



UNIVERSITY OF GOTHENBURG

Sustainability Aspects in Requirements Engineering: The Case of Commute Greener!

A Case-Study of the software application of Commute Greener! regarding the relations between the requirements of the application and sustainability aspects.

Master of Science Thesis in Software Engineering

IOANNIS PLIAKIS

University of Gothenburg
Chalmers University of Technology
Department of Computer Science and Engineering
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IOANNIS PLIAKIS

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Examiner: JAN-PHILIPP STEGHÖFER
Supervisor: JAN LJUNGBERG

University of Gothenburg
Chalmers University of Technology
Department of Computer Science and Engineering
SE-412 96 Göteborg
Sweden
Telephone + 46 (0)31-772 1000

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1. Introduction

Observing our everyday lives, our routine, the news around the world that talks about the pollution that we, as humans, are causing to the planet, it is not difficult to understand that environmental sustainability is an urgent and important topic to address. People, through different organized groups, are struggling to find solutions in different areas of research. Over the world there are plenty of organizations, firms, even countries that are changing, or planning to change parts of their working and functioning processes in order to become more environmentally friendly.

Software services are not an exception in the sustainability direction. People are expecting more and more to use the software services in their own personal way. Technology has provided these possibilities and keeps evolving in this direction by giving users the capability to customize more and more features of their devices or/and software services. The requirements of users vary a lot though. Different socio-cultural contexts are defining different requirements for software services (Johann and Maalej, 2013). One of the main focuses of the latest years is the sustainability aspects of requirements in a software service.

Observing software product development companies over the last few years, one can understand that among other different perspectives, there is a focus on sustainability in different kinds of software services in different areas of interest. Software product managers do not have enough information about how to embody different aspects of sustainability in product management and in decision-making for requirements selection (Penzenstadler et al., 2013). These “new” sustainability aspects for requirements and the impending challenge of managing and implementing them during the development of a software system, lead to the following research questions:

1. What is the relation between requirements and sustainability goals in a software

system?

2. What sort of conflicts between the requirements of a software system and a firm's goals are rising, while aiming for sustainability and how can they be managed?

The study becomes important because it relates the Software Engineering science with sustainability aspects. As it has been explained above, there is a great need to include sustainability in as many aspects of our lives as possible. By doing so, the chance of rising awareness in order to improve our lives becomes bigger. Sustainability aspects in software systems is going to help towards this direction by making people who are using these systems aware of the need for sustainability. One way to include sustainability aspects in software systems is to embody them in Requirements Engineering. This thesis becomes interesting in a way of explaining how sustainability aspects could be included in the requirements of a software system. The purpose of the thesis is to give a real scenario of sustainability aspects that have been included in the requirements of a software system. However, this scenario is only a possible way of embodying sustainability aspects in Requirements Engineering and it cannot be generalized. The goals of this thesis are to answer the two research questions that have been described above, as well as to build upon the existing literature regarding the sustainability aspects in software systems. Although this body of literature exists, it is a field that it is not much studied yet.

Moreover, it is expected to be used not only by researchers who could be motivated and conduct similar studies, but also by practitioners that would like to relate requirements with sustainability aspects. The case of the Commute Greener! Initiative and more specifically the software application from the requirements management point of view, focusing on the sustainability aspects, will be examined.

Commute Greener!

Commute Greener! is an initiative that derives from Volvo employees. Their idea was to motivate people to do something good for the environment. They believed that everybody is in a position to help, in order to have a more sustainable environment.

The reasons that the people from Commute Greener! are suggesting that people use the application are based on the idea to contribute to our environment by focusing on the environmental care. Clearly, climate change is one of the most important and most discussed issues of the most recent years. Volvo supports that one of their core values is the environmental care, hence they are trying to reduce the negative impacts on the environment caused by their products and operations. Volvo Group claims that they are improving fuel efficiency and considering their operations, reducing waste, emissions, energy consumption and carbon footprint. Another area that people from Commute Greener! are focusing on is the improvement of the existing road network, as they claim. By using the application, people will eventually be convinced to commute in a greener way, and the road network will be relieved from the pressure that exists today. Traffic jams will cease to exist and new alternative ways of commuting will make their appearance (Commute Greener!, 2009).

Technically speaking, Commute Greener! is running on Pocketweb's Pocket Life Platform, a platform for mobile and location based services across web and mobile operating systems (Pocket Life, 2010). Pocketweb provides mobile technologies for Location Based Services (LBS), Messaging, Contact Management, CRM, Media Management and Geo-advertising (PocketWeb, 2013).

Commute Greener! has been selected for this thesis because it will indicate that there is a relation between sustainability goals and a software system's requirements. This initiative includes the development of a software system that the company claims it takes sustainability aspects under consideration. That is how this thesis focuses on the way that people from this initiative have tried to develop not just a common software system, but one that is having specific sustainability goals. And as in any other system, the software's goals are always affected by its requirements and vice versa. That is what this thesis is aiming to study. This

will be a real life example from an ongoing initiative that also might shed light upon solving whatever conflicts might arise between the requirements of the system and the firm's goals while aiming for sustainability.

2. Theoretical Background

2.1 Concepts of sustainability

To begin with, it is critical to define what sustainability is and how it can be applied to software engineering. The most cited definition of sustainable development is to “meet the needs of the present without compromising the ability of future generations to satisfy their own needs” (United Nations World Commission on Environment and Development, 1987). This commission states that in order for sustainable development to be achieved, three dimensions need to be satisfied, the dimensions of society, economy and environment. Goodland (2002) claims that there is a fourth dimension to be covered as well, human sustainability, but it is less present in the public discussion (Penzenstadler et al., 2012).

As Silviu and Schipper (2010) state, sustainability is one of the most important challenges of our time. “In its broadest sense, sustainable development strategy aims at promoting harmony among human beings and between humanity and nature” (United Nations World Commission on Environment and Development, 1987). Dyllick and Hockerts (2002) present three points of interest regarding sustainability. First, they claim that in sustainability, economical, environmental and social aspects are integrated. This concept indicates that these three dimensions are connected, and therefore may influence each other in many different ways. These interrelations are generally well known, however trying to achieve sustainability in one dimension, one might neglect to focus on the consequences to the other two. Second, while aiming for sustainability, one has to take under consideration to combine both short term and long term aspects. This concept suggests that attention should be given throughout the whole life cycle of the matter at hand. For example, it has been observed that in economical sustainability more attention is being given to short term effects than to long term effects. At the same time, environmental and social impacts might not be yet visible until the long term. Third, sustainability suggests to consume the income and not the capital. This concept is about the idea that in sustainability the natural capital remains intact. This implies that the main functions of the environment should not be degraded. “Therefore, the extraction of renewable resources should not exceed the rate at which they are renewed, and the

absorptive capacity of the environment to assimilate waste, should not be exceeded.” (Gilbert et al., 1996).

2.2 Sustainability in Software Engineering

Moving the focus to how sustainability can be applied in software engineering, it is critical to understand that sustainability is important in software engineering. Penzenstadler and Fleischmann (2011) claim that there are many levels on which sustainability is affecting software engineering. This comes as a natural outcome since information technology is actually helping manufacturing more systems in less time. In their work, they define that sustainability in software engineering could mean sustainable development, while at the same time there is a limited and responsible use of the resources. Also, they clarify that sustainable development could mean either “to construct a sustainable product”, or “to construct a product by utilizing sustainable methods”.

Hilty et al. (2011) are trying to describe how informatics has involved the environmental aspects in its scope. In their work about sustainability in Information and Communication Technology (ICT) they claim that environmental information has been included in ICT applications for a long time now, for example in software systems that deal with the protection of the environment, or systems that do research for environmental purposes, or even systems that are performing risk mitigation. On the one hand, the advanced technology in computer science and informatics improved our way to analyze the biological, chemical and physical phenomena in the environment. On the other hand, the environment itself and its complexity is a very attractive subject that challenges informatics and computer science as well. Additionally, when it comes to the software systems as products, they are not all the same. For some systems it is necessary to take under consideration the power consumption during the use, while other systems are designed by targeting their recyclable potentials, or by minimizing the impact at their end-of-life stage.

Penzenstadler et al. (2012) argue that sustainability in software engineering can exist in both development and use of software systems. There are two more aspects in each of these two categories. Looking into the first, they argue that there is the *development process* aspect where sustainability is achieved with the proper use of ecological, human and financial resources on the early stages of development of software. The second aspect concerns the

maintenance of software by constantly looking upon quality until the software will be replaced by the latest version of it. Continuing with the second category of *production and usage*, there is the *system production aspect*, with a focus on using green IT principles and hardware components that they have been produced with sustainable ways. From this point of view, sustainability of software is considered to be a product that its resources for production (mass production aspects, logistics and factory organization issues) are being used responsibly. The last aspect is the *system usage aspect*, where sustainability of software as a product for usage is embedded in using green business processes.

Penzenstadler et al. (2012) in their work expect that the above described aspects are about to differ on how much impact they will have in different kinds of software, hoping that the system usage aspect will have the biggest one. The system usage aspect having the biggest impact also means that there is an improvement potential. Nonetheless, in their work they are looking for all four aspects of sustainability in software engineering as they are interested in researching each one of them.

