Software ecosystem sustainability assessment: an investigation of the state of the art and stakeholder perceptions

David van der Sluijs[1]

[1] Utrecht University, Princetonplein 5, 3584 CC Utrecht, Netherlands
d.m.vandersluijs@uu.nl
Supervisors: Sergio España and Slinger Jansen

Abstract. Sustainability is a key driver for innovation and is reshaping many industry sectors. The software ecosystem (SECO) industry is likely to follow soon with the new initiatives that are starting to appear for sustainability. This means that the success of a SECO will not solely be measured from the point of view of profit anymore, but also from their social responsibility and environmental impact. Traditionally, SECOs have mostly been concerned with the economic dimension of sustainability, as a result of the body of knowledge to analyze sustainability in software ecosystems is small. The purpose of this study is to investigate how the adoption of a more holistic conception of sustainability in SECOs could affect the industrial and academic impact on the SECO community. We conducted interviews to investigate sustainability as a holistic concept and created a list of material sustainability topics. Afterwards, we conducted a survey with these identified sustainability topics in order to do materiality assessment, so we could see which topic is more material for sustainability in software ecosystems. The results indicate that sustainability practices in SECOs are not yet common. Sustainability is a new concept for SECOs and the academic community and practitioners did not yet have the concept of sustainability well defined or even analyzed in their SECOs, even though they did indicate that analyzing their sustainability can bring competitive advantages for several SECOs. With our research, we identified 16 sustainability topics. These 16 sustainability topics were prioritized using materiality assessment, so that the most material sustainability topics can be used as a starting point to improve the sustainability for SECOs in the future.

Keywords: Sustainability, Sustainability Topics, Software Ecosystems, Materiality Assessment.

1 Introduction

Motivation

Sustainability concerns are reshaping many industry sectors, for diverse reasons; e.g. as a response to raw material scarcity (Global Reporting Initiative, 2017), as a result of

the enactment of stricter policies (Cohen, Eimicke, & Miller, 2015), due to ethical consumer pressure (Chen, 2010), considering sustainability a key driver of innovation (Nidumolu, Prahalad, & Rangaswami, 2009). The hardware industry is already experiencing transformations, affecting even the supply chains (Wernink & Strahl, 2015). The software industry will likely follow soon and initiatives such as the Fair Trade Software Foundation start to appear ("Fair Trade Software Foundation", 2018). This will entail new challenges for software ecosystems (SECOs), since the success of SECOs will not solely be measured from the point of view of profit anymore, but also of their social responsibility and their environmental impact (Seelos & Mair, 2005). Software ecosystems need to become increasingly sustainable to answer these trends in the market.

In this work, we understand sustainability as a holistic concept that encompasses at least three dimensions, which are often referred to as the triple bottom line: economic, social, and environmental sustainability. Other works include additional dimensions e.g. technical (Lago, Koçak, Crnkovic, & Penzenstadler, 2015), personal (Becker e.a., 2015). Sustainability is deeply intertwined with business ethics and they are almost indistinguishable in many conceptual frameworks (Van Marrewijk, 2003), policies ("European Parliament", 2014), topics and standards ("GRI Standards", 2017). Therefore, for the sake of brevity, we include business ethics under the notion of sustainability.

Traditionally, SECO researchers and designers have mostly been concerned with the economic dimension of sustainability, which typically refers to performance, profit and business models (Gawer & Cusumano, 2014). As a result, the body of knowledge and methods to analyze the sustainability of software ecosystems is small. Evidently, the economic sustainability is key for its survival, since a SECO is at the risk of extinction without the proper business models serving the SECO and its actors (Manikas & Hansen, 2013). But the social and environmental dimensions of sustainability are also important. Some authors have defined quality models for SECOs that include sustainability as a characteristic (Franco-Bedoya, Ameller, Costal, & Franch, 2014), SECO conceptual frameworks that include sustainability as a concept (Dhungana, Groher, Schludermann, & Biffl, 2010), and handbooks including sustainability guidelines for SECO partners (Popp & Meyer, 2010). However, they place the focus on the purposes of SECO health, business continuity and partner survival. So far, no method to analyze the sustainability and business ethics of a software ecosystem has been proposed.

Observed Problems

The lack of a holistic conception of sustainability related to SECO sustainability have implications in the academic and industrial domains. Without a proper understanding of the notion of sustainability in the context of SECOs, the research community will keep disregarding the social and the environmental dimensions and no theories on the matter can be elaborated. Without a holistic conception of sustainability in SECOs, the SECO academic and industrial community is likely to remain skewed towards the economic dimension, while governmental policies are already starting to request disclosure on a sustainable society.

Main Goal

This research aims to investigate how the adoption of a more holistic conception of sustainability in SECOs, such as the triple bottom line perspective, could affect the industrial and academic impact on the SECO community. Eventually, we intend to provide insight into sustainability topics and the needs of the SECO community that could be used to make SECOs more sustainable.

2 Research Questions

Problem Investigation
RQ1: How are software ecosystems going to be affected by sustainability topics?
RQ2: What are the existing methods and their limitations to analyze software ecosystems from a sustainability point of view?

Research Execution
RQ3: How does the software ecosystem industrial and academic community understand and analyze sustainability in software ecosystems?
RQ4: What are material sustainability topics in software ecosystems?
RQ5: What are the barriers of industrial and academic adoption for a method analyzing the sustainability in software ecosystems?

3 Conceptual framework on analyzing the sustainability in SECOs

3.1 Sustainability

Considering that sustainability is one of the key drivers of innovations (Nidumolu e.a., 2009), we need to understand sustainability. In general, sustainability is often defined as "the capacity" of a system "to endure" ("The Oxford Dictionary of English", 2010). Additionally, another definition is that development meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). However, this compromise is heavily influenced by ethical values of society. These ethical values create a value system that provides us with important sustainability topics that need to be analyzed.

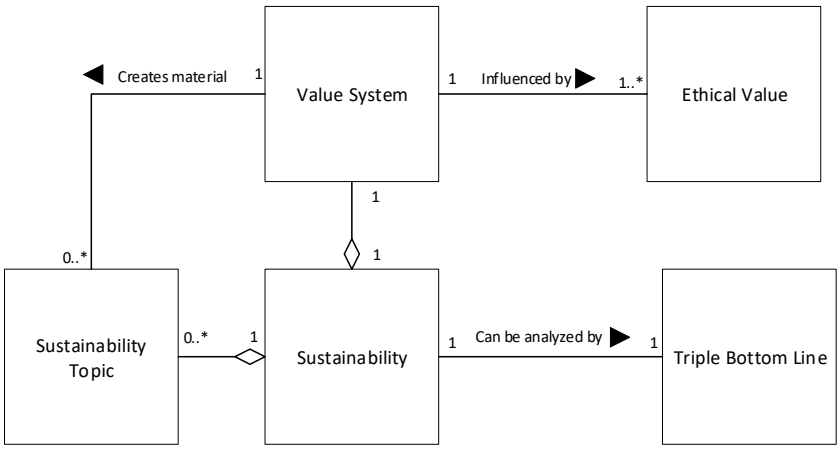
The most common framework, often used in accountancy, is to analyze sustainability from the triple bottom line perspective; economic, social and environmental sustainability (Russo, 2008). The key idea is that human society is only sustainable if it can be sustained in all three hierarchical dimensions because the economy is a subsystem of society, which in turn is a subsystem of the environment (Becker e.a., 2015). However, this perspective can be identified as weak sustainability by those that only concern themselves with these dimensions. To achieve strong sustainability you should also

take into account the biophysical limits of the natural sources of planet earth. (Becker e.a., 2015).

Materiality is an approach that helps to improves the stakeholder's relationships and contributes to processes to for the creation of shared ethical values. The purpose of materiality assessment in sustainability reporting is to identify, select and prioritize the issues that have the most significance to the ecosystem and their stakeholders (Calabrese, Costa, Levialdi, & Menichini, 2016). To prioritize sustainability topics, materiality can be used to see how significant these topics are. As suggested by the GRI G3 guidelines ("Sustainability Reporting Guidelines 3.1", 2011), the materiality of sustainability topics can be determined using two dimensions; "significance of the topic to stakeholders" and "influence of the topic on business success", whereas the most material sustainability topics score good on both dimensions. This method is widely used by many organizations to determine sustainability topics (Hsu, Lee, & Chao, 2013).

Figure 1 shows the conceptualization of the most common way to analyze sustainability.

Figure 1: The most common way to analyze sustainability.



3.2 Organizational Sustainability

Analyzing sustainability and reporting on it is often already done in large organizations. Large organizations generally use a Corporate Sustainability Reporting (CSR) standard that makes them report on their sustainability impacts, such as the GRI (Initiative, 2017), ISO 26000 ("ISO 26000 Social responsibility", 2018), and Standard SA 8000 ("Social Accountability International | SA8000® Standard", 2018). CSR refers to a company's activities demonstrating the inclusion of social and environmental topics in business operations and in interactions with stakeholders (Van Marrewijk, 2003). CSR lets organizations report on sustainability topics and each topic has its own

sustainability metrics, that could be addressed in these reports. Additionally, CSRs also report on their internal principles, external drivers and ambitions. These parts address organizational change and how the organization is changing to support sustainability in the future, so it is not only a report that analyzes the sustainability of the current state of the organization, but a CSR also provides a vision for the organization in the future. There are several methods used to analyze corporate sustainability, such as the methods provided by the Global Reporting Initiative, the Common Good Matrix, and the Integrated Sustainability Framework. These methods provide metrics that can be used to analyze and improve sustainability in organizations.

The Global Reporting Initiative provides a way to analyze and improve sustainability in organizations. This method uses a standardized format to report on organizational sustainability matters. Additionally, it uses the triple bottom line approach to report on environmental, social and economic sustainability ("GRI Standards", 2017).

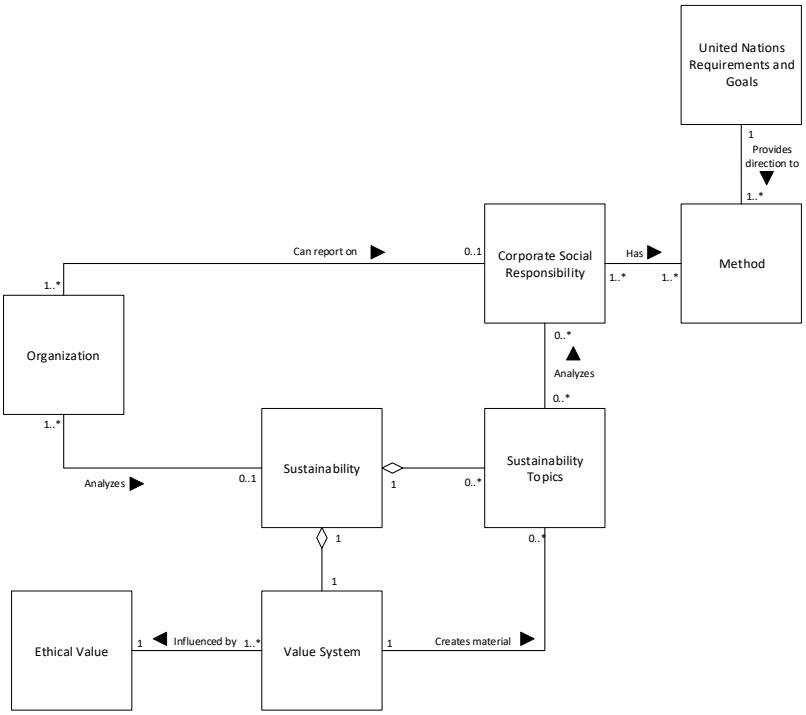
The Common Good Matrix provides 20 common-good themes that provide guidance to analyze the organizational sustainability. This method is used to analyze the values of different stakeholders and compares them. The purpose of this framework is to analyze and position an organization based on their organizational impact ("Common Good Matrix", 2018).

