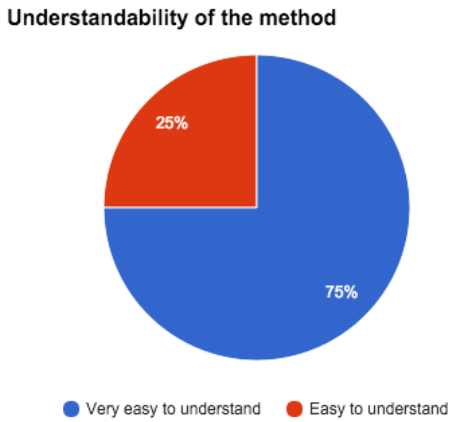


Figure 5-8. Understandability of the method.

Figure 5-8 shows that all the subjects understand how the method works.

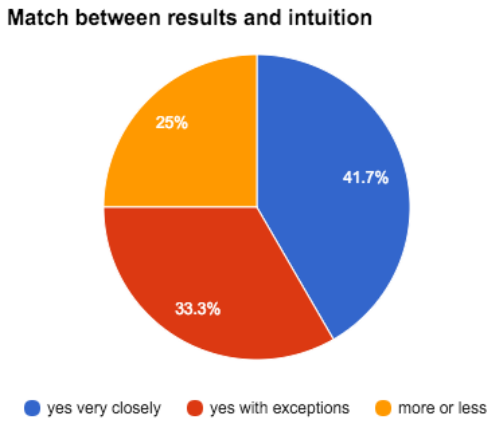


Figure 5-9. Match between results and intuition.

Figure 5-9 shows that 75% of the subjects claim that the requirements prioritized with Binary Priority Backlog match their human intuition. Another 25% percent affirms be more or less aligned with their intuition.

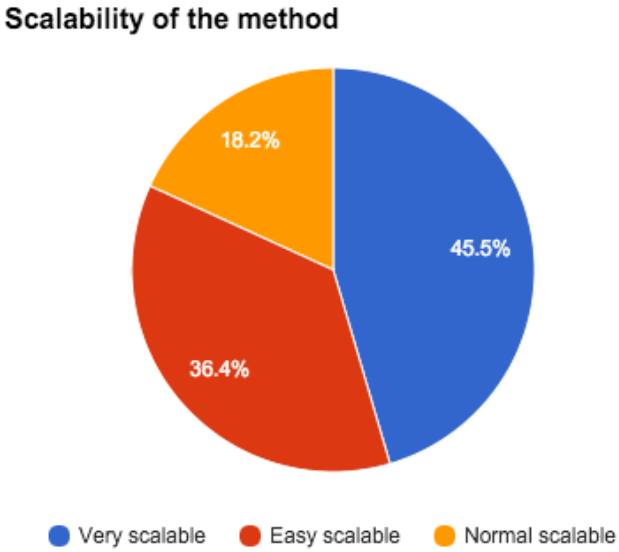


Figure 5-10. Scalability of the method.

Figure 5-10 shows that all subjects affirm that Binary Priority Backlog is scalable to more requirements and can be used with multiple applications.

Chapter 6. Discussion

Based on the previous chapter results, surveys and conversations with the Product Owners and developers that participated in the experiment iterations, these are our preliminary insights:

- Dependency between requirements always skews the prioritization.
    - After the subjects finished the prioritization task they said that they always were thinking in requirements dependency when they were prioritizing each requirement and that made it difficult to think of only the comparison made at that moment.
- Intuitively the tool can scale to many more requirements.
    - After the prioritization task subjects feel that the tool is scalable. That is because that short time to took to prioritize and it is an easy method.
- Familiarity with Agile methods helps.
    - Subjects use agile methodologies and feel comfortable with the definition of business value of the Binary Prioritization Backlog (BPB) method.
- Easy to use, accurate and able to scale up.
    - The result of the experimentation and the surveys indicates that Binary Priority Backlog (BPB) method is easy to use, give an accurate results and it is able to scale up even if there are many more requirements.
- More people involved increases the accuracy.
    - We noticed that when more people are involved in the prioritization tasks, the accuracy increases. This finding is aligned with previous studies that have shown that averaging individual estimates leads to better results (Hoest & Wohlin, 1998) as group discussions of estimates do (Jørgensen & Moløkken, 2002).
- Even developers with experience struggle to prioritize.
    - The survey shows that also developers with more than 5 years of experience still have problems to define the criteria to prioritize requirements. See Figure 5-4 and Figure 5-2.
- General Applicability
    - Several participants expressed that the method could be very useful in other fields like personal issues, economy, politics, etc.. Because it makes it easy to compare different alternatives.
- There is still a lot to improve in the tool
    - The tool is still incomplete because it too considerable amount of time in a spreadsheet to combine the different results and arrive at the proper prioritization.