2.3 Sustainability in Requirements Engineering

Focusing more on the requirements engineering perspective of software engineering, Penzenstadler (2012) in her work describes a usage scenario where a requirements engineer and a quality engineer are working together in order to improve the sustainability of a software system. In this possible usage scenario the requirements engineer underlines the sustainability goals in a Domain Model. Furthermore, a System Vision is created in which the sustainability goals are emphasized in order for the requirements engineer to be able to convince the customers of a business process that the software system will be more environmentally sustainable.

By taking these sustainability goals that the requirements engineer managed to take from the Domain Model and emphasize in the System Vision, a Goal Model is created with the goals that derived from the workshop. Using this Goal Model, the requirements engineer creates use cases and from them, functional requirements and user stories that are aiming for quality goals. This is one very interesting version of how requirements of a software system under development can be related to environmental sustainability goals. The fact that a requirements engineer can point out quality requirements and pass them to the quality model, could be very useful for the quality assurance.

As described above, when the quality engineer gets to measure the requirements engineer's work, he finds out that sustainability goals (like reducing energy consumption and emissions) have been achieved. Also, the quality engineer can contribute to the sustainability of a software system under development by progressively improving the support for these sustainability goals and measuring this process.

Shifting the focus from environmental sustainability to the social dimension of sustainability in requirements engineering, an interesting contribution to this field is the position paper by Johann and Maalej (2013). They examine if there is a possible impact from the society or the economy on software or vice versa. More interesting and related to this thesis work is the fact that they are questioning if there is a need for new kinds of techniques

in requirements engineering regarding the social dimensions of sustainability. According to the United Nations document (1987), sustainability refers to three aspects, the economical, the ecological and the social. Johann and Maalej (2013) argue that software systems are influencing all three of them. First, they affected the economical processes and became a main part of the global economy. Secondly, they can have positive or negative influence on the environment. Last, software systems changed a lot the way people communicate and socialize.

Sustainable software is mostly known as software that is reusable and easy to maintain, not including any ecological or societal aspect, (Tate, 2005). Maalej and Pagano (2011) though, in their work, put it very beautifully by claiming that the majority of users and their communities are particularly capable of supporting sustainable software engineering through engineering processes. Naumann et al. (2011) in their work, gave their own definition for a Sustainable Software as a software “*whose direct and indirect negative impacts on economy, society, human beings, and environment that result from development, deployment, and usage of the software are minimal and/or which has a positive effect on sustainable development*”. From this definition it is clear that there is on the one hand a focus on the positive impact on sustainable development of software and on the other hand a focus on software that minimizes its own possible negative impact on sustainable development. Especially the second type of sustainable development could be more related to requirements engineering, because it is more generic and covers every software system. Furthermore, sustainability should be seen as a basic non-functional requirement (Johann and Maalej, 2013).

As an example of the social aspects in a software system, Johann and Maalej (2013) talk about the Infrastructure for Spatial Information in the European Community (INSPIRE). This initiative is “*an EU initiative to establish an infrastructure for spatial information in Europe that will help to make spatial geographical information more accessible and interoperable for a wide range of purposes supporting sustainable development*”, (Benoit, 2011). The problem that Johann and Maalej (2013) point out starts with the fact that only a few Europeans are aware that such an initiative exists. Also, in this huge amount of data users without technical

background and knowledge will find it very difficult to find specific information that they would like to. Moreover, applying this initiative to rural areas where the majority of people do not own computers, but cell phones, the requirements for this initiative change radically.

Continuing with the societal aspects of software systems, one can observe that people's participation and influence in a software system is happening more often during the last few years. Applications like Facebook and Twitter allow users to express their opinions which can be discussed, supported or fought by other users. In the end, these discussions formulate a democratic expression of opinions that are not limited by hierarchy or any kind of constraints (Johann and Maalej, 2013).

Furthermore, Johann and Maalej (2013) notify that firms which develop software systems found it more effective to have feedback from their users in order to improve or extend the use of their products. This trend is going both ways. More and more, users desire to communicate their opinions and affect the development of a product that they would like to buy or already own. Tate (2005) claims that there is a need in requirements engineering for building sufficient systematic feedback methods. By doing that, requirements from different groups of users could be gathered. The involvement of the users in software systems contributes to the social aspects of software engineering. Hammouda et al. (2008) describe how software engineering could be considered social by defining Social Software Engineering as *“the application of processes, methods, and tools to enable community-driven creation, management, deployment, and use of software in on-line environments”*.

Another important social aspect for software systems is accessibility, as Johann and Maalej (2013) claim. There are no global rules or definitions considering the implementation of accessibility yet. There have been software systems that are implementing accessibility options like several operating systems that have screen readers or specialized color settings. But these options are referring only to people that experience physical difficulties. Situations with people from different social backgrounds and environments that differ in their accessibility requirements still need to be addressed. A good example is the specific requirements in Esoko, a software that provides market information to users. In this software,

information is accessible to specific social environments. Users that are farmers from rural countries can be notified via email or by SMS about the prices of the world markets. So they no longer have to depend on resellers about the price at which they would sell their goods, and they could now decide themselves.

Going back to the general idea of sustainability in software systems, Rodriguez and Penzenstadler (2013) discuss about analysis and assessment of sustainability on a software system with the IMAGINE approach (Bell and Morse, 2008). More specifically, they try to analyze a software system that affects the sustainability of the mobility of the city from a sustainability point of view. In this analysis, they use the IMAGINE approach that was suggested by Bell and Morse (1999). The IMAGINE approach was designed to establish the cooperation between all experts in all levels regarding the identification and understanding of the problems of sustainable development. Also it tries to define optimal indicators for measuring success, and to elaborate on decisions for further development. Finally, in this approach, the activities that lead to the desired scenarios are included (Rodriguez and Penzenstadler, 2013).

Rodriguez and Penzenstadler (2013) in their work study the case of a DriveNow, a project that was developed for a car sharing system in three German cities by the combination of BMW, Mini and Sixt in a 50%-50% venture. The general idea was to give new mobility options that citizens could be attracted to, while being socially sustainable. The business model of DriveNow suggests vehicle renting in a city for a short period of time, and using public park stations in order to cut any additional parking costs. The goal of this system is mainly to reduce the CO2 emissions and ways to achieve this goal are by replacing old cars for individuals with new cars and the possibility of sharing them. Also, electric cars were introduced and new technologies were integrated. One of the most interesting conclusions that Rodriguez and Penzenstadler (2013) came to, is that they noticed improvements in the elicitation process of requirements. With the IMAGINE approach, the identification of stakeholders from different levels and areas contributed to the achievement of balance in prioritization and completeness of the elicited requirements.

Moving the focus to the decision-making of requirements, as it has been mentioned, there are no documented guidelines for software product managers on how to embody different aspects of sustainability in software systems (Penzenstadler et al., 2013). Considering the awareness of the public regarding the environmental, social, economical and human sustainability, an interesting question arises. How can a firm make innovative products that are satisfying the customers, and at the same time these products have been built in a socially responsible and sustainable way? Penzenstadler et al. (2013) in their work are focusing in this direction and try to give answers. They use the Software Value Map in order to have guidelines for software product management decisions.

The Software Value Map presents a consolidated view of software value, utilizing four major perspectives: financial, customer, internal business process and the innovation and learning (Khurum et al., 2013). This view (Software Value Map) is unifying the value of software, and each component is organized as value aspects and sub-aspects. Those elements can later be used by professionals in order to achieve a common understanding of value, as the Software Value Map itself could behave as a decision support system that helps managers not to ignore or overlook any value aspect.

In order to build the Software Value Map, Kurum at al. (2013) are defining 3 basic steps. The first step is taxonomy, where they categorize the value components based on a set of measures agreed by the professionals. The second step is about structure and definitions. In this step each value component needs to be specifically defined and categorized. This is the main challenge while creating the Software Value Map, to carefully categorize and show all the value components in a clear and organized way. The third and last step is about interrelationships between value components. They were identified using three different bases. Interrelationships located in the selected papers for study, interrelationships that were found during the categorization of the value aspects and interrelationships that were identified while making patterns as the selected case study was evolving (Khurum et al., 2013). Khurum et al. (2013) are mentioning the achievement of differentiation and isolation of the interrelationships preventing any addition of not necessary value components, as a contribution of the Software Value Map. But this conclusion is notified

as under future research, since it was not addressed during the industrial evaluation of the Software Value Map.

Penzenstadler et al. (2013) argue that the Software Value Map helps in having a more unified view of value, and no value perspectives would be unintentionally overlooked. For example, in the requirements selection, short term revenue for one firm could co-exist with the sustainability view of the firm in long term revenue.