The Integrated Sustainability Framework (Dao, Langella, & Carbo, 2011) provides us with a method that strives to improve the organization by analyzing the organization's current internal and external sustainability by trying to improve it each day, so that sustainability standards can be met. This provides organizations in ways to improve themselves by being more sustainable in the future.

Corporate sustainability has some sort of obligations to meet sustainability standards provided by the United Nations (UN). The UN provides 17 sustainable development goals that have to addressed in organizations, so that the society can be more sustainable in the future ("Sustainable Development Goals", 2018). However, these standards are not yet enforced and provide governmental guidelines to organizations.

As seen above, many methods and guidelines already exist for organizations to analyze their sustainability. Each method has a different focus and there is no real standard. This provides organizations options to choose if they want to report on sustainability using a method. Figure 2 shows the conceptualization analyzing sustainability within organizations using methods.

Figure 2: Relationship between concepts in organizational sustainability.



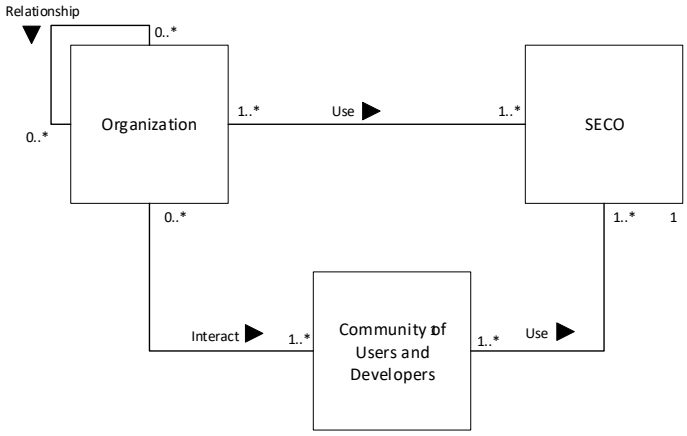
3.3 Software ecosystems

A conceptual framework is created to better understand sustainability in software ecosystems (SECOs). As a starting point, we investigated a systematic literature review by Manikas & Hansen (2013) and in this paper, the most common definition of SECOs is given:

"a set of businesses functioning as a unit and interacting with a shared market for software and services, together with the relationships among them. These relationships are frequently under-pinned by a common technological platform or market and operate through the exchange of information, resources, and artifacts (Jansen, Finkelstein, & Brinkkemper, 2009)."

By analyzing this definition and consulting Slinger Jansen – the creator of the academic research related to SECOs - several entities are identified; (1) organizations, (2) community of developers and users, and, (3) lastly, the software ecosystem itself. These entities are conceptualized in Figure 3.

Figure 3: Software Ecosystems conceptualized.



3.4 Sustainability in Software Ecosystems

The discipline of Software Engineering (SE) plays a major role in sustainability, because of the extent to which software systems mediate in many aspects of our lives (Becker e.a., 2015). Considering that software ecosystems are a part of Software Engineering, this means they are also likely to play a role in sustainability. However, current research is lacking, because sustainability in SECOs has not yet been analyzed from a holistic point of view.

Economic sustainability refers to the obligation to preserve the present-day economic opportunities for the future, so the performance, profit, and business models should fit these purposes (Anand & Sen, 2000). However, no rules exist at the moment to match the present and future in SECOs. This means when there are performance, profit or business models fitting a short-term purpose SECOs will use this as an opportunity for business (Gawer & Cusumano, 2014).

Social sustainability includes a concern for a broad spectrum of issues ranging from quite tangible, very basic requirements – like potable water and healthy food, medication, housing – to less tangible needs concerning education, employment, equity, and justice. It is anticipated (or hoped) that positive environmental benefits will follow (Vallance, Perkins, & Dixon, 2011). Social sustainability is often seen in software ecosystems as the well-being and the collaboration between software developers in the software ecosystem. The outcome of previous work shows also that the social interactions of software developers influence the adoption and the permanence of a SECO. In order to improve social aspects in a SECO, this work suggests that a SECO should support collaboration, interactions, and events for their developers (de Souza e.a., 2016).

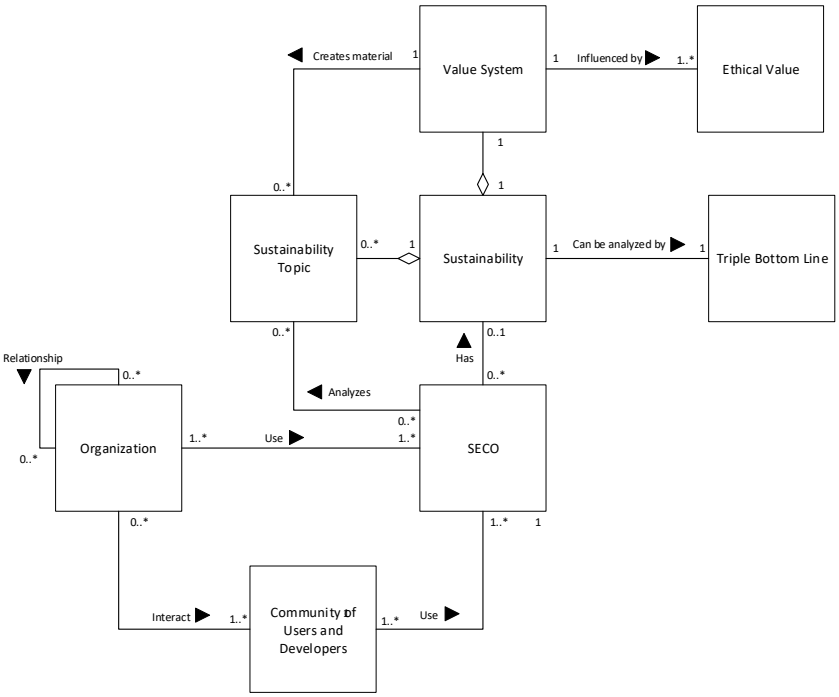
Environmental Sustainability could be defined as a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity (Morelli, 2011). However, no research on environmental sustainability in software ecosystems is yet conducted while it could be very important. For example, SECOs can consume a lot of energy keeping their platform up and running or SECO partners can outsource to a third world country that employs child labor. Therefore, it is important that this is analyzed because it could harm society.

The definition used for sustainability in SECOs does not include the triple bottom line as a concept;

"A software ecosystem that can increase or maintain its user/developer community over longer periods of time and can survive inherent changes such as new technologies or new products (e.g., from competitors) that can change the population (the community of users, developers etc.) or significant attacks/sabotage of the ecosystem platform (Dhungana e.a., 2010)."

Figure 4 shows concepts related to sustainability in software ecosystems using the triple bottom line.

Figure 4: Sustainability in Software Ecosystems using the triple bottom line.



3.5 Reporting on Sustainability

Deterioration of the natural environment poses risks and opportunities for business organizations (Melville, 2010). Therefore, many organizations report on their sustainability (e.g. corporate sustainability reports). However, these reports are lacking a standardized reporting format, they provide detailed overview of quantitative and qualitative sustainability indicators, but no industry standards are provided about their performance indicators (Melville, 2010). This poses threats to the natural environment, because organizations can manipulate these reports to their own benefits. For example, organizations can look better using a different format because that certain format only report on the metrics they do well on.

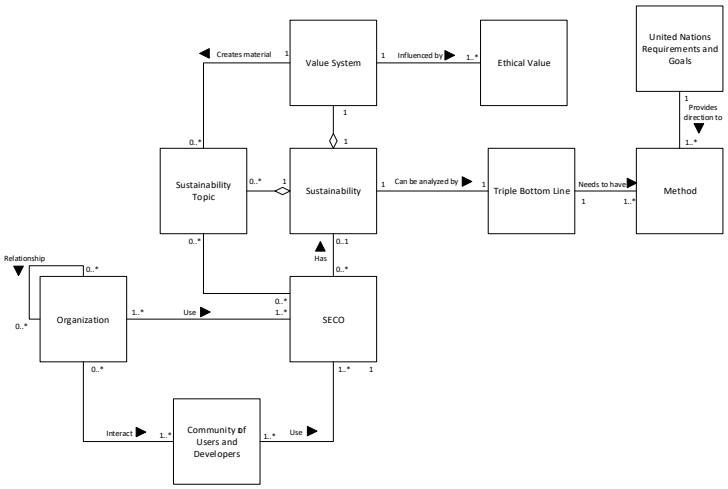
Additionally, there are no sustainability standards in SECOs, while SECOs are probably going to be affected by sustainability concerns. The sustainability of a SECO can only be measured by combining the results of each individual organization participating in a SECO. The holistic concept of SECO is related to a group of organizations and individuals creating a market that exchanges goods, services and information. In order to analyze a SECO in a holistic way, a method should exist that analyzes the sustainability in the whole SECO.

3.6 Analyzing Sustainability in SECOs

As mentioned earlier in this work, we understand that sustainability encompasses at least three dimensions; environmental, social and economic sustainability (Russo, 2008). In order to analyze sustainability in a holistic way, we propose to analyze SECOs using this same methodology because SECOs still need to address these sustainability issues. However, the methodologies for organizations currently do not fit SECOs, because SECOs are more complex with their multiple communities of developers and organizations. To create a holistic standard we propose to use an existing format that is already widely accepted and adjust it to SECOs because creating a whole new method would be redundant in many parts. However, SECOs are different from organizations, so these methods should analyzing different metrics than those of organizational sustainability.

Figure 5 shows the proposed concepts to understand how to analyze sustainability using methods in SECOs. Appendix A summarizes all the concept and their definitions used to create the conceptual framework.

Figure 5: The proposed concepts to understand how to analyze SECO sustainability.



4 Research Protocol

This research is structured according to design science principles (Wieringa, 2014). The initial research methodology for the project proposal is found in Appendix B.

4.1 Research method

This research conceptualizes sustainability in software ecosystems. By analyzing sustainability in general and organizational sustainability we created a conceptual framework that can be used to define sustainability in software ecosystems.