- Low correlation of all values.
    - In Experiment 2 Real-world project when calculating the correlation of all the data it is pretty low just approx 15%. This data was disheartening. However when looking closely to the table it was detected that grouping requirements in subsets was much more interesting.
- High correlation between subsets.
    - The data was split in five subsets: Top 82.09%, high 34.55%, normal -70.95%, low 56.53%, and bottom 55.11% priority. In each on of this subsets the correlation was pretty high. Which means that although not exactly match, the experiment and the real-world agree in the sets of most and least valuable user stories.

Chapter 7. Conclusions

This work started with the goal to improve Scrum Backlog prioritization using Binary Priority Backlog method to define Business Value.

In order to see if this was reached, the following table presents a summary of the research questions, conclusions and evidence supporting the claim:

Given Research Question	Conclusion	Evidence that supports the conclusion
RQ1: How can we better prioritize and estimate software projects?	The proposed technique of Binary Priority Backlog (BPB) takes the strongest points of Scrum, using the comparison matrix of AHP and BPL to provide a coherent and easy to understand algorithm to prioritize and estimate a project requirements.	Answers in the survey and the experiments results with two different sets of developers arriving at a very similar prioritized backlog.
RQ2.A: How can we define business value more precisely using Scrum and at the same time keep the flexibility of the metric to sort different products?	Using the comparison matrix of AHP helps us to define business value by decomposing it in independent variables. A product owner may define what variables describe what business value is.	In this experiment business value was defined as Risk (ROI and # of Users) and Value (time and cost). However any product owner could have chosen other variables of business value.
RQ2.B: How can we help humans to make better time estimates using Scrum?	Using the psychological effect that comparing is easier than estimating.	i.e. Surveys confirmed that is much easier to ask developers which requirement could take more time between two alternatives than to ask for fixed estimates.
RQ3: Using Scrum, is it possible to define the concepts of business value and improve Time Estimates?	Yes, the experiment shows that using the comparison matrix of AHP is possible estimate requirements based in the defined business value	Three iterations of the experiment show that it is possible; however calculating the results took considerable effort in a

	variables.	spreadsheet.
RQ4: Is it possible to use BPL to speed up and better serve in Scrum?	It is possible by replacing the requirement comparison matrix used in AHP with the BPL. Although again a software tool is indispensable for this task	A matrix can be obtained from a set of requirements prioritized with BPL.

After answering the research questions we can conclude:

- Binary Priority Backlog method is a promising method for Prioritization and Estimation projects requirements, although it needs to be tested more in the real world with real-world software development projects.
- A software tool is indispensable to apply Binary Priority Backlog.
- Despite the current tool is useful, it still lacks of functionality.

In closing let's reflect in this quote:

"If we all make systematic mistakes in our decisions, then why not develop new strategies, tools, and methods to help us make better decisions and improve our overall well-being? That's exactly the meaning of free lunches- the idea that there are tools, methods, and policies that can help all of us make better decisions and as a consequence achieve what we desire-pg. 241"
— Dan Ariely, Predictably Irrational: The Hidden Forces That Shape Our Decisions

That the reason why Binary Priority Backlog (BPB) is important, because it is a tool that can help us take better decisions using our brain's strengths and not its weaknesses.

Chapter 8. Future Work

This thesis indicates that Binary Priority Backlog is a good method for prioritizing requirements. However, there are some issues that could have an impact on the result:

- Estimate more software projects in real-world.
    - Experiment 2 - Real-world project demonstrated that the proposed technique of Binary Priority Backlog (BPB) is useful to use in a real-world software development company, but needs to be tested in other projects.
- Requeriment dependency.
    - We need to consider task dependency because we observed that it biases the opinion of all the parties involved in the process. People can not decide considering one variable. For example: What provides more ROI? A shopping cart or a home page? Most people said the Home Page because it was a prerequisite to have a shopping cart. Then, people is considering dependency over the actual question.
- Try to simplify the model even more.
    - One suggestion that we got is that when combining the different variables we could use only the top 5 on each BPL thus simplifying the model even more.
- Make a collaborative interface for the tool.
    - Right now the tool requires that each role be in a meeting where they can vote on which requirement is more important. One of the most required features was to create a collaborative interface that a Team could estimate a project without the need to be collocated.
- In the tool implement the comparison matrix of AHP to obtain the compose weight.
    - Currently only the Binary Priority List functionality is part of the tool the calculation of the composite weight is done apart in a spreadsheet this calculations should be part of the tool.
- Fix bugs that duplicate cards. Sometimes when an user starts to prioritize, an error that produce a duplication of cards in the backlog list occurs.