Penzenstadler et al. (2013) try to identify the value aspects of sustainability in all four dimensions as an addition to the Software Value Map. Regarding human sustainability, despite the fact that value aspects are not clearly connected with all of the product management decisions, they are influencing other value aspects from the sustainability dimensions. In the social dimension of sustainability, value aspects could include the improvement of community support, the need to achieve a sufficient level of market communication, the urge to secure customer privacy and monitor investment and procurement practices (Silvius and Schipper, 2010). Moving on with the economic sustainability, Penzenstadler et al. (2013) claim that it is important to constantly maintain and evolve software systems, in order for them to be economically sustainable throughout their whole life-cycle. At the same time, to obtain economic sustainability for the firm itself, competitive advantage needs to be maintained as well. Last but not least, in the environmental sustainability, by innovating, regular hardware upgrades could be avoided. In addition to all of the above, interrelationships between value aspects from the different dimensions of sustainability could be possible as well. Penzenstadler et al. (2013) categorize these interrelationships in three effects. First, positive impacts on a value aspect can have positive impacts on other sustainability dimensions. Second, negative impacts on a value aspect can have negative impacts on other sustainability dimensions. Third, positive impacts on a value aspect can have negative impacts on other sustainability dimensions and vice versa.

In other words, conflicts between value aspects could occur. For example, the most common conflict that one can think of is the one between the economic and environmental

dimension. Such conflicts and trade-offs could be solved by goal prioritisation (Penzenstadler et al., 2013). With the few last years as an exception, unfortunately so far, firms were always focusing mainly on the economic dimension. In the end, which dimension should be prioritised as most important is a decision that considers more scientific fields, not only software engineering.

3. Methodology

In this thesis work, literature has been reviewed in order to provide a theoretical background on the sustainability aspects in software engineering. Also, the case of the initiative Commute Greener! (powered by Volvo) has been studied. Case study was selected as an empirical method for research, because a case study offers in-depth understanding of how and why a particular phenomenon occurs, and can provide insights into how the cause-effect relationships occur (Flyvbjerg, 2007). In this particular thesis, case study has been selected in order to closely observe the sustainability aspects in requirements engineering in its natural context, an initiative that tries to do exactly that.

The type of the research methodology that was used in this case study is exploratory, based on Robson's (2002) classification. Explanatory research aims to find an explanation of a phenomenon in the form of a causal relationship mostly, as he mentions, but not always like that. In this thesis, the idea of having sustainability aspects in software engineering causes a series of effects and relationships that are going to be studied and examined. The research questions are raising this causal relationship themselves. The first research question is aiming to investigate the relation between the requirements of a software system and sustainability aspects. This is leading to the fusion of the two notions of requirements and sustainability aspects, and this relationship is causing a series of effects that this thesis is studying. The second research question is trying to answer whether there are any conflicts between the sustainability aspects that a firm is trying to include or achieve and the overall firm's goals in total. Also, in case there are actually conflicts, the second question will furthermore cover ideas on how they could be managed. Conflict is a form of a relationship; a relationship that connects two notions of contradicting interests. Conflicts are prone to enable a series of effects that this thesis is studying as well.

Concluding, the case study is trying to find out what is happening in a specific area of interest, seeking new understandings and generating hypotheses for new research.

3.1 Setting

Commute Greener! as a phone application was released in the spring of 2009 for Volvo employees. They could measure the time, efficiency and the environmental impact of their commuting. The application takes under consideration the CO2 footprint that people are registering, and the first results were positive for Volvo. Employees could reduce their CO2 footprint by 30% in only a month. Later in time, key partners supported this idea as well. The Commute Greener! initiative now is a global service with which Volvo aims to help individuals, companies, even whole cities around the world to understand how to commute in a greener way. The more people are joining the Commute Greener! initiative, the bigger impact they claim that we can have on the environment (Commute Greener!, 2009).

The case of the Commute Greener! initiative has been selected because it is a case that could illustrate the phenomena that this thesis is studying. Commute Greener! is an initiative that aims to change the behavior of people who are using their cars very often. This goal is translated to environmental and social sustainability by making people communicate about their reduced CO2 footprints. This thesis work aims to study the relationships between the requirements and the sustainability goals of software applications, and more specifically in the software application of Commute Greener!. Also, possible conflicts or tensions are going to be examined. The application of Commute Greener! is suitable for this thesis work, because its requirements are aiming to environmental and societal goals, and because of the fact that a company built this application, which could cause conflicts and tensions between these requirements and some of the company's goals. The application of Commute Greener! exists as a standalone smart phone application and as a Facebook application. None of the versions were examined separately, but the software system as a whole (in all platforms) was studied as the main ideas and goals are the same, according to the employees from Commute Greener!.

3.2 Data Collection

In this particular case study a survey has been used to aid the collection of the data in order to study. A survey is the “collection of standardized information from a specific population, or some sample from one, usually but not necessarily by means of a questionnaire or interview” (Robson, 2002).

The plan of the case study had the following structure (Robson 2002):

- Objective to achieve
- The case itself
- Theory
- Research questions that needed to be answered
- Method about the collection of the data
- Right strategy for collecting the data

Considering the objective, the case study is aiming to achieve the connection of sustainability aspects with requirements engineering through a real scenario. What is studied in this thesis (the case), is the phenomenon of companies trying to build software systems while taking under consideration sustainability aspects at the same time. Regarding the theory, examples of similar cases have been studied, documented and included in this thesis in order to make this study’s research clear for both the researchers and the reviewers (Runeson and Höst, 2008). The research questions were raised while studying the theoretical background of the previous studies and researches, and they are intended to be answered as this study develops. Additionally, it was determined from the design time of the case study that interviews will be used in order to conduct the survey, directly feeding the case study with the necessary data. Finally, the selection of the subjects that would have been interviewed was intentionally, although during the process, availability of the subjects played an important role in the selection strategy as well (Runeson and Höst, 2008).

An overview of the interview questions is necessary here. It was important to connect

the interview questions to the research questions of the case study itself, since this thesis studies a very specific phenomenon. In order to achieve this, the interview questions were divided in four groups. In the first group there were questions about the background of both the people who were involved in this initiative and the users of the software system. Since the people who were involved in this initiative were the first users of the software system from the earlier stages until now, they have been interviewed as users as well. Also, there were questions that could clarify basic concepts of this initiative's requirements that were directed only to the people involved in this initiative. The third part was trying to answer to the first research question. It included questions that are aiming to clarify the relationships between the requirements of the software system and the sustainability aspects that this initiative was trying to include or achieve. Finally, the second and the fourth part were made out of interview questions that were aiming to answer to the second research question. The second part of interview questions were focused on the value that potentially could be created for Volvo by this initiative, and also trying to find potential conflicts between some of the firm's goals and the sustainability aspects this initiative is aiming for. In addition to that, the fourth part comes to end this search for conflicts, along with trying to find a possible management for these potential conflicts.

The data was collected by interviewing people who were, or still are working on Commute Greener!. People who used the software application were interviewed as well. In this thesis work, eleven interviews took place (Table 1). Interviews, as method for data collection, have been chosen because questions have been asked to a set of subjects related to the areas of interest of the case study (Runeson and Höst, 2007). Semi-structured interviews were selected because, despite the fact that the questions were already formed in a structured way, they provide more freedom to the interviewer to choose the order of the questions even during the development of the interview (Runeson and Höst, 2008). They are helping to extract not only the information foreseen, but also information that was not expected (Seaman, 1999). Data (source) triangulation has been used in this particular case study. It has been used more than one data source to gather the information needed, people that were involved and people that were not involved had been interviewed, as literature about the initiative has been studied as well. Also, it has been used the first degree of data

collection techniques, according to Lethbridge et al. (2005). That technique suggests that direct methods have been used in the case study in order to collect the data. Furthermore, the researcher was in direct contact with the subjects, and collected data in real time. The advantage of this technique is that the researcher could control what data is collected, in what way it is collected, or the form that it is collected, at an important extent. Most of the interviews were face to face and recorded, one was via email and two were through Skype. First, the Managing Director has been chosen to be interviewed as the most relevant person to the overall idea of the application's requirements and goals. Later, the Managing Director indicated more associates to interview and as a result, more and more people were indicated by the associates to be interviewed. Users were randomly selected in order to give valuable information about their understanding and their behavior. It was decided that no more interviews would take place because no new information or viewpoint was gained from new subjects (Corbin and Strauss, 2008).

People who worked or are still working in Commute Greener! have been chosen to be interviewed because, among other responsibilities in the whole initiative, they were also responsible for the requirements that were finally implemented on the software application. Since this master thesis is examining the sustainability aspects on requirements engineering in the case of Commute Greener!, it was critical to interview this target group. Their answers and their opinions were used to answer the research questions that have described in the introduction part.

People that have used the software application of Commute Greener!, have been chosen to be interviewed in order to clarify if the implemented requirements on the application actually helped the initiative to achieve its sustainability goals. The answers and the opinions from the users did not help to answer any of the research questions; however, they were used as feedback for the goals and plans that people from Commute Greener! have. In other words, these answers were used to test, in a way, if the implemented requirements for the software application actually succeeded in their goals regarding sustainability.