To find out the limitations of the current literature in software ecosystems. We investigated all the available methods for sustainability in SECOs by using a *systematic literature review (SLR)*. These methods were analyzed by identifying the method and classify them using the taxonomy defined in the conceptual framework. The results of the SLR are used to investigate the state of art of sustainability in SECO literature.

Additionally, we think that it was also important to know how academics and professionals currently understand and analyze sustainability in software ecosystems. Thus, we conducted semi-structured interviews (Stewart, 2002) with academics researching SECOs or organizations that were either software ecosystem orchestrators or conducting business using a software ecosystem. These interviews investigated three subjects related to sustainability; (1) how the interviewees understood sustainability initially, (2) which sustainability topics they think that were material for their SECO, (3) what current methods they used and their needs to analyze the sustainability in SECOs.

The interviews were analyzed using NVivo 12 to transcribe and code them. The results are used (1) to see whether sustainability is understood by the academic and professional SECO community correctly, (2) provided us with a list of sustainability topics rated in order of important topics that are material for SECOs in general, (3) and it provided us with the methods and needs to analyze sustainability in SECOs.

To validate the results of the interviews we created a survey that was sent to the same academic and professional SECO community as used to conduct the interviews. This survey is used to confirm that sustainability topics gathered from the interviews can be applied to the whole academic and professional SECO community. In the survey we explained each sustainability topic by providing a definition. We let participants rate these sustainability topics on a Likert scale of 1 (low) to 7 (high). This was based on both dimensions for materiality assessment using their own experience with SECOs.

Figure 6 elaborates on the connection between the interviews and the survey. The whole research method is summarized in Figure 7.

Figure 6: The relationship between interviews and survey.

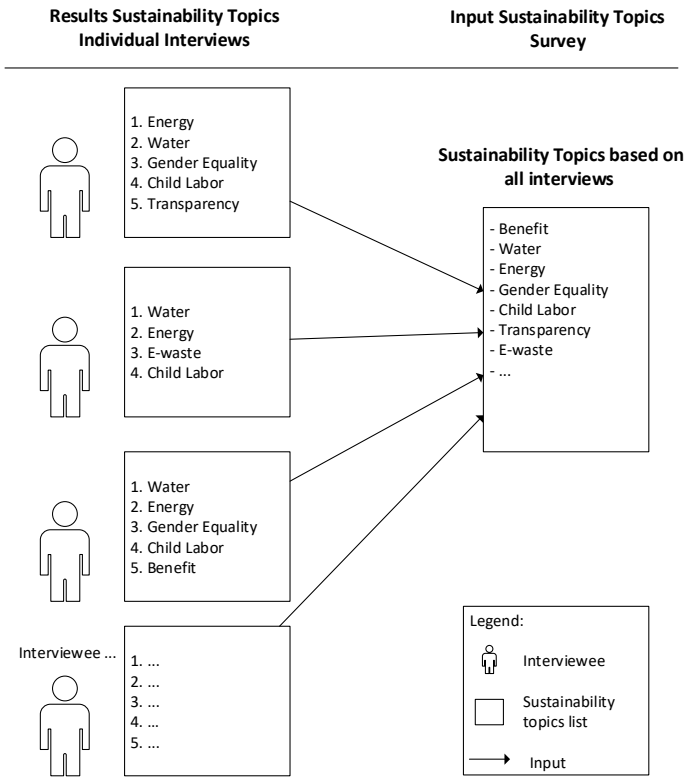
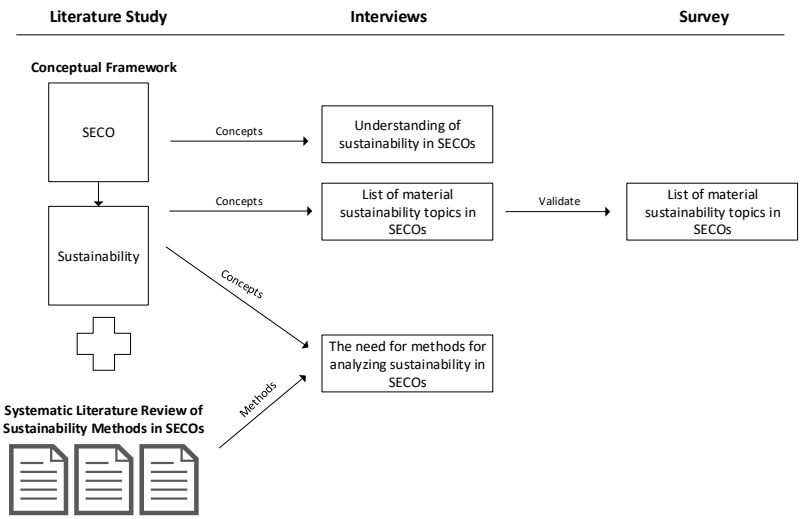


Figure 7: Summarization of the research method.



4.2 Systematic Literature Review on methods analyzing the sustainability in SECOs

The systematic literature review is structured using the protocol of Kitchenham (2004).

Research Questions
In order to determine the state of the literature of software ecosystems from a sustainability point of view, we formulated a research question (also found in chapter 2);

RQ2: What are the existing methods and their limitations to analyze software ecosystems from a sustainability point of view?

This research question aimed to gain insight into the methods of analyzing software ecosystem from a sustainability point of view. It was our expectation that literature only analyzes software ecosystems from an economic point of view, while sustainability also addresses social and environmental issues.

Resources to be searched
The following four digital libraries are searched; IEEE Xplore, ACM Portal, Science Direct, and Springerlink

Search String
Derived from the research questions we identified several terms that need to be included; software ecosystems, method, and sustainability. This resulted in the following search string:

("Software Ecosystem" OR "Software Ecosystems") AND (method OR methodology) AND Sustainability AND year > 2003

Inclusion Criteria
Publications related to sustainability in software ecosystems are of interest of this systematic literature review. This resulted in the following inclusion criteria:

- Publications that describe methods, techniques, metrics or tools to analyze software ecosystems
- Publications that measure sustainability in software ecosystems
- If several publications refer to the same method, technique, metric or tool, we will identify the most relevant publication and then we will bundle the rest with it.

Exclusion Criteria
This field of study is related to software ecosystems, so only publications are taken that are related to software ecosystems. This resulted in the following exclusion criteria:

- Publications that do not investigate a method, technique, metric or tool used in software ecosystems.
- Publications that are neither in Dutch or English.

Extraction Template
The extraction template consists of two parts; the first part consisting of general information about a paper and the second part consisting of information related to sustainability in software ecosystems (Table 1).

Table 1: Extraction Template SLR.

Method	Method measuring the metrics mentioned in the publications.
Purpose/Intention of the method	Purpose of the method, so why is this method used in a certain context by providing solutions and problems mentioned in the publications.
PDD of the method	Activities and deliverables of the method using Process Deliverable Diagram (PDD) (Weerd & Brinkkemper, 2009).
Analysis Dimensions	The reader decides if the method is either in economic, social, environmental dimension or combination of dimensions for sustainability.
Metrics	The individual parts of the method that helps constructing the whole method.
Modeling language	Briefly describe the modeling language(s) used for this method (e.g. natural language, UML, etc.)
Tools	Tools that support the method mentioned in the publications, if any.
Validation	How was the method validated? Technical action research, interviews, case study, etc.

The list of publications that scientifically contribute to the method	If there are multiple papers.
Number of citations	The number of citations of the main paper. Use the number given by Google Scholar.

4.3 Survey

The survey was created using Google Forms and consisted of four parts. The first part was a brief explanation of our research and what we aimed to achieve with this survey. The second part was related to the participant information, where we asked their name and their previous experience related to SECOs and sustainability. The name was not mandatory, because sometimes participants felt that this subject it could contain sensitive information. In order to improve the response rate, we decided that it was not mandatory. The third part was prioritizing the sustainability topics that resulted from the interviews based on materiality assessment. We asked the participants for each topic two questions; (1) the importance of the topic to stakeholders, and (2) the impact on business success. These terms were explained with examples, so the interviewees could get used to this way of thinking. Then the fourth and last part was a closure of the survey; where they could leave their email behind if they want the results and there was room to add something else. The survey can be found in Appendix D.

4.4 Validation of research protocol

This research protocol is validated using both supervisors of this master thesis. The first supervisor – Sergio España – participated in a brainstorm session, read this document a multiple times and provided feedback to improve this research protocol. By validating this research protocol we had multiple versions. The second supervisor – Slinger Jansen - gave his general thoughts on the document and provided input for the SECO conceptual framework. Furthermore, some MBI students provided feedback on my research protocol and helped me improve it.

5 Systematic Literature Review of the current methods

Results

The literature review returned 72 unique publications. By reading through the publications, we found out that there were only two specific methods that analyzed a part of sustainability (Appendix E). Many publications were discarded, because they either did not analyze a part of sustainability in their methods or were not analyzing SECOs (Figure 8).

The first method that we found analyzed a part of sustainability, which was related business models of SECOs using the Business Model Canvas (BMC). This method analyzes sustainability from an economic point of view and can be used in either SECOs and organizations. A business model describes the rationale of how an organization or

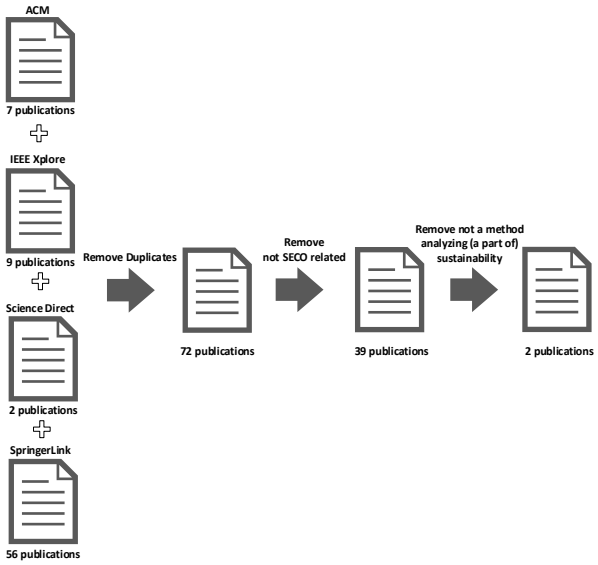
SECO creates, delivers and captures value by interacting with suppliers, customers, and partners (Popp & Meyer, 2010). The Business Model Canvas gives a description of a software vendor's business model. In the list below you find the metrics analyzed using natural language in the BMC.

- **Customers Segments;** an organization serves one or several customers.
- **Value proposition;** it seeks to solve customer problems and satisfy customer needs with value propositions.
- **Channel;** value propositions are delivered to customers through communication, distribution, and sales channels.
- **Customer Relationships;** customer relationships are established and maintained with each customer segment.
- **Revenue Streams;** revenue stream result from value propositions successfully offered to customers. At this part a pricing scheme is added, so tools can be compared on revenue models.
- **Key Resources;** key resources are the assets required to offer and deliver the previously described elements by performing a number of key activities.
- **Key Activities;** see key resources.
- **Key Partners;** some activities are outsourced and some resources are acquired outside the organization.
- **Cost Structure;** the business model elements result in the cost structure.