References

Adell, L. (2014). Benefits & Pitfalls of using Scrum software development methodology Retrieved from http://blog.belatrixsf.com/benefits-pitfalls-of-using-scrum-software-development-methodology/

Ahl, V. (2005). An experimental comparison of five prioritization methods. Master's Thesis. Department of Systems and Software Engineering, Blenkinge Institute of Technology, Roonneby

Analytic hierarchy process. (n.d.). In *Wikipedia.* Retrieved October 26, 2015, from https://en.wikipedia.org/wiki/analytic_hierarchy_process

Ariely, D. (2008). Predictably irrational: the hidden forces that shape our decisions. New York, NY: HarperCollins Publishers.

Bebensee, T., & Van de Weerd, I., & Brinkkeper, S. (2010). Binary priority list for prioritizing software requirements. Department of Information and Computing Sciences.

Bourdeaux, P. (2009, August 16). Three Common Mistakes When Estimating With Planning. Retrieved from *https://www.sundoginteractive.com/blog/three-common-mistakes-when-estimating-with-planning-poker*

Business value. Retrieved October 19, 2015, from https://en.m.wikipedia.org/wiki/customer_value#customer_value

Cohn, M. (2006). Agile estimating and planning. Upper Saddle River, NJ: Prentice Hall Professional Technical Reference.

Cohn, M. (2012, February 13). *Agile Succeeds Three Times More Often Than Waterfall. Retrieved from https://www.mountaingoatsoftware.com/blog/agile-succeeds-three-times-more-often-than-waterfall*

Conte, S. D., Dunsmore, H. E., & Shen, V. Y. (1986). Software engineering metrics and models. Menlo Park, CA: Benjamin/Cummings Pub. Co.

Cooper, L. & Stone, J. (2015). Agile Value Delivery: Beyond the Numbers. Lulu Press, Inc

Davis, A. M. (1993). Software requirements: objects, functions, and states. Englewood Cliffs, NJ: PTR Prentice Hall.

Gass, S., & Rapcsák, T. (2004). Singular value decomposition in AHP. European Journal Of Operational Research, 154(3), 573–584. http://doi.org/10.1016/s0377-2217(02)00755-5

Genuchten, M. V. (1991). Why is software late? An empirical study of reasons for delay in software development. IEEE Transactions On Software Engineering IIEEE Trans. Software Eng., 17(6), 582–590. http://doi.org/10.1109/32.87283

Hartwich, F. (1999). Weighting of Agricultural Research Results: Strength and Limitations of the Analytic Hierarchy Process, Stuttgart: Gauer Verlag, Research in Development Economic and Policy. Discussion Paper No. 09/99

Heemstra, F. J., & Kusters, R. J. (1991). Function point analysis: evaluation of a software cost estimation model.European Journal Of Information Systems Eur J Inf Syst, 1(4), 229–237. http://doi.org/10.1057/ejis.1991.45

Hihn, J., & Habib-Agahi, H. (1991). Cost estimation of software intensive projects: a survey of current practices.[1991 Proceedings] 13th International Conference On Software Engineering. http://doi.org/10.1109/icse.1991.130653

Host, M., & Wohlin, C. (n.d.). An experimental study of individual subjective effort estimations and combinations of the estimates.Proceedings of the 20th International Conference on Software Engineering. doi:10.1109/icse.1998.671386

How to respond when you are asked for an estimate? Retrieved October 3, 2015, from http://programmers.stackexchange.com/questions/648/how-to-respond-when-you-are-asked-for-an-estimate

Jones, C. (1996). Software defect-removal efficiency.Computer, 29(4), 94–95. http://doi.org/10.1109/2.488361

Jørgensen, M., & Moløkken, K. (2002). Combination of software development effort prediction intervals. Proceedings of the 14th International Conference on Software Engineering and Knowledge Engineering - SEKE '02. doi:10.1145/568760.568833

Jørgensen, M. (2004). A review of studies on expert estimation of software development effort. Journal Of Systems and Software, 70(1-2), 37–60. http://doi.org/10.1016/s0164-1212(02)00156-5

Karlsson, J., Wohlin, C., & Regnell, B. (1998). An evaluation of methods for prioritizing software requirements. Information And Software Technology, 39(14-15), 939–947. http://doi.org/10.1016/s0950-5849(97)00053-0