Type	Position	Interview
Commute Greener! Employee	Managing Director of the Commute Greener! initiative	Face to face
Commute Greener! Employee	Solution Manager of the Commute Greener! initiative. (Responsible for the Road Map ,for the functions that are going to be included in the application and for the releases of the application)	Face to face
Commute Greener! Employee	Former Developer	Face to face
Commute Greener! Employee	Former Tester (Acceptance testing after every development sprint)	Face to face
Commute Greener! Employee	Supporting releases, Acceptance Tester, Communication on Campaigns	Skype Interview
Commute Greener! Developing Partner	Director of the Developing Company Partner	Skype Interview
Commute Greener! Developing Partner	Employee of the Developing Company Partner	E-mail Interview
User (Outside speaking partner)	Employee of a company that had an informal research collaboration with Commute Greener!	Face to face
User	Student	Face to face
User	Student	Face to face

User	Student	Face to face
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Table 1. People that have been interviewed for this thesis work. It showed the type of the person, if it was a user or an employee. It also showed the position that the person from Commute Greener! had or still has, and finally it showed the way in which the interviews were conducted.

3.3 Data Analysis

To analyze the data, qualitative data analysis methods have been used. As Runeson and Höst (2009) claim, the basic idea of the analysis is to derive conclusions from the data with a clear chain of evidence. That means that the reader should face no difficulty in following the conclusions from the data at any time. This requires a step by step walkthrough provided from the researcher to the reader. The questionnaire that was used has been updated by either deleting older not so interesting questions, or adding new more interesting questions and more depended on the people who are going to be asked on. More specifically, while performing an interview and listening to the answers of the subjects, notes were being taken in order to improve the questions asked, add new ones, delete old ones, or even group the questions better for the subjects that were about to be asked later.

Hypothesis generating techniques have been used in this particular case study. To begin with, after the data collection, the data was coded, meaning that parts of the text were tagged with a code that represents a certain notion. As Runeson and Höst (2009) mention, one code was assigned in many parts of the text, and one part of text was assigned in more than one code. Part of the analysis of the data was carried out at the same time with the data collection in this case study, in order to collect possible new insights that have been found during the analysis. Furthermore, during the analysis of the data, whatever new hypothesis was found in the data, they have been spotted and written down by the researcher. Specifically, after the collection of data from interviews, part of the data analysis took place that indicated some hypothesis. These hypotheses were used when more data collection took place from the interviews. As this iterative process continues, a small set of generalizations is taking shape and in the end all these generalizations produce a complete body of knowledge which satisfies the research. Also, the technique of “constant comparisons” has been used in order to analyze the data (Seaman 1999). The data was coded according to the interview questions, and after several iterations of comparisons, it was organized in the different categories that the interview questions are grouped into. The comparisons took place in order to finally categorize the data under the research questions.

4. Results

Research Question 1:

“What is the relation between requirements and sustainability goals in a software system?”

In order to be able to answer this first research question in the context of this case study, attention must be given to how the requirements of the software system were spout.

Technically, the application of Commute Greener! is an iterative approach regarding software development. Teams were working with agile ways, including sprints. On each sprint they were having different requirements to implement from a backlog. Descriptions for agile techniques are available online (Mountain Goat Software, 2012). Also, they are working with different collaboration parties, customers, like NGO's (non-governmental authorities) or public authorities, and they shape different requirements for the application.

According to the people from Commute Greener!, this initiative is trying to change the behavior of people, considering their CO2 footprint. Today, existing initiatives are trying to achieve that quite manually, as the Solution Manager claims. They are interviewing a group of people to find out what they do and what their behavior towards the environment is, then they run a campaign and then they are conducting interviews again to get the feedback of the people. After that, they can evaluate their work. Commute Greener! is trying to automate that. With the application, people can instantly keep track of their CO2 footprint and Commute Greener! employees can use this data for evaluation. Another different approach with the application is the fact that it was introduced the idea of rewards and competition for people who are using the application. Therefore, more people became more attracted by it. In other words, the gamification of the campaign, to give rewards and enable people to communicate these rewards with others, made Commute Greener! attractive. Gamification is “the use of game design elements in non-game contexts” (Deterding et al., 2011).

CO2 emissions reduction and improved air quality, as it has been mentioned before, are the main targets for environmental sustainability, regarding the goals of Commute

Greener!. From the societal perspective, people of this initiative are trying to change people's behavior in a positive way. Many negative ways have been tried before, like tolls for the vehicles that are entering the city center, parking fees, ban of driving cars with a specific license plate number on specific days, and people are trying to find solutions to go around these negative measures, the Managing Director states. For example, if people are allowed to drive their cars through the city center on Mondays, Wednesdays and Fridays they usually buy a second car so that they can drive the rest of the days. This is not very effective. Commute Greener! is showing a positive way that people are more likely to follow. So, a societal requirement was implemented by introducing competition based features and reward people when they are reducing their CO2 footprints. In this way, this initiative is attracting people to use the application, comments the Solution Manager. Also, by providing a platform for the users to be able to communicate the rewards that they are getting when they are commuting less CO2 and make them compete with each other, is another way to indicate how the application is aiming to social sustainability, a tester of the application claims. Moreover, the feature that allows car pooling, the possibility for users to share a car for their journeys, was a requirement that was aiming to social sustainability as well. People who are using the Commute Greener! application are motivated to think about limited resources on the one hand and on the other hand they are allowed to collaborate with teams/initiatives, a developer claims. Also, by getting people into public transportation and reducing the cars in the streets, transportation becomes a lot easier and faster in the city, and that is helpful from a societal point of view.

The requirements aiming for sustainability were those that measure the daily/monthly CO2 footprint of the people who were using the application. In an early version, it was a feature implemented that required from the users to input the emissions of their cars in order to keep track on them, but it was really difficult, because almost no user knows that. That is why people from Commute Greener! decided to generalize by using data from different cars and have a standard CO2 emission for a car, a bus, a tram etc., a tester claims. Moreover, flight emissions were included as well in an older version of the application, but people from this initiative decided to scale down the application to make it more accessible, including only routine, weekly journeys of the users. Going back to the requirements that are aiming for

sustainability, they were there from the beginning, in 2009, but they were targeting only people working in a company, employees. So, these employees could measure their CO2 footprint and compare it with other colleagues. Therefore, whole departments could compare their results with other departments under the same company and in the end, companies could compare their results with other companies, or even the same company in different cities or countries could compare their results. Those requirements were aiming to change the behavior of the people by using gamification techniques, instead of carrots and sticks, as the Solution Manager claims, increasing the use of the application as well with this kind of techniques (Zichermann and Cunningham, 2011).

Classically, there are three main categories of requirements regarding usability that the industry is working with, when firms are developing software systems according to the Managing Director of Commute Greener!. The first is desirability, considering why a user would want to use the application. Second, technical feasibility, including the features of the application and/or in what devices they will be installed. The third is the viability that speaks about the cost to achieve the implementation of the application, including the type of the platforms that would be installed, in how many languages it would be translated and so on. What is not there that much, according to the Managing Director, is how a company can have benefits from a software system, in which sustainability requirements are implemented.

From sustainability point of view, Commute Greener! application had 3 generations of different requirements. Initially, individuals as users are recording each journey that they make. Eventually people involved with this initiative understood that users were not very interested in recording every day's activity in a singular way. Explaining that, there was not much of effectiveness on changing people's behavior towards the environment by just recording their journeys. Then, people from Commute Greener! moved to the second generation of requirements, where users need to report only deviations and differences from their normal way of transportation. For example, if a user is going every day to work by car and one day he/she decides to take the bus, then he/she can record the journey. And the third generation was to encourage positive changes and improvements in people's behavior. The idea of points and credits was implemented in the third generation of requirements for the application. The reason for all these changes was that they wanted to improve the impact of

this initiative on the environment, therefore to change people's behavior. In order to do that, they needed to attract more people to use the application and more investors. For example, considering that investors are expressing their interest in reaching out to people in a specific area, they can influence the use of the application by these people. If they are able to provide rewards to people who are using the application, then more people will be attracted to use the application. Also, people who are already using the application could communicate and invite other people to use this application as well.

Asking the Managing Director about the results of the initiative towards sustainability and the possible ways to measure them, he speaks about the fact that they noticed reductions in people's CO2 footprints in the percentage of even 30%. One employee who was involved in the communication on the campaigns also agrees on that. Of course, as she mentions, people could cheat the application and lie about their emissions. They do not have a way to understand any false registered emissions. Individuals and departments that are changing their behaviors for one day per week are reducing their emissions up to 20% and they measured that if people are changing their behaviors only for even one day per month, they can still reduce their CO2 footprints up to 5%. And the way of not pushing everyone to do exactly the same, to change their behavior for one day every week, but letting people freely decide when and what are they are going to do, helped the company to achieve their sustainability goals. Contrary to the Managing Director's opinion, a developer claims that given the overall number of users, the impact from the initiative's goals is still too limited. Additionally, the Solution Manager states that the budget for the Commute Greener! initiative has been lowered. This has as a result for the initiative to prevent it from achieving its goals, possibly all of them. He states that the people from the initiative were planning to do more campaigns to other cities, to other companies, but unfortunately, the finances did not allow that. They know that people changed their behaviors when they run the campaigns and the results were positive, but they also know that people will fall back into their old behavior once the campaign stops. They did not have any indication for this assumption, but the Solution Manager's opinion is that they usually do after some weeks. For the time that the people from Commute Greener! are running the campaigns, people are changing their behavior and people from Commute Greener! are getting the results they wanted. In the long run though,

people would need new challenges in order to continue to give the same results.