The second method analyzes social sustainability in SECOs based on sustainable collaborative relationships. This method aims to create a healthy and sustainable software ecosystem by analyzing a keystone platform developers to elicit and analyze their objectives and decision criteria. This method takes three major steps in analyzing their keystone developers; (1) explicating objectives of the developers, (2) deriving design requirements, and lastly (3) concluding requirements and reaching design solutions.

Concluding on this literature review, we found no existing method that analyzed sustainability in SECOs as a holistic concept and we only found two methods that analyzed a part of sustainability. This indicates that there is a gap in the literature related to analyzing sustainability as a holistic concept in SECOs.

Figure 8: Results of the sustainability method SLR.



6 Stakeholder Perceptions on Sustainability in SECOs

This section contains the results of the interviews and survey based on the perceptions of participants on sustainability in SECOs.

6.1 Interviews

This section summarizes the most important results of the interviews. First, demographic information of the participants is given. Second, their perception of sustainability in software ecosystems is given with relevant quotes. Third, the relevant sustainability topics are given with the relevant quotes. Fourth, the currents methods are provided to analyze sustainability in software ecosystems compared to methods used to analyze sustainability in organizations. Fifth and lastly, the need for a method analyzing sustainability is given based on the perceptions of interviewees.

6.1.1 Demographic Information

In total, 9 participants were interviewed. Out of those 9 participants, 2 were researchers and 7 were working with a SECO. The software ecosystems that the participants had experience with were SAP, Eclipse, Unit4, Exact, Healthcare systems, and one more SECO that want to stay anonymous for this research. The age of the participants was between 32 and 56 years old with an average age of 41 years old. All the participants have been working with SECOs for a longer period of time, where each participant has worked for at least 6 years with SECOs. Furthermore, the experience of most

participants on sustainability was very limited, whereas most of the participants had no prior experience with sustainability (Figure 9). The summarization of the demographic information of the participants is found in Table 2.

Figure 9: Experience of interview participants with sustainability.

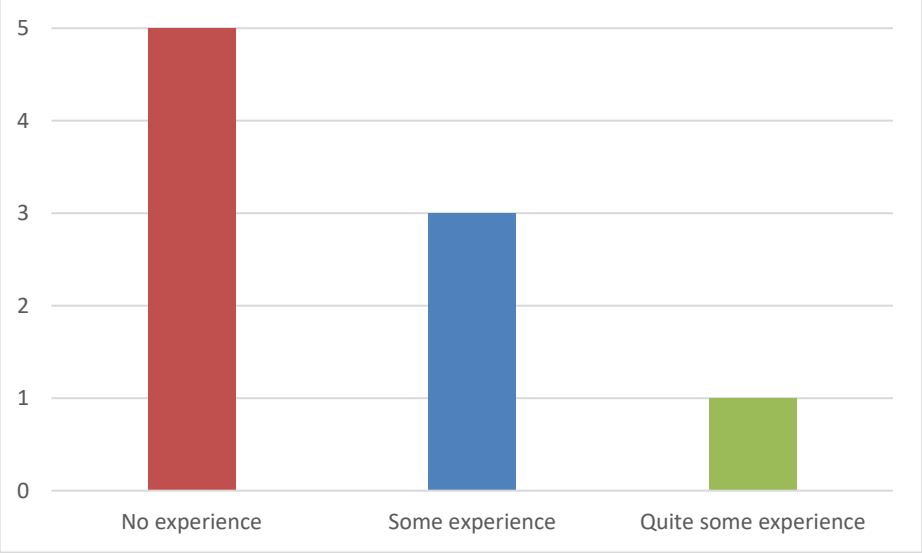


Table 2: Demographic information of interview participants.

Role	**Age**	**Experience with SECOs**	**Prior experience with Sustainability**	**Identifier**
Researcher	42	17 years	Some experience	4
Researcher	32	7 years	No experience	6
Product Marketing Manager	32	8 years	Some experience	9
Senior Business Transformation Consultant	43	14 years	Some experience	8
Senior Business Consultant	39	6 years	No experience	5
Consultant	39	12 years	No experience	2
Entrepreneur in Consulting	46	20 years	Quite some experience	3
Director Ecosystem	56	-	No experience	1
Manager R&D Office	36	9 years	No experience	7

6.1.2 Perceptions on sustainability in SECOs

There were multiple definitions given by participants on their perception of sustainability in SECOs. Both of the researchers were referring to SECO health as a concept that influenced the sustainability in a software ecosystem;

"For me, the concept of sustainability is related to health. How healthy and capable the ecosystem is to endure and maintain in the market. (Participant 4)"

Participant 4 elaborated that the two constructs of sustainability and health are interrelated, but it was not clear how they were related. Participant 4 suggested that it would be interesting to look at the relationship between those two constructs.

Additionally, the two researchers initially also mentioned sustainability topics related the economic and social sustainability, such as sustainable collaborations and relationships (P4&6), create enough value (P6), and lastly, should bring positive economic results for each stakeholder (P4&6).

The other participants that worked with a SECOs, had no theoretical background on sustainability in SECOs. Therefore, SECO health was never mentioned by these participants.

While researchers did not perceive environmental sustainability as an initial part of sustainability, some other participants did. Four participants (P2, 5, 8, 9) mentioned environmental sustainability related to paper usage, energy consumption, and CO2 consumption. Furthermore, participant 3 mentioned environmental sustainability in a different way, but this encompasses more than just environmental sustainability;

"The fit it has with its environment (Participant 3)"

This quote could also be perceived as economic and social sustainability. However, most of the other participants explicitly mentioned some part of economic (P1, 2, 5, 7, 8, and 9) or social sustainability (P1, 3, 5, and 8) as a part their explanation of sustainability in SECOs. The result of asking to their definition of sustainability in this way is that participants always used sustainability topics to elaborate on their definition of sustainability in SECOs.

6.1.3 Sustainability Topics

In total 16 sustainability topics are identified by the interviews. Each interview was analyzed by gathering each sustainability topic interviewees mentioned. There was sometimes overlap between multiple sustainability topics, so we combined and mapped those to a single or multiple other topic(s) till there was eventually no overlap between the different sustainability topics. The sustainability topics are found Table 3.

Table 3: Sustainability topics identified using interviews.

Sustainability Topic	**Description**	**Mentioned by interviewee**
Transparent revenue Models	A revenue model is a framework for generating revenues. It identifies which revenue source to pursue, what value to offer, how to price the value, and who pays for the value. If the revenue model is fair and transparent, then all stakeholders in the software ecosystem are made aware of it.	4, 7, 8
Continuous Ecosystem	The software ecosystem should be continuous by being up-to-date with developments in the market and creating enough value for each group of stakeholders, so the software ecosystem can continue to exist for a longer period of time.	6, 7, 8
Financial Benefits for Stakeholders	Financial benefits gained from an outcome or a result of participating in the software ecosystem. Finding the right balance for financial wealth between different stakeholders, so that not only a single party mostly benefits of the software ecosystem.	2, 4, 6, 7, 8, 9
Balancing Ecosystem Social Responsibility with profit	The software ecosystem can be conscious of the kind of impact they are having on all aspects of society including economic, social, and environmental impact. By creating a balance between ecosystem social responsibility and profit, the software ecosystem can aim to be more sustainable in the society.	3, 5, 9
Efficiency of the Ecosystem	Efficiency is the (often measurable) ability to avoid wasting materials, efforts, and time in doing something or in producing the desired result. In a more general sense, it is the ability to do things well, successfully, and without waste. This is mostly related to business processes, hardware usage, and software solutions.	1, 2, 3, 5, 7, 9
Creating a solidarity community	By creating a solidarity community around your software ecosystem, you can strengthen your market position and continuity of your software ecosystem. This can provide opportunities for multiple stakeholders in the software ecosystem.	3,7
Healthy work environment	The work environment should be a good place for each stakeholder to freely and feel welcome to participate in the software ecosystem. Stakeholders working with the software ecosystem should be able to develop themselves and receive other quality of life benefits by participating in it.	2, 3, 4, 5, 7

Sustainability Topic	**Description**	**Mentioned by interviewee**
Healthy relationships with individual stakeholders	The software ecosystem can benefit on multiple aspects from strong relationships with individual stakeholders; customers are more likely to use and buy your products, suppliers are more likely to design a supply chain that is aligned with your software, and partners are more likely to implement your products at their customers. By providing guidelines on how to participate in the software ecosystem in a fair manner, you can align expectations with different stakeholders.	3, 4, 5, 7, 8, 9
Shared decision making and collaboration	By creating an environment for shared decision making and collaboration between stakeholders can be very beneficial, such as increase profits and better software. This can help to improve the power balance and relationships between different stakeholders in the software ecosystem.	3, 4, 6, 7, 8, 9
Diversity in the software ecosystem	Diversity in the software ecosystem refers to the total makeup of the workforce and the amount of diversity included. Diversity refers to differences in various defining personal traits such as age, gender, race, marital status, ethnic origin, religion, education, and many other secondary qualities.	1, 2, 4, 5, 6, 8
Good purpose of use	The software ecosystem can be used for many purposes. Some purposes of these purposes are not for the common good of society, such as war. The customers of a software ecosystem can be analyzed in order to improve public opinion.	1
Good reuse of components	Reuse of different components in the software ecosystem. This mostly relates to the reuse of hardware and software components.	1, 2, 3, 8, 9
Reasonable energy consumption	Energy consumption is the amount of energy or power used by the software ecosystem. The software can be executed in a lot of different places and these places can consume a lot of energy.	2, 3, 7, 8, 9
Reasonable heat consumption	Heat consumption is the amount of heat or warmth created by the software ecosystem. The software can be executed in a lot of different places and these places can create a lot of heat.	2
Reasonable CO2 emission	Traveling within the software ecosystems is very common. Stakeholders often have structures in place to reduce CO2 emission by traveling, such as electric cars, and conference technologies.	1, 2, 3, 5, 7, 8, 9

Sustainability Topic	Description	Mentioned by interviewee
Reasonable paper usage	The amount of paper used by stakeholders in the software ecosystem to reduce the ecological impact on the environment.	7, 8, 9

6.1.4 Prioritization of sustainability topics

All the interviewees provided us with their material sustainability topics in their software ecosystem. However, three of the nine candidates did not want to prioritize due to different reasons;

"I find it very hard to give a score to these sustainability topics. We also don't do that internally, because all these sustainability topics are equally important to reach our goal. (Participant 5)"

"I do not think you would ever want to answer this question, because it is more important to find a balance between these sustainability topics. (Participant 2)."

"If I say this is at the moment very important for us, then it looks like the other sustainability topics do not matter. (Participant 1)"

These three interviewees did provide us with a list of sustainability topics after kindly asking to do it anyways. However, these answers could be skewed to a socially desired answer, so we discarded them. Although the other six candidates did prioritize the sustainability topics, only one of them provided us with scores based on both dimensions for materiality assessment. The other five of the interviewees only provided us only with one score for both the dimensions for materiality assessment.