Karsten, R., & Garvin, T. (1996). The use of the analytic hierarchy process in the selection of participants for a telecommuting pilot project. Proceedings Of the 1996 ACM SIGCPR/SIGMIS Conference on Computer Personnel Research - SIGCPR '96. http://doi.org/10.1145/238857.238888

Koova, M. (2009, October 19). Scrum Methodology Retrieved from http://scrummethodology.com/

Kitchenham, B., Pfleeger, S. L., Mccoll, B., & Eagan, S. (2002). An empirical study of maintenance and development estimation accuracy. Journal Of Systems and Software, 64(1), 57–77. http://doi.org/10.1016/s0164-1212(02)00021-3

Laranjeira, L. (1990). Software size estimation of object-oriented systems.IEEE Transactions On Software Engineering IIEEE Trans. Software Eng., 16(5), 510–522. http://doi.org/10.1109/32.52774

Lederer, A. L., & Prasad, J. (1992). Nine management guidelines for better cost estimating. Communications Of the ACM Commun. ACM, 35(2), 51–59. http://doi.org/10.1145/129630.129632

Little, J. (2008, March 5). Agile & Business. Retrieved from http://agileconsortium.blogspot.mx/2008/03/toward-general-theory-of-business-value.html

Marvin, G. (1992). Quality Software Management: Systems Thinking v1: System Thinking. John Wiley & Sons.

McConnell, S. (2006). Software estimation: demystifying the black art. Redmond, WA: Microsoft Press.

Miller, G. A. (1956). The magical number seven, plus or minus two: some limits on our capacity for processing information.Psychological Review, 63(2), 81–97. http://doi.org/10.1037/h0043158

Moore, G. A. (1999). Crossing the chasm: marketing and selling high-tech products to mainstream customers. New York: HarperBusiness.

Nir, M. (2014). Agile project management : Agile Product Owner Secrets Valuable Proven Results for Agile Management Revealed. Sapir Consulting

Paynter, J. (1996). Project estimation using Screenflow Engineering.Proceedings 1996 International Conference Software Engineering: Education And Practice. http://doi.org/10.1109/seep.1996.533994

Rawsthorne, D., Shimp, D. (2009, December 21). Scrum In A Nutshell. Retrieved from https://www.Scrumalliance.org/community/articles/2009/december/Scrum-in-a-nutshell

Regnell, B. F., Höst, M., Dag, J. N. O., Beremark, P., & Hjelm, T. (2001). An Industrial Case Study on Distributed Prioritisation in Market-Driven Requirements Engineering for Packaged Software. Requirements Engineering,6(1), 51–62. http://doi.org/10.1007/s007660170015

Saaty, T. L. (1980). The analytic hierarchy process: planning, priority setting, resource allocation. New York: McGraw-Hill International Book Co.

Saaty, T., & Hu, G. (1998). Ranking by Eigenvector versus other methods in the Analytic Hierarchy

Process. Applied Mathematics Letters, 11(4), 121–125. http://doi.org/10.1016/s0893-9659(98)00068-8

Stott, W., & Newkirk, J. (2007). *Visual studio team system: better software development for agile teams*. Upper Saddle River, NJ: Addison-Wesley.

Sims, C., & Johnson, H. L. (2012). Scrum: a breathtakingly brief and agile introduction.

The Agile Manager. Retrieved October 11, 2015, from http://www.rosspettit.com/2011/12/business-value-is-weak-currency.html

The American Heritage Dictionary entry: estimate. Retrieved October 15, 2015, from https://ahdictionary.com/word/search.html?q=estimate

Value-based Prioritization in Scrum. Retrieved October 20, 2015, from http://www.Scrumstudy.com/blog/value-based-prioritization-in-scrum/

Vestola, M. (2010). A Comparison of Nine Basic Techniques for Requirements Prioritization. *Helsinki University of Technology*.

What is planning poker? - Definition from WhatIs.com. Retrieved from http://searchsoftwarequality.techtarget.com/definition/planning-poker

Wohlin, C., Runeson, P., Host, M., Ohlsson, C., Regnell, B., & Wesslén, A. (2000). Experimentation in Software Engineering: an Introduction.

Whyte, L. L., Wilson, A. G., & Wilson, D. M. (1969). Hierarchical structures; proceedings. New York: American Elsevier Pub. Co.