Considering the requirements that aim to sustainability, the Managing Director states that it was more like setting up the initiative, releasing the application with only implemented the requirements that were covering the functionality of recording the user's journeys in a singular way, "*listening*" to what people have to say, and afterwards formulating the requirements for sustainability in a better way. So, their requirements were mostly formed from the feedback that they got from the users. In addition to that, a developer stated that Commute Greener! is achieving its goals due to these requirements for the application, like the rewards, the feedback to the users, the possibility to share results with others.

In the question if there is anything more to be done in order for the initiative's goals to be completed, the Managing Director stated that they would stop when we, as humans, will stop fighting for the environment. So, clearly, Commute Greener! is still active, and people are working towards sustainability. The Solution Manager argues that there is more to be done in three major areas. First, there is more to be done on informing the users about how they could change their behavior regarding CO2 emissions. Second, to give them alternative and positive solutions like car pooling, bicycling and so on. Third, there is more to be done by giving the users monetary rewards. Discounts on some goods, for example, for the positive change of their behavior is something that was always attractive to users of any kind of service or activity. But as the Solution Manager stated, someone needs to pay for this kind of rewards, and right now, Volvo is not willing to give this budget to Commute Greener!. Mainly, there is a need for more funding from Volvo in order to be able to continue with their campaigns and/or expand to new ones, as a developer stated. In addition to the need for more funding, an employee who was involved with the support on new releases of the application, was participating in acceptance tests and was working on the communication on the campaigns, stated that there is a need for a systematic user feedback to make the application more usable and more desirable to the users. But still, because of the lack of funding, they cannot have this input from the users, as she stated. Supposing that they had the money that they needed, according to her, they should try to have more campaigns to inform people about this initiative, or organize systematic user feedback in order to make the usability of the software better. Moreover, one tester stated that he would like to see more

interaction between the users. Commute Greener! can achieve that by investing more in the gamification techniques, in his opinion, and by making the application more interactive. Also, he believes that there should be given more attention to the people who are already using only the public transportation or bicycles. It has to be mentioned that in this point, after the involvement of this developer with Commute Greener!, a reward system has been implemented on the application for the people who are already using public transportation or bicycles, as one employee that was working on supporting new releases mentioned. She stated that because of the fact that users who are already using public transportation or bicycles they are no more interested in using the application. So, people from Commute Greener! introduced a rewarding system for them as well, for example they are rewarding people as the best bicycler of the week. But still, until now the new functionalities have not been presented to a campaign. She claims that new features will be presented on a new campaign on the European Mobility Week this year in Sweden. Several counties will be able to compete each other for reducing the CO2 emissions from the 1st of September until the 22nd of October. As a developer and a tester claim, it would be optimal to have more users, and one way to do that, in their opinion, is by extending the selling activities to attract more users.

The Managing Director and a developer are claiming that they are still active in the requirements elicitation. The developer mentioned that they are trying to understand requirements from cities and corporates. The Solution Manager though argues that they are not active in requirements elicitation, but if on a running campaign, on a city or on a corporation, a new requirement comes up, they are willing to take it under consideration in order to help the implementation of the campaign. In other words, only if something needs to be done during a running campaign, people from Commute Greener! will take care of it, according to the Solution Manager.

As a result, it is the Solution Manager that claims that Commute Greener! has helped people to see how much good they have done by seeing how many trees for example they saved, which is a feature in the application. He also expresses the hope that people will see the environmental problems through this initiative by using the application and seeing their own personal emissions. Most of the people, he claims, do not even know how harmful their

actions are. They see big, generalized numbers on a European and world level, and they do not even realize that they are also harming the environment on a personal level. The application's implemented features might help people realize this aspect, and hopefully they might see how easy it is to change their behavior. Specifically, all of the developers stated that the application helped them realize how much CO₂ they are producing by commuting, and that they are now trying to produce as less CO₂ emissions as possible. It changed their commuting behavior. An employee from Commute Greener! stated that she is more aware now of how much CO₂ she is actually producing personally. Also, a developer claims that he is trying to make Commute Greener! a part of his work, wherever it is possible.

Regarding the results for this research question from the users' point of view, it needed to be shown what the users understand for the Commute Greener! Initiative, and what its goals are. Then, it has been asked from them with different interview questions to describe, if possible, the relation between requirements and sustainability goals as they observed it in this initiative.

For the users, the perspective and the goals of Commute Greener! were clear, according to the interviews that have been conducted, which is to make them change their behavior and reduce the CO₂ emissions. They faced some difficulties in understanding how the application is actually working. Also, one of the users expressed the concern of the hypothesis that people might completely change their behavior and never take their cars again to go to work. They would use only busses, trams, or bicycles for example. This question has been written down, and has later been addressed to people from Commute Greener!. One developer stated that it has not been implemented something special for this occasion. There are some rewards like the best biker of the week and similar prizes and badges, but there is nothing more that Commute Greener! is giving to these people. The developer supported the idea that it should be something more to be done for these people.

Another point that has been notified by some users is that the general idea from the initiative is not clearly presented. Excluding the email notifications that they are getting, it is not really obvious for some users what to really do with the application. For example, there was one user who was going to work with the bus, and the application suggested that he leaves the bus and shares a car with other users, which is not sustainable according to the

user's opinion. Also, most of the users mentioned that initially, the application was not easy to understand. They faced difficulties on understanding what they have to do in order to start using the application. Furthermore, most of the users found it hard to translate the information of how many trees the application claims that they saved by reducing CO2 emissions.

Users who do not own a car and go with the bus, or tram to their work did not find the application educative, or much of a help. And that is because they do not really have a choice, as they explained. Considering though the hypothesis of owning a car, they have been asked what they would do, they would still use the public transportation, or their cars, some of them answered they will definitely use public transportation because of the congestion in the city. One user stated that she would consider the application educative because it shows you how easy it is to actually change your behavior and use public transportation. On the other hand, some of them answered that they would prefer their cars for more convenience, but they might consider the idea of the alternative solutions that Commute Greener! suggests, because the application made them think that way. They feel like the application makes them consider their behavior, regarding their CO2 footprint, at least one day per week. Also, a user stated that there is the type of people that are not very far away from changing their behavior, and they only need a motive. Commute Greener! could be this motive to make them stop using their cars that often, and use public transportation more often. This user also stated that the application was not very educative because the numbers of the CO2 emissions from the cars were not correct. The numbers were fixed for every kind of car, so the information to the users was misleading, he claims. Also, when users get feedback about how many trees they saved, it is not very educative as well. This information is very general and not very helpful for the people to understand what exactly they have been doing by changing their behavior, and this has been noticed by other users as well.

Most of the users have chosen as the most important and favorite feature the gamification techniques used on it. They felt motivated by the possibility to get a reward for their behavior and also by the fact that they could communicate the rewards with other users. They claim that these techniques could even make users start paying attention to the rewards if they haven't done it before, because other users that are gaining rewards could start teasing them and make them compete with each other in the end. An early user stated that it

was a very interesting application, because he could see how much CO2 emissions he personally really releases into the environment, and he saw that he had space for improvement. Another user agrees on that, by claiming that it is very helpful to actually see how much of CO2 emissions a person produces, set a goal of how much of CO2 emissions that person wants to reduce, and see in the end the results of their actions. Another good feature that this user indicated was the social communication that users could have with each other. The publicity and the recognition of who commutes greener are features that could be important to some people. But some other users might not like this kind of publicity, he mentions. This kind of users could be happy, though, by the rewards and the badges that they might win, without going public with their results. As he claims, not everybody can be pleased with the same features.

Finally, users have indicated more features that they believe the software system could provide. There were some ideas that could feed the initiative with sustainability goals and be implemented through new requirements. What they suggested is to extend the application for use in the house as well. For example, to suggest greener ways to do your laundry, to cook and in general support a greener behavior inside the household. Also, some improvements could be useful on the application that would consider the people who are using only the public transportation, according to some users. Another point that was made by a user was the fact that it would be more preferable for the users to change their journeys easier. Moreover, the user who had the role of the outside speaking partner indicated some well-thought improvements. First of all, he mentioned that it would be a good idea for the application to give something more useful to the people who are using it. Right now, people have to give the input to the application manually every time that they are doing something differently. This is not very attractive, because when the application does not give the users something for them of use, they will eventually stop using it that often, or even maybe never use it again. He mentioned examples of how the application can provide information to users, for example in case that somebody is driving and sees a police officer in the road, they can input the information to the application for other users to see that and they can lower their car's speed. This, in his opinion, is something that will keep users constantly using the application. Also, according to that user, it would be more educative to provide more

information when users are getting feedback about how many trees they saved. More text like why it is important to save the trees and how exactly users helped the environment, for example by not producing more CO₂ to the atmosphere and by this action helping in not increasing the temperature of the planet and so on. Furthermore, the most important feature that could be included, according to the same user, is that of automatic detection of the means of transportation, a user is using in real-time. This kind of technology was not available when this initiative started, but it is now. So, it would be more accurate to the calculations of the CO₂ that users are producing, and users would not have to report their journeys every time and what means of transport they used. All of the above were potential features with sustainability aspects that were introduced by users. What is important to mention is that the already implemented requirements that are connected to sustainability goals prepared the ground for new ideas coming from users that could possibly relate to new requirements for the software system.