The results of the materiality assessment can be found in Table 4, based on only one combined score for both dimensions for materiality assessment.

Table 4: Prioritization of the sustainability topics (10 points if not in list).

Global Rank	Total Points	Sustainability Topic	P3	P4	P6	P7	P8	P9
1	15	Shared decision making and collaboration	4	2	1	1	3	4
1	22	Financial benefits for Stakeholders	-	3	3	3	1	2
3	32	Healthy relationships with individual stakeholders	-	4	-	4	3	5
4	35	Continuous ecosystem	-	-	2	2	1	-
5	37	Transparent revenue models	-	1	-	4	2	-

Global Rank	Total Points	Sustainability Topic	P3	P4	P6	P7	P8	P9
5	37	Efficiency of the ecosystem	3	-	-	3	-	1
5	37	Healthy work environment	1	5	-	1	-	-
8	43	Creating a solidarity community	2	-	-	1	-	-
9	44	Diversity in the software ecosystem	-	6	4	-	4	-
10	47	Reasonable energy consumption	-	-	-	5	5	6
11	48	Balancing ecosystem social responsibility with profit	5	-	-	-	-	3
12	49	Reasonable CO2 emission	-	-	-	5	5	9
13	52	Good reuse of components	-	-	-	-	5	7
14	53	Reasonable paper usage	-	-	-	5	-	8
15	60	Reasonable heat consumption	-	-	-	-	-	-
15	60	Good purpose of use	-	-	-	-	-	-

6.1.5 Analyzing sustainability in SECOs

Analyzing sustainability in a SECO is not very common. Four out of the seven participants that work with a SECO either did not know if they analyzed sustainability in their SECO or they did not analyze it (P1, 2, 7, 9);

"We do not monitor the sustainability in our software ecosystem. We do have numbers about diversity, but we do not monitor it with a certain intention in the context of sustainability. (Participant 1)"

"Not that I am aware of. (Participant 7)"

Two different interviewees explained how they used certain metrics to analyze their sustainability as a SECO (P5, P8). These measurements were either an agreement with a partner or set by the orchestrator as a goal;

"One of the measurements we use is; one billion lives. It is our intention to improve one billion lives with our software. (Participant 5)"

"If you look at your partners, then we have contractual agreements around dependencies and turnover. This is simply discussed with our partners, and we have partner

managers working that are specifically in contact between us and the partners. (Participant 8)"

Participant 3 is working to create a sustainable ecosystem in the health sector. This project has a goal to be sustainable as a software ecosystem. He explained that they had two previous projects; (1) was a case study done by students where they used SECO health as a metric to create a more sustainable software ecosystem, and (2) they tried to identify a sustainable business model for their software ecosystem by comparing around 20 different models for viability.

Participants 5, 7, 9 also mentioned some metrics or methods for organizational sustainability, such as Corporate Social Responsibility (CSR), employee satisfaction survey, and Net Promoter Score (NPS) for customer satisfaction. However, this is out of the scope of this research.

6.1.6 Perceived needs for a new method

Every participant except participant 1 agreed that a new method for analyzing the sustainability in SECOs could be useful. However, the participants also gave some conditions for the method;

"It should be easy to use and produce a meaningful result. It should have those two criteria to be really applicable to software ecosystems. (Participant 4)"

"Yes, everything is welcome. I would also think it is useful, provided that it can take into account the complexity of SECOs that we were talking about. (Participant 3)"

Additionally, participant 6 & 9 elaborated on the fact that a method for analyzing their sustainability in SECOs could also bring competitive advantages in the market. This is a reason why they think that they will use it, provided that it can take into account their conditions.

6.2 Survey

The survey was available for a month (July 13th till August 15th). In total, we found 22 people working with software ecosystems willing to participate in the survey. These people were found through the author's connections, through LinkedIn, and through the connections of participants. This resulted in a variety of participants and in total they mentioned 34 different SECOs they worked with.

Additionally, the participants had to rate their experience with sustainability in general on the scale of 1 to 5. The participants had an average of 3.09 with a standard deviation of 1.01, so some participants had (quite some) experience with sustainability and some did not. Figure 10 shows a boxplot with the experience of participants on sustainability in general.

The survey did a materiality assessment of the 16 sustainability topics provided by the interviews. The descriptive statistics of the materiality assessment of each sustainability topic can be found in Table 5.

Because there is no comparison material available to compare these topics, we decided to create a material assessment graph with the materiality of each topic. This can be found in Figure 11.

Figure 10: Boxplot with the experience of the participants on sustainability in general (1 is low, 5 is high).

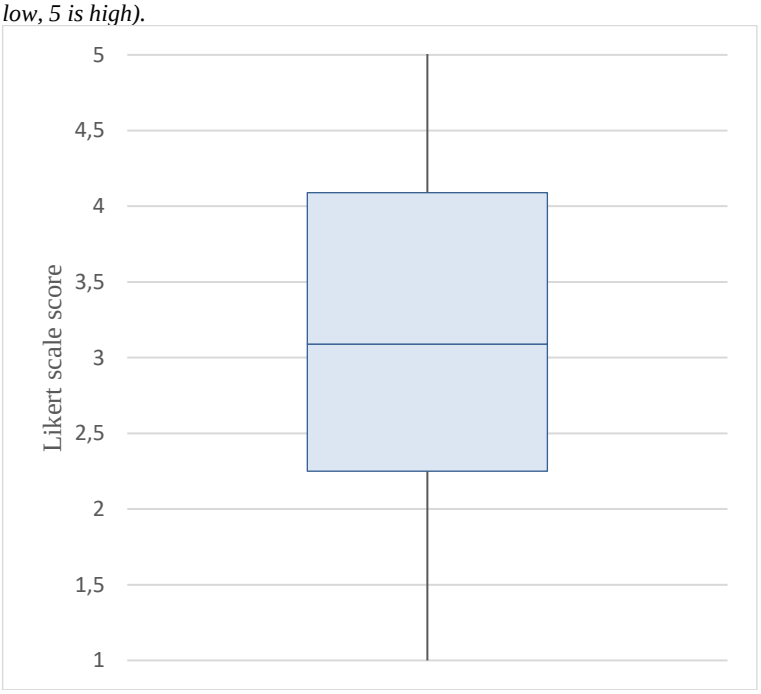
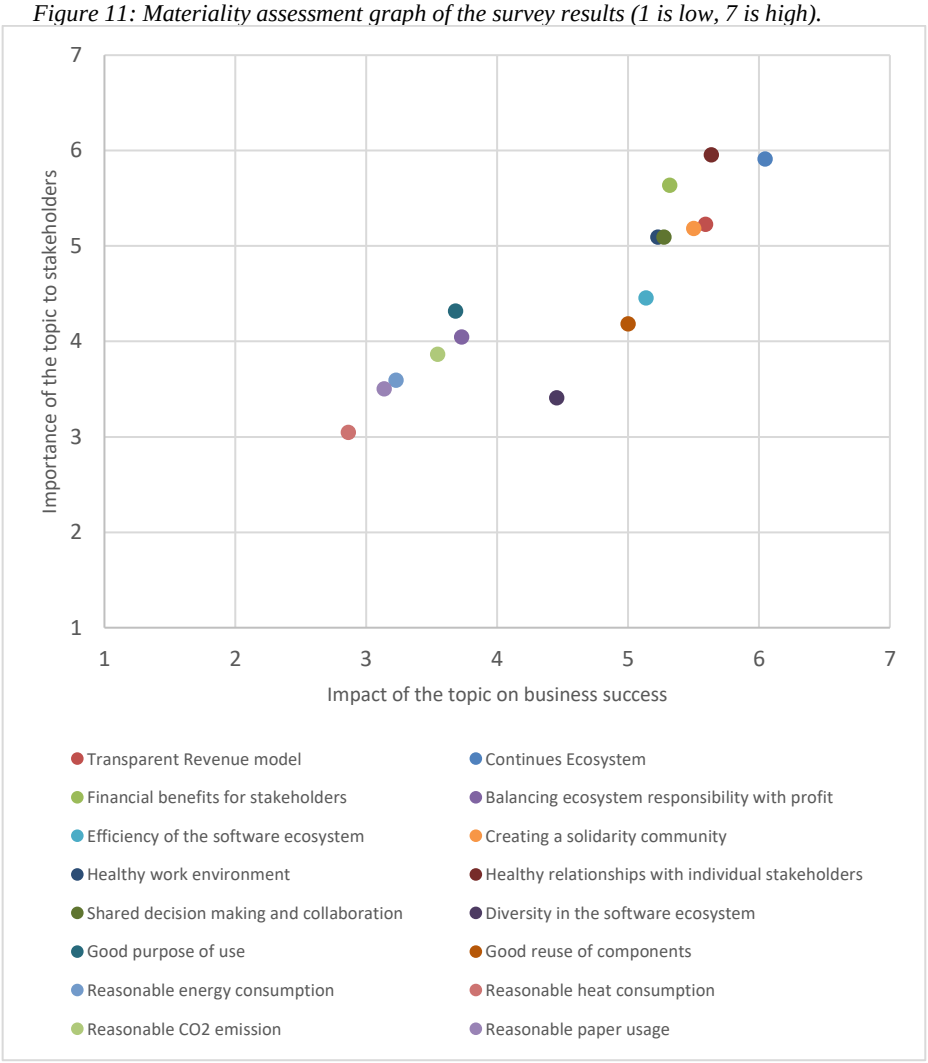


Table 5: Descriptive statistics of survey results (on scale of 1 to 7).

Topic	Mean	Standard Deviation	Range (Min – Max)	Mean	Standard Deviation	Range (Min – Max)
	Importance to Stakeholders			Impact on Business Success		
Transparent revenue model	5.23	1.19	6 (1 – 7)	5.59	1.03	6 (1 – 7)
Continues ecosystem	5.91	0.97	6 (1 – 7)	6.05	0.78	5 (2 – 7)
Financial benefits for stakeholders	5.64	1.19	6 (1 – 7)	5.32	1.26	6 (1 – 7)
Balancing ecosystem responsibility with profit	4.05	0.97	6 (1 – 7)	3.73	1.25	6 (1 – 7)
Efficiency of the ecosystem	4.45	1.50	6 (1 – 7)	5.14	1.14	6 (1 – 7)
Creating a solidarity community	5.18	1.00	5 (2 – 7)	5.50	0.86	5 (2 – 7)
Healthy work environment	5.09	0.84	5 (2 – 7)	5.23	1.00	5 (2 – 7)
Healthy relationships with individual stakeholders	5.95	0.70	3 (4 – 7)	5.64	0.76	3 (4 – 7)
Shared decision making and collaboration	5.09	1.01	5 (2 – 7)	5.27	1.00	5 (2 – 7)
Diversity in the software ecosystem	3.41	1.54	6 (1 – 7)	4.45	1.23	6 (1 – 7)
Good purpose of use	4.32	1.35	6 (1 – 7)	3.68	1.29	6 (1 – 7)
Good reuse of components	4.18	1.74	6 (1 – 7)	5.00	0.82	5 (2 – 7)
Reasonable energy consumption	3.59	1.41	6 (1 – 7)	3.23	1.09	4 (1 – 5)
Reasonable heat consumption	3.05	1.33	5 (1 – 6)	2.86	1.21	5 (1 – 6)
Reasonable CO2 emission	3.86	1.60	6 (1 – 7)	3.55	1.28	4 (2 - 6)
Reasonable paper usage	3.50	1.28	6 (1 – 7)	3.14	1.42	5 (1 – 6)

Figure 11: Materiality assessment graph of the survey results (1 is low, 7 is high).