Appendices

Appendix 1. Relevant links

There are some relevant links:

- Trello's Board. https://goo.gl/SYeXcS
- Binary Priority Backlog repository. https://goo.gl/xAFXke
- Experiments Spreadsheet. https://goo.gl/cK9379

Appendix 2. How replicate the environment

Download the latest release of Binary Priority List from this source
https://goo.gl/xAFXke

Currently, the vagrant environment is provided.

Make sure to cover the following Requirements:

- Virtualbox
- Vagrant

After this, run:

vagrant up

2 Machines will then be created. puppetmaster and agent

To fetch and apply the configurations on the agent run:

*puppet agent -t --environment {$environment} *default environment set to production*

All the data and classes are provided by Hiera.

Modules should be located in environments/{$environment}/modules
Node classes are now assigned in hieradata/{$environment}/node/{hostname}.yaml under the classes key

To see the site go to the vagrant public ip address http://192.168.33.10/

Appendix 3. Basic example of Binary Priority Backlog

Backlog of requirements.

Requirement	Description
R1	As a company owner, I need to Integrate User Account Registration so that I can have the customers information
R2	As a company owner, I need to create coupons so that I can encourage visitor registration
R3	As a company owner, I need implement a payment processing service so that customers could pay online
R4	As a customer, I need to do checkout so that I could purchase the order´s products
R5	As a customer, I need to subscribe to plan so that I can have multi-seasonal services

Make comparison matrix of #Users

#Users						
Choice	R5	R2	R4	R1	R3	Priority Vector
R5	1.000	3.000	5.000	7.000	9.000	50.28%
R2	0.333	1.000	3.000	5.000	7.000	26.02%
R4	0.200	0.333	1.000	3.000	5.000	13.44%
R1	0.143	0.200	0.333	1.000	3.000	6.78%
R3	0.111	0.143	0.200	0.333	1.000	3.48%
SUM	1.787	4.676	9.533	16.333	25.000	100.00%

Calculate priority vector of #Users

Choice	R5	R2	R4	R1	R3	Priority Vector
R5	0.560	0.642	0.524	0.429	0.360	50.28%
R2	0.187	0.214	0.315	0.306	0.280	26.02%
R4	0.112	0.071	0.105	0.184	0.200	13.44%
R1	0.080	0.043	0.035	0.061	0.120	6.78%
R3	0.062	0.031	0.021	0.020	0.040	3.48%

Make comparison matrix of ROI

ROI						
Choice	R2	R4	R5	R3	R1	Priority Vector
R2	1.000	3.000	5.000	7.000	9.000	50.28%
R4	0.333	1.000	3.000	5.000	7.000	26.02%
R5	0.200	0.333	1.000	3.000	5.000	13.44%
R3	0.143	0.200	0.333	1.000	3.000	6.78%
R1	0.111	0.143	0.200	0.333	1.000	3.48%
SUM	1.787	4.676	9.533	16.333	25.000	100.00%

Calculate priority vector of ROI

Choice	R2	R4	R5	R3	R1	Priority Vector
R2	0.560	0.642	0.524	0.429	0.360	50.28%
R4	0.187	0.214	0.315	0.306	0.280	26.02%
R5	0.112	0.071	0.105	0.184	0.200	13.44%
R3	0.080	0.043	0.035	0.061	0.120	6.78%
R1	0.062	0.031	0.021	0.020	0.040	3.48%

Calculate compose priority vector between #Users and ROI

Criteria	#Users	ROI	Priority Vector
#Users	1.000	2.000	66.67%
ROI	0.500	1.000	33.33%
SUM	1.500	3.000	100.00%

Compose			
Criteria	#Users	ROI	Priority Vector
#Users	0.667	0.667	66.67%
ROI	0.333	0.333	33.33%
SUM	1.000	1.000	100.00%

Compute the overall composite weight of each alternative choice based on the weight.

PRODUCT BACKLOG			
Criteria	#Users	ROI	Compose Weight
	66.67%	33.33%	
R5	50.28%	13.44%	38.00%
R2	26.02%	50.28%	34.11%
R4	13.44%	26.02%	17.63%
R1	6.78%	3.48%	5.68%
R3	3.48%	6.78%	4.58%
			100.00%

Product backlog result.

PRODUCT BACKLOG	
Requirement	Description
R5	As a customer, I need to subscribe to plan so that I can have multi-seasonal services
R2	As a company owner, I need to create coupons so that I can encourage visitor registration
R4	As a customer, I need to do checkout so that I could purchase the order´s products
R3	As a company owner, I need implement a payment processing service so that customers could pay online
R1	As a company owner, I need to Integrate User Account Registration so that I can have the customers information

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