Research question 2:

“What sort of conflicts between the requirements of a software system and a firm's goals are rising, while aiming for sustainability and how can they be managed?”

This research question is referring to conflicts that might or might not exist between the requirements and the firm's goals of this particular system, while aiming for sustainability. To answer this question, the values of both the initiative and the firm need to be clear.

One way that the interviewees consider that Commute Greener! is valuable for Volvo, is that when a city has better transportation infrastructure, customers can buy Volvo's busses and trucks. If a city is having major problems in transportation, measures have to be taken in order to solve the congestion. If there are no alternative solutions to change people's behavior in a positive way (encourage the use of busses, trams, bicycles), like Commute Greener! for example, cities will have to take effective measures without caring to make them attractive. So, fewer customers (companies) will buy trucks or busses for example because the only way to enter a city could be by trams or subway. Another way of seeing how valuable Commute Greener! is for Volvo, is that it made people aware of their CO₂ footprint and therefore brought an easy solution for reducing it to their consciousness. According to one developer, that could make Volvo a more environmental friendly company in the eyes of the customers. In the end, one can observe two kinds of rewards; direct impact on people's awareness for the environment and a possibility in the long run to make customers buy more of their busses.

Considering the fact that Volvo is selling busses and trucks that are using petrol, an interesting question was whether Commute Greener! has a negative impact for the company. People from Commute Greener! disagreed and stated that combining the core values of the company (Volvo Group Global, 2014), the long term perspective that the company desires to exist for at least as many years as they already do and the better utilization and efficiency of transportation, Commute Greener! is not having any negative impact for the company. They are claiming also that there are too many cars in the cities today and nobody wants to sell congestion. Also, it is not efficient to have an empty bus on the streets. So, with the combination of the above three features, they believe that they are helping people to behave

in a more sustainable way. Another interesting argument that people from Commute Greener! used in order to answer the above question, is that they are not the same company that produces cars. So if Volvo cars are selling more cars it does not affect Volvo Group.

Considering the monetary profits that Commute Greener! might have provided to the Volvo company, people from the initiative see that the answer to this question is complicated. Looking into the bottom line, this initiative has not yet provided direct cash flow to Volvo, in relation to what it has been invested and to what Volvo aimed for initially. But it is mentioned in the annual report as a good initiative, and helps to generate sales for busses as it has been described above. Volvo sees the Commute Greener! initiative as a very young initiative and it still has to be evolved. An employee who was working on supporting releases of the application, mentions that in every project and initiative from Volvo there are people that are helping on selling their products, but Commute Greener! does not. Also, by selling Commute Greener! campaigns to cities and other companies, it made the initiative to be almost a self-sustainable business on its own. Another way to think of an indirect monetary profit was expressed by a developer; better environment means better health of the people, better health means more people can come to work and be more productive, so Volvo employs more people, and therefore this could be translated as an indirect source of monetary profit.

Having all the above in mind, there is an issue if there was any possible conflict between the requirements that are aiming for sustainability and the goals of the company and if there was, how they could be solved and what sort of trade-offs, if needed, took place. In such a question, the Managing Director of Commute Greener! answered that there is no conflict at all. Looking again at the core values of the company (Volvo Group Global, 2014), the desire of the company to stay on business for long time and the efficient use of transportation (as all mentioned already above), he claims that there was no such thing as conflicts in the requirements, while aiming for sustainability. He clearly mentions a comment from Dr. Lee Shipper (Stanford, Nobel Prize) “Commute Greener! can help to reduce the conflict between the economic development and environmental sustainability goals”. People from Commute Greener! are not supporting the idea of “stop using your car forever”, but the idea of “use your car less, or/and in a more efficient way (car pooling for example, where more than one person can use one car to go to the same place instead of everybody uses

their own cars for the same destination)”. If everybody owns a car and wants to use it, it would be impossible because of the huge congestion in the streets. In the end, as a developer claims, the main idea of making Commute Greener! was never to sell more busses.

In the application, there is an option to walk your journey or take a bicycle. That was mentioned in the interviews as a possible point of misunderstanding. The application actually rewards you more if you walk/bicycle, second in rewarding comes the trams/trains and third in place comes the busses. Considering that Volvo is producing busses and not bicycles, trams, or even trains, the Solution Manager of Commute Greener! explained that it could be misunderstood as a conflict. From his point of view, after talking with users, they are quite sure that if they did not reward the bicycles, trams and trains at all, or even reward more the busses than the bicycles, or trams and trains, it would risk the confidence of their users. They would look at Commute Greener! as just a marketing campaign for Volvo and they would not use it. It would risk that this initiative would be seen as a green washing business, and that is the least preferable way that people from Commute Greener! would like it to be seen as. Also, the fact that a user has the option to walk their journeys, or even take the bicycles or the trams, does not oppose the effort that Volvo is making to sell busses and cars. This is happening mainly because of the distance that users have to travel, argues the Manager Director. For example, there are places that a tram does not go and there are places (like outside of the cities) that no user would prefer to take the bicycle. Also, it is a matter of the weather conditions and the time a user has for traveling to their destinations. For example, if it rains a lot, or someone needs to go in another city at a specific time, of course a car or a train would be an optimal solution, rather than a bicycle. The problem that Commute Greener! is trying to solve, mentions the Managing Director, is focused on those people who are taking their cars to go everywhere. Even to small journeys, people prefer to take their cars to travel. This initiative encourages and rewards alternative and more environmental friendly solutions for the people to make their journeys. Even if there is a journey of 20 km, most of the users will argue that it is a long way to take the bicycle to go to work for example. Still, Commute Greener! encourages to take the bicycle for a short way, then leave the bicycle and take the bus/tram for another part of the way and reach to a place that there is a car pool, for example, and share a ride with colleagues and finally go to work. This could be considered as an

improvement of the people's behavior as well.

In the end, the Managing Director clearly states that if you treat each requirement, each aspect separately, there are no real conflicts between them. Examining all together the aspects theoretically, it is possible to have some conflicts. He claims that in sustainability user, financial and technology requirements all need to be balanced. So, if a requirement is isolated and not compared with others, while working with it, there will be no conflicts at all. And specifically Volvo Group is not facing a conflict when Commute Greener! is actually suggesting to people, or even reward them more, to take their bicycle. This is happening because of the distance. People cannot go everywhere with their bicycles and not every day. But they could use their bicycles in order to produce less CO2 emissions in the environment by making small journeys to work for example, for some days every month. Considering Volvo Cars, as it is a totally different company, as people from Commute Greener! explained many times, they do not have any conflict as well, the Managing Director explained, because they do not want to sell congestion. Commute Greener! focuses on changing the behavior and does not speak about ownership. They do not say to people to stop using their cars when they want to go on vacation, or to go somewhere on the weekend. They are trying to grow awareness to the people to reduce their CO2 emissions. Also, an employee from Commute Greener! supports the idea of maybe in the future, regulations from country or city authorities might force companies to include sustainability aspects in some of their products and business. That would make it easier for the companies to finance more of this kind of applications. In addition to the above, the Solution Manager supports the idea that if a company's financial state is not facing difficulties, then these applications that are aiming for sustainability would not face any conflicts with the monetary goals of the company. But if a company is facing financial problems, they would rather go for solutions that they have already tried before and had profits with, than go for applications with a level of uncertainty in profits in the short run, as these applications with sustainability aspects might have. That is the only case when the monetary goals of a company could stand against the requirements for sustainability in applications like Commute Greener!.

Moving to the users' results for this research question, it is requested from them to indicate their understanding for what is valuable for the firm and what the purpose of the

initiative is from a sustainability point of view. Then, it can be investigated if there are possible conflicts between the requirements of a software system and a firm's goals while aiming for sustainability.

Regarding the question if this initiative is considered to be valuable for Volvo, users agreed that it could be. Some users claimed that it would extend the reputation of Volvo that follows a sustainable strategy, and in this way more people would be interested in this brand. Also, the fact that healthier people would go to their work, meaning more productive employees if they are in a good state of health, that could count as a positive value for Volvo as well. On the other hand, some users believe that because of the fact that Volvo is producing cars (some users do not know that Volvo Cars is not the same company as Volvo AB), trucks and busses that use petrol, this initiative might have a negative impact on the company. User's concern is how a firm that produces cars is telling people to stop using their cars. In their opinion it is counter-productive. In the long run though, people would not stop buying cars because of any initiative, the users claim. Even though the differentiation has been made for them to know, they still think that it is counter-productive because trucks are using petrol as well. However, there was a user that, as people from Commute Greener! did, referred to the Volvo AB and the Volvo Cars as two separate companies. So, he supported the idea that it could not affect Volvo (as the company that made this initiative) because they do not sell cars. As an addition to the value for the company, users got confused by the fact that by using the application you can get more rewards by using a bicycle rather a bus. In this point, a user thought that if more people are using bicycles, then more seats on busses will be empty. Therefore, people that would not think of getting on the bus because it is too crowded, might consider getting on the bus again and eventually use the bus as an alternative means of transport. In this way, Volvo is capturing monetary value indirectly by selling more busses to the companies that have a contract with cities that require more busses for the people.