7 Discussion

7.1 Interpretation of the results

At the moment there are **limited methods available** related to sustainability in SECOs. The systematic literature review provided us with only two papers that analyzed a part of sustainability in SECOs. One method analyzed a part of economic sustainability and the other was related to social sustainability. However, we can see with the sustainability topics provided by our research that these methods are also not investigating these

individual parts completely. For example, the method that analyzes social relationships does not take into account diversity in the software ecosystem, which is also a part of social sustainability. Furthermore, it could be interesting to investigate individual organizations that participating in a SECO, by analyzing each individual member of several SECOs you can investigate how these organizations are assessing their own sustainability at the moment (e.g. financial reports, CSRs, and certifications). This can also be used to find more sustainability topics that are perceived important by individual organizations.

The two constructs SECO sustainability and SECO health are interrelated. Both the interviewed researchers gave their thought related to sustainability in SECOs and they both mentioned that SECO health is related to SECO sustainability. However, they did not know the relationship between these two constructs. SECO sustainability encompasses more concepts than SECO health with the environmental sustainability, but SECO health does encompass also more subjects that were not mentioned in our interviews, such as bug fix time, new downloads, mailing list responsiveness, etc. (Jansen, 2014). There was also some overlap with the literature and our study related to social relationships (or social sustainability) and economic benefits (or economic sustainability)

The definition of sustainability in SECOs was perceived different for every interviewee. Many explanations were given, but many of the explanations only provided a part of sustainability, so either one of the three dimensions used in this research. This is due to limited research and the lack of attention to sustainability in SECOs because **no SECO orchestrator actively monitors their sustainability of their SECO**.

The 16 identified sustainability topics by interviews were prioritized differently in the interviews compared to the materiality assessment of the survey. That makes it hard to compare them, but what we can identify is that **the awareness of all the sustainability topics is very important if you want to do materiality assessment**. We found out that some of the sustainability topics that were not prioritized highly by the interviews were due to lack of awareness of these topics. For example, the topic continues ecosystem was only mentioned three times by interviewees and thus not prioritized very high. While during the materiality assessment in the survey it scored it very high on both dimensions because everyone was aware of this topic.

The interviews provided us with only material sustainability topics. The result of the survey clearly shows that every topic of the 16 identified sustainability is material in SECOs where the lowest score was 2.86 for the impact of the topic on business success and 3.05 for the importance of the topic to stakeholders.

The 16 identified sustainability topics could be different if we interviewed different persons. Every person is different, so are their beliefs and origin. This makes it hard to identify all existing sustainability topics in SECOs because this requires a lot of diversity within the research. However, these 16 sustainability topics that we found were quite accurate, because the materiality assessment in the survey found out that every topic is material. Therefore, we think that these 16 sustainability topics **provides us with a direction for sustainability in software ecosystems**.

The barriers to adoption of a method that analyzes sustainability are the availability of the method. 8 of 9 interviewees were interested in a method that analyzes

sustainability in their SECO. **Interviewees think if they can analyze their sustainability that it could bring competitive advantages**. However, the method should be easy to use and take into account the complexity of SECOs. We think that this question could relate itself to selection bias, because these participants were already willing to get interviewed, so they were open to analyze their sustainability in SECOs. We still think if some interviewee already sees benefits for a method that analyzes their sustainability then it should be created.

7.2 Sustainable as a SECO

This research investigated sustainability in SECOs. Software ecosystems are more complex than an organization because is a set of businesses functioning as a unit and interacting with a shared market for software and services (Jansen e.a., 2009). This means to be sustainable as a SECO you should look at all the business and agreements in the shared market for software and services. This is not simply just the sum of all the energy consumption within the SECO, because this completely depends on the core activities of partners. (E.g. using energy to create a clean water versus using energy to create profit.)

To achieve a sustainable SECO it is important that you have set the right structure in place. Many of the participants indicated that some of the sustainability topics do not apply in a SECO, because either the stakeholders do not care or it is not prescribed by the law. However, this is not sustainable for the future. The software industry is already affected by sustainability topics because most sustainability topics of this research are already material to many SECOs that participated in this research.

It is hard for any SECO to be completely sustainable. Many aspects of sustainability are also within the individual players of the software ecosystem itself because you cannot enforce your sustainability within individual organizations itself. Therefore, it is hard to say that a SECO can become completely sustainable. However, the orchestrator of the software ecosystem itself can provide the right structure to create a sustainable environment as a SECO. In our research, we analyzed sustainability by investigating beliefs of participants on how a sustainability structure should look like in their SECO and how to increase their sustainability as a SECO. By identifying these material sustainability topics, we provided a direction on what is important for sustainability in SECOs.

As many ways exist to analyze sustainability, this work chose to analyze sustainability from the triple bottom line perspective; economic, social and environmental sustainability. This was needed to provide structure to the participants of this research because many participants were not familiar with sustainability. These concepts helped us guide the participants in providing us with many different sustainability topics.

The economic and social parts of sustainability are often already common within SECOs because they improve the productivity and turnover of SECOs directly. Often there is already some structure in place to promote this e.g. diversity in different teams working on different projects in SECOs (participant 8 of the interviews).

Sustainability can be also seen as a threat by SECOs. If sustainability is not conducted well an ecosystem can lose business and turnover of it, as seen with some other

businesses that were not sustainable in the past (e.g. Volkswagen scandal). Therefore, some participants were not completely transparent, because they were skeptical about the outcomes of this research. This was one of the reasons why some of the participants did not want to prioritize sustainability topics because they were afraid of benchmarks.

By improving these proposed 16 material sustainability topics in this research can provide resistant forces within the SECO because people generally are resistant to changes (Handel, 2003). People are afraid to lose their jobs or just do not like the new way of working in the SECO. This should be approached carefully when actually improving these topics.

7.3 Threats to validity

In this section, we discuss the threats to the validity of this research, which helps us understand the outcomes of the interviews and survey. Moreover, threats and risks that this research is subject to are explained. The validity threats are grouped into four different kinds of validity threats based on Wohlin et al. (2012).

Conclusion Validity

Sample Size was not large enough to derive conclusions of the survey (22 participants). However, we only did a materiality assessment, so not hypothesis testing was needed. This gave us the option to find some quantitative data about the sustainability topics without having to worry about sample size.

Unreliable measures could relate to the dimension of materiality assessment of the importance of the sustainability topic to stakeholders. The participants could have limited knowledge about their stakeholders. We think that the results are still reliable because we mostly conducted the survey at SECO orchestrators. These people are mostly in contact with their stakeholders, so we are quite sure participants do have knowledge related to this subject.

Heterogeneity of the subjects was not applicable to our study, because participants were quite diverse. The participants were from multiple nationalities, gender, and ecosystems. Mostly the participants were from the Netherlands, but we mitigated that by also having some international participants.

Internal Validity

Selection Bias is a severe threat to this research. This threat comes out of the method we used to approach participants to participate in this research. All the participants were approached to opt-in into our research, which could lead to improper conclusions related to the importance of sustainability topics in SECOs. This could be mitigated by future work to do a materiality assessment where everyone that is selected must participate.

History could relate to different answers of participants. Some that were very experienced could give different answers than those more inexperienced. We tried to take the most diverse group of participants possible to mitigate this effect.

Maturation of the interviewees could also harm this research. There were a few weeks in between the interviews and the survey. People that participated in both the interview and survey could change their thoughts related to sustainability in that timeframe.

Regression toward the mean of the survey. We took a 7-point Likert scale to conduct materiality assessment. However, participants do often not want to score a sustainability topic with the highest or lowest score. The results also indicate that by having a mean with the highest score of 6.05 and lowest score of 2.85. This means that both upper and lower end were not filled as often by everyone.

Change of direction was very common in this research. We explored sustainability in SECOs and this led to many adjustments of the research protocol. For example, the prioritization of the interviews should have been compared to that of the survey. However, this was not possible due to the answers of the participants in the interviews. This could be avoided by using a Q-sort method for interviews in the future.

Construct Validity

Hypothesis guessing was possible for the survey. However, there was no reason to do hypothesis guessing, because we only asked about their experience. Some of the inexperienced participants could use this as a method to fill in the gaps they did not have knowledge about.

Bias of design research as we interviewed different people with different background for sustainability topics. Some of these people were inexperienced with sustainability as a concept. This could have led to sustainability topics that were actually not applicable.

Evaluation apprehension could be a severe threat because some participants were afraid of benchmarks. Due to this some of the participants were very open and some were not, because they were afraid to be compared with others. Additionally, they could have given some misleading information to look better.

External Validity

Participant population was not a threat, because we took many participants with different backgrounds and SECOs. The only threat is that they were mostly from the Netherlands.

Different Locations the interviews and survey were conducted in different locations. The interviewees were held at different offices, which could influence their answers. The survey was sent to the participants, so this was also not controlled.

Generalizability is not yet applicable, because the materiality assessment is just an indication of important sustainability topics in SECOs. Therefore, we think more research is needed to make this generalizable, but we think these sustainability topics are a good starting point for research in this field.

Replication of this research might be hard. The sustainability topics came forth out of the nine interviews we conducted. By conducting different interviews it could be

possible that different sustainability topics would be identified. This is not an issue, because we are aware that this list is not yet complete.

8 Conclusion

The main goal of the current study was to investigate how the adoption of a more holistic conception of sustainability in SECOs, such as the triple bottom line perspective, could affect the industrial and academic impact on the SECO community. The results indicate that sustainability practices in SECOs are not yet common. Sustainability is a new concept for SECOs and the academic community and practitioners did not yet have the concept of sustainability well defined in SECOs. This was also seen in the interviews where we had many definitions for sustainability in SECOs. Additionally, practitioners in SECOs indicate that analyzing their sustainability is not yet common on a SECO level, while they indicated that analyzing their sustainability can bring competitive advantages for several SECOs. With our research, we identified 16 sustainability topics that can provide a direction to analyze sustainability in the future. These 16 sustainability topics were prioritized using materiality assessment, so most of the material sustainability topics can be used as a starting point to improve the sustainability in SECOs. Figure 6.1 shows the results of the materiality assessment.

We also found out that there were limited methods available for sustainability in SECOs. There was no method that analyzed sustainability as a whole in SECOs. Interviewees indicated that they would use a new method that analyzes sustainability in SECOs as long as it was easy to use and could take into account the complexity of SECOs because analyzing their sustainability could bring competitive advantages for their SECO.

Furthermore, we found out that SECO sustainability is related to SECO health. However, the relationship between those two constructs was not clear from this research. This requires further investigation because both constructs have some overlap with the topics they address.

Future work

In this study, we found out that sustainability practices in SECOs are not yet common in SECOs and none of the interviewed SECOs was actively measuring their sustainability. To be able to measure their sustainability as a SECO they could use a method. However, this was not yet available, because the literature and the practitioners did not provide any method that could be used to measure sustainability. Most of the interviewees indicated that they would use a method if it was available. We suggest for future work to create a method for sustainability that would take into account the complexity of SECOs. The 16 sustainability topics of this research could be used as a starting point to investigate their metrics, so SECOs can analyze them.

Furthermore, it would be beneficial to further investigate more sustainability topics for SECOs to create a larger list to do a materiality assessment. By creating a longer list, sustainability can be better identified as a concept, so it can be measured and

applied by the SECO community. It would also be good to replicate this study to see if the same sustainability topics can be identified using different participants. This provides credibility to these sustainability topics because it is then validated by another study.

Lastly, as already indicated in the conclusion, the relationship between SECO sustainability and SECO health should be investigated. The researchers both mentioned that these two constructs were interrelated to each other. These constructs do definitely have some overlap, but it is not yet clear how they are related.

9 References

Anand, S., & Sen, A. (2000). Human development and economic sustainability. *World development*, *28*(12), 2029–2049.

Becker, C., Chitchyan, R., Duboc, L., Easterbrook, S., Penzenstadler, B., Seyff, N., & Venters, C. C. (2015). Sustainability design and software: the karlskrona manifesto. In *Software Engineering (ICSE), 2015 IEEE/ACM 37th IEEE International Conference on* (Vol. 2, pp. 467–476). IEEE.

Brinkkemper, S. (1996). Method engineering: engineering of information systems development methods and tools. *Information and Software Technology*, *38*(4), 275–280. https://doi.org/10.1016/0950-5849(95)01059-9

Calabrese, A., Costa, R., Levialdi, N., & Menichini, T. (2016). A fuzzy analytic hierarchy process method to support materiality assessment in sustainability reporting. *Journal of Cleaner Production*, *121*, 248–264. https://doi.org/10.1016/j.jclepro.2015.12.005

Cambridge English Dictionary. (2018, april 20). Geraadpleegd 20 april 2018, van https://dictionary.cambridge.org/dictionary/english/organization

Chen, Y.-S. (2010). The drivers of green brand equity: Green brand image, green satisfaction, and green trust. *Journal of Business ethics*, *93*(2), 307–319.

Cohen, S., Eimicke, W., & Miller, A. (2015). *Sustainability policy: hastening the transition to a cleaner economy*. John Wiley & Sons.

Common Good Matrix. (2018). Geraadpleegd 31 januari 2018, van https://www.ecogood.org/en/common-good-balance-sheet/common-good-matrix/

Dao, V., Langella, I., & Carbo, J. (2011). From green to sustainability: Information Technology and an integrated sustainability framework. *The Journal of Strategic Information Systems*, *20*(1), 63–79. https://doi.org/10.1016/j.jsis.2011.01.002

De Reuver, M., Bouwman, H., & Haaker, T. (2013). Business model roadmapping: a practical approach to come from an existing to a desired business model. *International Journal of Innovation Management*, *17*(01), 1340006. https://doi.org/10.1142/S1363919613400069

de Souza, C. R. B., Figueira Filho, F., Miranda, M., Ferreira, R. P., Treude, C., & Singer, L. (2016). The Social Side of Software Platform Ecosystems. In

Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (pp. 3204–3214). New York, NY, USA: ACM. https://doi.org/10.1145/2858036.2858431

Dhungana, D., Groher, I., Schludermann, E., & Biffl, S. (2010). Software ecosystems vs. natural ecosystems: learning from the ingenious mind of nature. In *Proceedings of the Fourth European Conference on Software Architecture: Companion Volume* (pp. 96–102). ACM.

Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups. (2014). Official Journal of the European Union.

Fair Trade Software Foundation. (2018, april 18). Geraadpleegd 18 april 2018, van http://ftsf.eu/

Franco-Bedoya, O., Ameller, D., Costal, D., & Franch, X. (2014). Queso a quality model for open source software ecosystems. In *Software Engineering and Applications (ICSOFT-EA), 2014 9th International Conference on* (pp. 209–221). IEEE.

Gawer, A., & Cusumano, M. A. (2014). Industry platforms and ecosystem innovation. *Journal of Product Innovation Management*, *31*(3), 417–433.

GRI Standards. (2017). Global Reporting Initiative. Geraadpleegd van https://www.globalreporting.org/standards/

Handel, M. J. (2003). *The Sociology of Organizations: Classic, Contemporary, and Critical Readings*. SAGE.

Hsu, C.-W., Lee, W.-H., & Chao, W.-C. (2013). Materiality analysis model in sustainability reporting: a case study at Lite-On Technology Corporation. *Journal of Cleaner Production*, *57*, 142–151. https://doi.org/10.1016/j.jclepro.2013.05.040

Initiative, G. R. (2017). Global reporting initiative. *http://www. globalreporting. org/*.

ISO 26000 Social responsibility. (2018, april 11). Geraadpleegd 18 april 2018, van https://www.iso.org/iso-26000-social-responsibility.html

Jansen, S. (2014). Measuring the health of open source software ecosystems: Beyond the scope of project health. *Information and Software Technology*, *56*(11), 1508–1519. https://doi.org/10.1016/j.infsof.2014.04.006

Jansen, S., Finkelstein, A., & Brinkkemper, S. (2009). A sense of community: A research agenda for software ecosystems. In *Software Engineering-Companion Volume, 2009. ICSE-Companion 2009. 31st International Conference on* (pp. 187–190). IEEE.

Kitchenham, B. (2004). Procedures for performing systematic reviews. *Keele, UK, Keele University*, *33*(2004), 1–26.

Lago, P., Koçak, S. A., Crnkovic, I., & Penzenstadler, B. (2015). Framing sustainability as a property of software quality. *Communications of the ACM*, *58*(10), 70–78.

Manikas, K., & Hansen, K. M. (2013). Software ecosystems–A systematic literature review. *Journal of Systems and Software*, *86*(5), 1294–1306.

Meertens, L. O., Iacob, M. E., Nieuwenhuis, L. J. M., van Sinderen, M. J., Jonkers, H., & Quartel, D. (2012). Mapping the Business Model Canvas to ArchiMate. In *Proceedings of the 27th Annual ACM Symposium on Applied Computing* (pp. 1694–1701). New York, NY, USA: ACM. https://doi.org/10.1145/2245276.2232049

Melville, N. P. (2010). Information Systems Innovation for Environmental Sustainability. *MIS Quarterly*, *34*(1), 1–21. https://doi.org/10.2307/20721412

Morelli, J. (2011). Environmental sustainability: A definition for environmental professionals. *Journal of environmental sustainability*, *1*(1), 2.

Nidumolu, R., Prahalad, C. K., & Rangaswami, M. R. (2009). Why sustainability is now the key driver of innovation. *Harvard business review*, *87*(9), 56–64.

Popp, K., & Meyer, R. (2010). *Profit from Software Ecosystems: Business Models, Ecosystems and Partnerships in the Software Industry*. BoD–Books on Demand.

Russo, M. V. (2008). *Environmental Management: Readings and Cases*. SAGE.

Sadi, M. H., Dai, J., & Yu, E. (2015). Designing Software Ecosystems: How to Develop Sustainable Collaborations? In *Advanced Information Systems Engineering Workshops* (pp. 161–173). Springer, Cham. https://doi.org/10.1007/978-3-319-19243-7_17

Seelos, C., & Mair, J. (2005). Social entrepreneurship: Creating new business models to serve the poor. *Business horizons*, *48*(3), 241–246.

Social Accountability International | SA8000® Standard. (2018, april 18). Geraadpleegd 18 april 2018, van http://www.sa-intl.org/index.cfm;jsessionid=2A1C4F96726BE329BF2E860E4300F6A7.cfusion?fuseaction=Page.ViewPage&pageId=1689&CFID=34793405&CFTOKEN=291c2a50ac2cfc0b-6FCBDB9A-1C23-C8EB-80DB21AD13CA70B7

Sustainability Reporting Guidelines 3.1. (2011). Global Reporting Initiative (GRI).

Sustainable Development Goals .:. Sustainable Development Knowledge Platform. (2018). Geraadpleegd 1 februari 2018, van https://sustainabledevelopment.un.org/?menu=1300

The Oxford Dictionary of English. (2010). Oxford University Press.

Vallance, S., Perkins, H. C., & Dixon, J. E. (2011). What is social sustainability? A clarification of concepts. *Geoforum*, *42*(3), 342–348. https://doi.org/10.1016/j.geoforum.2011.01.002

Van Marrewijk, M. (2003). Concepts and definitions of CSR and corporate sustainability: Between agency and communion. *Journal of business ethics*, *44*(2), 95–105.

WCED. (1987). Out Common Future. Oxford University Press.

Weerd, I. van de, & Brinkkemper, S. (2009). Meta-Modeling for Situational Analysis and Design Methods. *Handbook of Research on Modern Systems Analysis and Design Technologies and Applications*, 35–54. https://doi.org/10.4018/978-1-59904-887-1.ch003

Wernink, T., & Strahl, C. (2015). Fairphone: sustainability from the inside-out and outside-in. In *Sustainable Value Chain Management* (pp. 123–139). Springer.

What are ethical values? definition and meaning. (2018, april 20). Geraadpleegd 20 april 2018, van http://www.businessdictionary.com/definition/ethical-values.html

What is value system? definition and meaning. (2018, april 20). Geraadpleegd 20 april 2018, van http://www.businessdictionary.com/definition/value-system.html

Wieringa, R. J. (2014). Observational Case Studies. In *Design Science Methodology for Information Systems and Software Engineering* (pp. 225–245). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-43839-8_17

Wohlin, C., Runeson, P., Höst, M., Ohlsson, M. C., Regnell, B., & Wesslén, A. (2012). *Experimentation in Software Engineering*. Springer Science & Business Media.

Appendix A. Conceptual Framework Definitions

All the concepts and their definition used in chapter 3, conceptual framework on analyzing sustainability in software ecosystems.