Considering the monetary profit coming from this initiative, some users do not see that there is any. They support their belief by saying that there is no direct profit from the application because it is for free, and they do not see advertisements about Commute Greener!. Instead, some other users believe that healthier employees are working better, so in this indirect way, this initiative might help Volvo have monetary profit. Also, a user

mentioned that because of the fact that Volvo is producing busses, this initiative could indirectly lead Volvo to profit by selling more busses, if eventually people will be using public transportation more often. Moreover, this user also stated that the application was sold to cities and companies, so there was a direct monetary profit from the initiative.

Asking the users if this initiative was helpful for the society, all of them were positive. Especially one user stated that by indicating to users that there is a small difference by changing their behavior in producing less CO2 emissions, it might provoke more people to go on that direction, and then more people will see that through the application, and might go on that direction as well. Eventually the whole world, according to that user, could actually change their behavior, because of some people who decided to start producing less CO2 and published their change of behavior. In this way, the software application of this initiative is creating awareness to people.

Contrary to what people from inside Commute Greener! believe, some users expressed the opinion that this initiative does not help them change their behavior towards the environment. The main reason for this answer was because they have already been educated by so many other initiatives and projects that they are already educated and have already changed their behavior. Also, according to a user, because of the fact that the application is not providing enough information on how users are contributing to the environment, it is not helping people to change their view for the environment. Moreover, the fact that they removed the feature from the application that every user should provide the amount of CO2 emissions from their cars is affecting the credibility of the application's results. Consequently, users who would know how much CO2 emissions exactly their cars are producing would not learn something more from the application, or they would not change their commuting behavior because of the application.

Commute Greener! might affect people in their work, according to some users. They think that sharing a car for example and not taking their own car might be a burden, because of the fact that they have to arrange their journeys depending on the person who drives the car. On the other hand, some users did not see how sharing a car could be a problem in the timing for going to work and back, because they have done it before. Also, a user stated that despite the fact that the application of Commute Greener! did not affect him in his work,

another application that used some components of Commute Greener! (like the gamification techniques, and, more specifically, the rewards that users would get by using public transportation) affected him on taking for example a bicycle to go to work more often because of the award that he could get. But there is a difference here. The other software application was offering monetary rewards, like discounts for example, to users who were using public transportation. Something that Volvo had no interest in.

In general, applications like Commute Greener! could be more popular in the future, users are claiming. They have seen a lot of websites that are supporting communication between users in order for them to share a car to go to work for example. A user stated that they would be more popular because of the fact that they are raising awareness to the people of what they are doing to the environment, and how they could change their behavior. On the other hand, a user specifically stated that there is a conflict that concerns the publicity of the personal data. For example, some users might feel threatened by the application that would publish their daily journeys and their commuting behavior. Moreover, if police would subpoena a company in order to get access to some data about a suspect that used Commute Greener!, a lot of users would stop using the application, and a lot more users would consider twice to use it for the first time, according to the user's opinion. He hopes that the privacy issue will be managed in a way that will allow people to trust this kind of software applications.

In the end, users believe that requirements that aim to sustainability can co-exist with the monetary goals of a firm. They do not see any harm on making money out of a product or a service that is sustainable or focuses on sustainability aspects. According to a user, companies like Volvo, that produce vehicles, could always use different technologies on them and have less CO2 emissions, and people still buy from them. There could be a conflict if the profit out of this kind of applications was not enough to cover the costs, but the users are claiming that even then, companies should go towards sustainability. More specifically, a user argued that in short term, Commute Greener! application is not providing enough direct profits, but it could. He suggests that companies that are developing this kind of applications, which are gathering data from a lot of people, could alter their business models and sell their data to other companies, like public transportation companies and cities in the case of Commute Greener!. But Volvo is not interested in doing that because it does not contribute to

the company's vision, in his opinion. He suggests that Volvo could invest a lot of money in advertising the idea of the Commute Greener! more, so that everybody would use the application and change their behavior and eventually use more busses. Then, Volvo would have an indirect monetary profit by selling more busses.

5. Discussion

The discussion that is presented in this section concerns specifically and only this particular case study, and cannot be generalized for any other software application that aims towards sustainability.

Research Question 1:

“What is the relation between requirements and sustainability goals in a software system?”

Johann and Maalej (2013), as it was mentioned in the theoretical background, claim that software systems are influencing all three aspects (according to the United Nations document, 1987) of sustainability. According to them, software systems have affected the economical processes. They might have a positive or negative impact on the environment and they have changed the way that people communicate and socialize. In this case study, it has been the last two interferences that have been noticed in the software application. The goal of the whole initiative was to change people's behavior regarding their CO2 footprints. That is a direct, positive impact on the environment. This goal was implemented on the software application, the Managing Director and the Solution Manager claim. Users that were interviewed also consider changing their behavior and start using public transportation means or sharing a car more often. Also, employees from Commute Greener! were aiming to make people socialize and communicate through the application in order to increase the use of it, and to make users suggest other people to use the application as well. That was achieved by the gamification techniques that have been used, states the Solution Manager and a developer. They stated that people could communicate their rewards that they would get by reducing their CO2 footprint, and therefore socialize. That was also notified by the users, who liked the idea of competing with other colleagues and friends. In this way, the software application managed to have an impact on the societal aspect of sustainability.

Johann and Maalej (2013) also stated that software applications (like Facebook,

Twitter, etc.) lately supported people to have democratic discussions without being limited by any kind of hierarchy. In the software application of Commute Greener!, features like the rewarding system, users being able to communicate their rewards, or sharing a car with somebody else, allow people to socialize and communicate without any boundaries of hierarchies.

Furthermore, Johann and Maalej (2013) notify that it is more effective to have feedback from users in order to improve or extend the functionality of a software application. The involvement of the users in forming new requirements in a software application contributes to the social aspect of sustainability in requirements engineering (Johann and Maalej, 2013). Looking at the Commute Greener! software application, the Managing Director mentioned three different generations of the application. What made them form new requirements in order to change, improve or extend the features of the software application was the communication that they had with the users. It is better to listen to user's opinions and reform constantly their backlog with requirements, the Managing Director argues. Also, considering accessibility as another important social aspect for software applications according to Johann and Maalej (2013), the application of Commute Greener! took under consideration the people's knowledge. In an early version a requirement that was implemented was for the users to enter their car's CO2 emissions by themselves. That was not very useful because not everybody knows how much CO2 their car is producing, a tester claims. Eventually people from Commute Greener! changed that requirement and made the application more accessible to people by having fixed CO2 emissions for every car. That decision was made after research in their data about how much CO2 emissions different cars produce. That was a direct impact on the social perspective of the software application because it made it more accessible for even more people to use it.

Penzenstadler et al. (2013) in their work try to add value aspects in all four dimensions of sustainability in the Software Value Map (Khurum et al., 2013). One of these four dimensions that try to add value aspects is the social dimension. Considering this dimension, they are indicating that it could be included the improvement of the community support. Commute Greener! application confirms that this is a reasonable addition, because of the requirements that were implemented for car sharing options and for the communication of the

rewards of the users, according to people from this initiative. Users found it very helpful to have positive alternative suggestions about their journeys in order to commute less CO2 emissions.

Moving to the conclusions for this particular case study, it has been noticed that there is a direct connection between the requirements of the software application of Commute Greener! and the sustainability aspects, according to both the interviewees and to the theoretical background. Examples of requirements that are connected to sustainability aspects have been given in the *Results* section. It has also been noticed that users clearly understood the sustainability goals of the application, which means that the requirements that were implemented were aiming for these sustainability-oriented features. Finally, a clear answer to the first research question can be given. There can be a relation between requirements and sustainability goals in a software system, as it has been shown in this particular case study. This relation is direct like any other relation between requirements and goals for a software system. Like any other goal that a software system has in order to be achieved, the requirements that have to be implemented are mainly depending on the current technology, companies' decisions and end users' needs. Additionally, as it has been notified in this study, the increased need for taking care of the climate and the awareness of the global pollution is another factor that contributes to the relation between the sustainability goals and the requirements of a software system. It is this trend of trying to decrease the pollution and the serious negative effects that CO2 emissions have to the environment, that are defining the need for companies to try to achieve sustainability goals.

Research question 2:

“What sort of conflicts between the requirements of a software system and a firm's goals are rising, while aiming for sustainability and how can they be managed?”

An interesting point that emerged from this case study was that neither people from Commute Greener!, nor users of the application noticed any conflicts between the requirements that are aiming for sustainability goals. As the Managing Director stated, if each requirement was being dealt with separately from the rest, there would be no conflicts. Therefore, he leaves open the hypothesis that the effects of implementing one requirement might affect the implementation of another in either positive or negative way. Users expressed the opinion that they cannot see any possible conflict between the requirements that are aiming for sustainability and a firm's goals. More specifically, they do not see any obstacle in making money out of something that supports sustainability aspects, a user stated.

Contrary to what people of Commute Greener! claimed and what the users stated, there is a sort of conflict between the sustainability aspects and the firm's goals, according to this study. In relation to the theory, Penzenstadler et al. (2013) claim that there might be interrelationships between the value aspects that they are trying to add in the Software Value Map. One kind of these interrelationships is that positive impacts of one value aspect might have negative impacts on other sustainability dimensions and vice versa. This has been observed in this particular case study. As the Solution Manager claims, despite the fact that everybody (including him) denied any conflicts between the requirements that are aiming for sustainability and the firm's goals, there has been funding reduction to the Commute Greener! initiative. The possible reasons that people inside of Commute Greener! mentioned are that they do not have enough profit from this whole initiative. The Solution Manager, a developer and a tester mentioned that the year 2013-2014 was bad, economically speaking, for Volvo. The Solution Manager explained that because of this problem, Volvo had to focus more on the products and services that have more certain and secure ways of giving profit to the company, and cut the financing to initiatives and projects that do not offer a certain level of security for revenue streams. Concluding, the software application on which requirements that

were aiming to environmental and social sustainability were implemented, was not providing profits in the desirable certain and secure way to the company. In other words, the Commute Greener! initiative and its application could not establish the economical sustainability that Volvo needed, for the specific time given, so the company decided to cut the funding on this initiative. This is translated as a conflict between the requirements that aimed towards sustainability in a software application and a firm's goals.

In the end, a clear answer to the second research question can be given. Although it was not mentioned by the interviewees, a conflict has been noticed between the economical sustainability of the firm and the environmental and social dimension of sustainability. Because of the fact that no conflicts have been noticed by either the people from Commute Greener!, or the people who were using the application, it is not possible for them to find solutions for the particular conflict that was noticed in this case study. However, Penzenstadler et al. (2013) in their work suggest that possible conflicts can be resolved with goal prioritization. In this particular case, as it was noticed, Volvo decided to prioritize the economic sustainability of the firm against the environmental and the social dimension of sustainability.

6. Limitations

First, this thesis work is delimited to only one case study in order to examine the relations between requirements and sustainability aspects in software systems. More specifically, it is narrowed down to the case of the Commute Greener! and the software application that is derived from this initiative.

During the phases prior to the analysis, the validity of the thesis has been considered and addressed. In the time of the analysis of the external validity it has been notified that the findings of this study can be of use to other studies and researches. This had as a result to try to have an analytical generalization (Runeson and Höst, 2009) aiming to have results that can be used by studies with common characteristics, or the case itself can be used by other cases with similar findings. The validity of this case have been improved by trying to have subjects to interview from every possible stakeholder of this case and triangulate their answers. In addition, it has been improved by the review of the collected data and results from the case subjects.

7. Conclusions

In this thesis work, a case study of the Commute Greener! initiative was presented in order to understand the sustainability aspects in requirements engineering. Regarding to the first research question, the findings of this thesis work indicate that there can be a direct connection between sustainability aspects and requirements engineering. As it has been shown in the results, people from Commute Greener! mentioned high-level requirements of the software application, that were related to the environmental and the social sustainability. Considering the second research question, findings from this thesis work indicate that there might be conflicts between the requirements of a software system and the firm's goals, while aiming for sustainability. In this particular case, the company that produced the software application decided to cut the funding for the whole Commute Greener! initiative. Considering the fact that it is essential for a company to maintain economical sustainability, it has been observed that the initiative of Commute Greener!, along with the software application that aims to environmental and societal sustainability, had a negative impact on another dimension of sustainability, the economical sustainability (Penzenstadler et al., 2013). By negative impact, it is meant that the goals of this initiative, which were translated to requirements of the software application, were not profitable enough for the company.

It is of high importance to notice that this thesis work is the first real-life case study, and not an imaginary scenario that observed the sustainability aspects in requirements of a system and the possible conflicts between these aspects and a firm's goal. Its results, discussion and conclusion can be used for further research in other cases as a reference. Also, new real-life case studies can take place in the same or different firms, in order to verify or contradict the results from this particular case study.

Future work is suggested to be done in two directions. On the one hand, similar case studies could take place in order to have insights into other kinds of software systems, regarding the sustainability aspects in requirements engineering. On the other hand, by taking the results that were analyzed in the *Discussion* part and compare them with results from similar studies regarding the sustainability aspects in requirements engineering in other

software systems. By doing this, new knowledge might emerge and possibly extend the existing literature around this particular topic.

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Interview questions

The following questions are the main questions that have been directed to the interviewees. The questions that are followed by the mark “(C.G)” in the end were mainly dedicated to people inside Commute Greener! initiative, but not necessarily. The “User’s part” was dedicated only to the users of the application, but they have been asked not only these questions, but the rest of the questions here as well, depending on their background and how well they knew or have been used Commute Greener!.

In the 1st part, there are general questions about the people’s background. Also, there are some questions in order to understand basic matters about the Commute Greener! initiative and the requirements for it. In the 2nd part, the questions are focusing on the value of the Commute Greener! initiative for Volvo. The 3rd part is aiming at the possible sustainability impacts that Commute Greener! initiative might have caused to the people. The 4th part includes questions that are aiming to find out possible conflicts between the different types of requirements of the initiative.

1st Part

- What is your age? (optional)
- What is your education?
- What have you been doing until you came in the position you are now?
- Do you take the bus/bicycle? How often?
- Are you familiar with the Commute Greener! initiative?
- Have you been engaged in some other environmental activities? In what kind?
- What is your place in Commute Greener!?! (C.G)
- Why are you in Commute Greener!?! (C.G)
- What would you say Commute Greener! is aiming for? (C.G)
- Do you know other firms that are doing something similar as Commute Greener!?! Can you mention what you know about them?
- How did you come up with this idea? (C.G)
- Why now? (C.G)
- How was the course of the whole project so far? (C.G)
- Would you say that it is the same as you started or it changed in some ways? What exactly changed? (C.G)
- How far the requirements of this application have been covered? (C.G)
- What were the requirements for this application that they were related to environmental sustainability? (C.G)
- From the sustainability point of view, did you modify the requirements after the application was released for the people to use it? In what way? Why? Did you add new or delete old requirements? Would you say that these changes had any relation with the environmental goals of the application? (C.G)

User's part

- Was it easy to understand the application the way it works? (Why not?)
- What is your general impression of the application and the whole idea behind it?
- Would you say that it is educative or helpful?
- Would you say that it changed your behavior? (For example, would you use your car as least as possible?)
- What was the most important feature for you in the application?
- Did you find the application attractive? What was the key reason?
- Did you notice that the application needs some improvement in some points? Like what?
- Would you consider continuing using it? (what would you like to see/have in order to continue using it?)

2nd Part

- Would you say that this project is valuable for Volvo? How/How not?
- Considering the fact that Volvo is producing cars, buses, trucks that use petrol, would you say that this initiative actually has a negative impact on the company because it suggests people to actually stop using their car? Why/Why not?
- In your opinion, would you say that there is any monetary profit for Volvo coming from this project? How/How not?
- Were there any conflicts between the requirements that are aiming for environmental sustainability of this application, considering the fact that Volvo is actually selling cars, trucks and buses as well? How were you able to manage this trade – off? (C.G)
- In the application you have as a possible use case to walk your trip or use the bicycle. Would you say that this case opposes the idea of selling cars, trucks and buses from Volvo? Why/Why not? If yes, how did you manage to handle this contradiction with the sustainability requirements from the software management perspective? (C.G)

3^d Part

- Would you say that Commute Greener! is helpful for the society? How/How not? – By society, think of people, the behaviors and the relationships between them. (C.G)
- What were the requirements for the application in order to support the sustainability from a society perspective? (C.G)
- Would you say that Commute Greener! is achieving its goals? How/How not? How can you measure that? (C.G)
- Would you say that the implemented requirements for this application have helped to achieve the sustainability goals of the initiative? (C.G)
- Would you say that there is anything more that can be done in order for the initiative to be completed? What/Why not? (C.G)
- Are you still active in requirements elicitation for more or improved functionality from the sustainability point of view of the application? Why/Why not? (C.G)
- Do you think Commute Greener! helps you to have a different view of the environment? Why/Why not?
- Would you say that Commute Greener! affects you in your work? How/How not?

4th Part

- In your opinion, applications like Commute Greener!, where requirements are aiming for sustainability, could be possible or more popular? Why/Why not?
- In your opinion, could requirements for a software application that aim to sustainability, stand against or co – exist with the monetary goals that a firm has? In what way? Why not?
- Can you suggest other persons relevant to interview?