Concept	**Definition**
Sustainability	Development meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987)
Value System	A coherent set of values adopted and/or evolved by a person, organization, or society as a standard to guide its behavior in preferences in all situations ("What is value system?", 2018).
Ethical Value	The set of established principles governing virtuous behavior. In order to help assure that the company maintains a good business reputation ("What are ethical values?", 2018).
Sustainability Topic	A list of topics, often also called concerns, that influence a part of sustainability in an organization.
Triple Bottom Line	The most common framework, often used in accountancy, is to analyze sustainability is from the triple bottom line perspective; economic, social and environmental sustainability (Russo, 2008).
Economic Sustainability	Economic sustainability refers to the obligation to preserve the present-day economic opportunities for the future, so the performance, profit and business models should fit these purposes (Anand & Sen, 2000).
Social Sustainability	Social sustainability includes a concern for a broad spectrum of issues ranging from quite tangible, very basic requirements – like potable water and healthy food, medication, housing – to less tangible needs concerning education, employment, equity and justice. It is anticipated (or hoped) that positive environmental benefits will follow (Vallance e.a., 2011).
Environmental Sustainability	Environmental Sustainability could be defined as a condition of balance,

	resilience, and interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity (Morelli, 2011).
Materiality (assessment)	Materiality is an approach that helps to improves the stakeholders relationships and contributes to processes to for the creation of shared ethical values. The purpose of materiality assessment in sustainability reporting is to identify, select and prioritize the issues that have the most significance to ecosystem and their stakeholders (Calabrese e.a., 2016).
Organization	A group of people who work in an organized way for a shared purpose ("Cambridge English Dictionary", 2018).
Corporate Social Responsibility	Refers to a company's activities demonstrating the inclusion of social and environmental topics in business operations and in interactions with stakeholders (Van Marrewijk, 2003).
Method	A method is an approach to perform a systems development project, based on a specific way of thinking, consisting of directions and rules, structured in a systematic way in development activities with corresponding development products (Brinkkemper, 1996).
United Nations Requirements and Goals	The requirements and goals that the United Nations to create a more sustainable society.
Software Ecosystem (SECO)	A set of businesses functioning as a unit and interacting with a shared market for software and services, together with the relationships among them. These relationships are frequently under-pinned by a common technological platform or market and operate through the exchange of information, resources and artifacts (Jansen e.a., 2009).
Community of Users and Developers	A group of people using or creating a part of the software ecosystem.

Appendix B. Old Method and GANT-chart of Short Project Proposal

This research is structured using the design science methodology (Wieringa, 2014).

Problem investigation

We will start off with getting to *T1 - understand software ecosystems as a whole based on literature*. By analyzing literature we will create a conceptual framework on how sustainability is related to software ecosystems with their relations and definitions (**RQ1**).

We will also aim to get an understanding of how sustainability concerns change the market. By *T2 – conducting a literature study related to sustainable economics,* we will create a conceptual framework on enterprise sustainability and we will also identify existing methods to analyze the enterprise sustainability (either of single enterprises or groups of them acting in coordination) **(RQ1&2)**. The conceptual frameworks of T1 and T2 will be combined to create an overview of the definition of sustainability in software ecosystems.

Furthermore, we will investigate the current state of the literature of software ecosystems from the sustainability point of view. Therefore, we will *T3 - conduct a systematic literature review on the state of the literature related to analyzing sustainability in software ecosystems.***(RQ2&3)**. The systematic literature review will search five digital libraries and is explained in Appendix A.

It is also important to know if the identified limitations related to sustainability in software ecosystems is also experienced by professionals. By *T4 – conducting semi-structured interviews (Stewart, 2002) at software ecosystem orchestrators*, we will check if professionals have the same perception of the lack of sustainability methods in software ecosystems. We will also aim to validate our created conceptual framework in these interviews **(RQ1,2&3)**.

At the end of this section, a *T5 - list of problems is given that is extracted from information collected* through the different kind of tasks listed above **(RQ3)**.

Treatment Design

At the start of the treatment design, *T6 - the problems found in the problem investigation will be converted to requirements.* These requirements are input for the new method of analyzing sustainability in sustainable software ecosystems

To be able to compare, we will *T7 - create a method to that analyzes sustainability in software ecosystems*. We will design this method using existing methods. This allows us to include important aspects, such as business models, social and environmental metrics to create a well-grounded method **(RQ4)**. Additionally, the method we design will be a situational method, because different users do often have different needs. These situational methods can help users tailor to their needs.

Treatment Validation

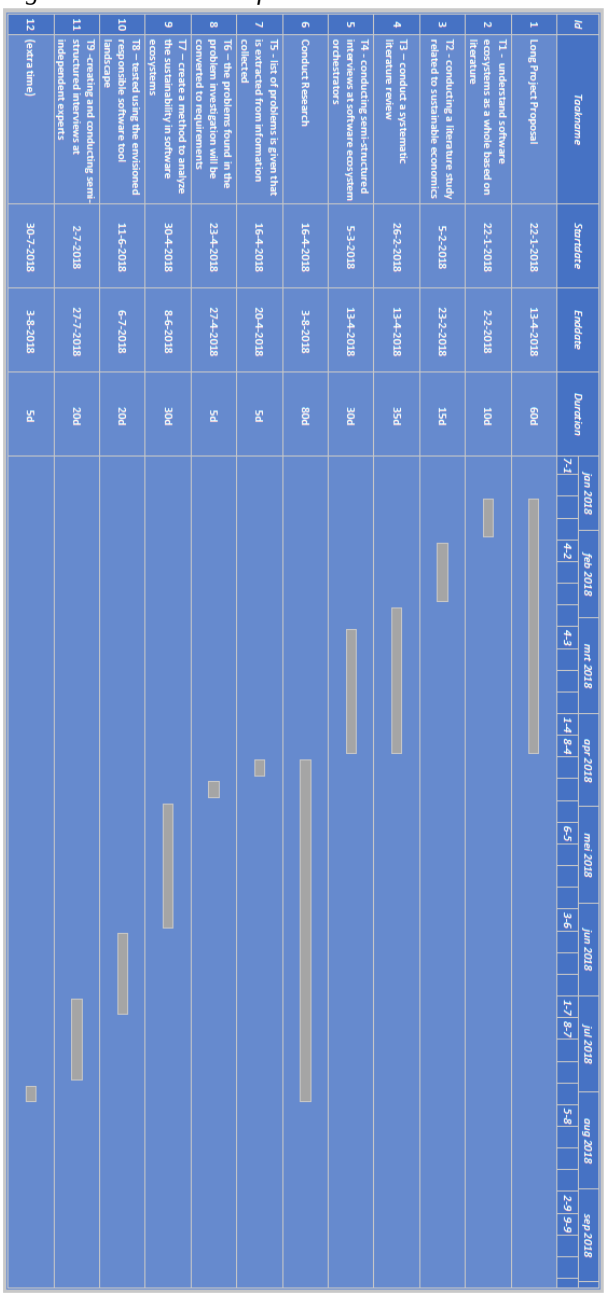
The newly created method for analyzing sustainability in software ecosystems will be *T8 – applied to an existing software ecosystem.* First, we will identify the whole software ecosystems by gathering materials related to this software ecosystem, and then we will analyze sustainability in the software ecosystem by looking into the business models and other related materials of the software ecosystem. Afterwards, we will conduct semi-structured interviews with businesses and users of this software ecosystem to see whether this method analyzes the sustainability in this software ecosystem correctly. This will provide us with feedback to determine if the method of analyzing sustainability in software ecosystems is good or not. Additionally, it will also provide us with input for improvements of this method **(RQ5)**.

Afterwards, we will also do an expert assessment by *T9 - conducting semi-structured interviews at independent experts* (about 3-5 interviews) to validate this method with independent experts that will not (necessarily) benefit from this software ecosystem. This can provide us with important information, because they can provide us with different kind of insights that will help us improve the method from an independent point of view (**RQ5&6)**.

Gantt-chart

In the figure 1 the preliminary planning of this research shown.

Figure 1: Gantt-chart of this research



Appendix C. Protocol for interviews

If interviewing organizations that are either SECO orchestrators or SECO users interviewees are free to interpret SECOs in general as the SECO they participate in as an organization. However, if interviewing an academic researcher they can refer to SECOs in general instead.

Consent
After introducing myself, I will ask the interviewee for their consent to record the interview. If no permission is given I will only write notes on the answers given during the interview.

Explain goal interview
I will explain the goal of the interview to the interviewee by telling the interviewee that I am doing research related to sustainability in software ecosystems. I am interested in his opinion and experience related to sustainability in their context. I will also tell him that I plan to use the results for my master thesis.

Record from this part.
Start Interview
I will start by asking the demographic information of the interviewee.
Q0.1: What is your name?
Q0.2: What is your age?
Q0.3: What is your job and daily activities involved in your job?
Q0.4: How long are you working for your organization?
Q0.5: How long are you already working with SECOs?
Q0.6: Did you do any projects on sustainability in the past? If yes, can you tell something about it?

After finish asking about demographic information, I will start with asking a question related to his understanding of sustainability in SECOs in general.

Q1: From your understanding, what is sustainability in the context of software ecosystems?

If they do not know what to answer there are two options; (1) rephrase it to "give a definition of sustainability for your SECO", (2) use the instance of their software ecosystem to explain it. The interviewee is free to explain their definition using examples of their SECO.

Q2: Can up mention relevant sustainability topics within your SECO? And why?

Q2.1: Follow-up if not given: Can you provide examples of why you think it is relevant for your SECO?

If not clear you can mention an instance of a sustainability topic; energy consumption. Let the interviewee speak freely, and if they do not provide us with many topics related to sustainability we still continue. This is also the situation if the interviewee talks about non-sustainability matters.

Task: Provide the interviewee with our definition of sustainability in SECOs by that sustainability could be analyzed using the triple bottom line. Tell the interviewee to use these definitions from now on if we talk about sustainability in SECOs

Economic sustainability refers to the obligation to preserve the present-day economic opportunities for the future.

As an example I will use the alignment of business models; that business models should align in the software ecosystem. By explaining that you should use fair pricing based on the business models of others. So if someone only receives 5% profit it is not fair to ask for a 10% transaction cost of the whole amount, because the other party will lose money on it.

Social sustainability includes a concern for a broad spectrum of issues ranging from quite tangible, very basic requirements – like potable water and healthy food, medication, housing – to less tangible needs concerning education, employment, equity, and justice. It is anticipated (or hoped) that positive environmental benefits will follow.

As an example, I can explain to the interviewee that you could think of the well-being of the developers in your SECO and how you maintain a good relationship with them to keep them satisfied.

Environmental Sustainability could be defined as a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity.

As an example, I will use things like the gas, electricity, and CO2 consumption of the whole SECO. I will also explain the direct environmental influence of the SECO existing, but also the indirect results, such as cutting forests to provide the electricity needed.

Task: Ask if the interviewee understood each definition. If no, ask what they do not understand and clarify it.

Continue interview normally when definitions are understood and clarified to the interviewee.

Q3: Can you go back to my previous question related to relevant sustainability topics within your SECO and think of other topics related to sustainability? And why are they relevant?

Q3.1: Follow-up if not given: Can you also provide examples of why you think it is relevant for your SECO?

Q3.2 Follow-up: Can you rate the sustainability topics you mentioned in the order of important topics for your SECO?
1 is very important and 5 is not important (based on 5 sustainability topics).

If the interviewee does not mention sustainability topics related to either of the triple bottom line parts then we can specifically ask for that certain part (e.g. of questions I will ask: Why did you not mention any sustainability matter on Economic sustainability? Do you think it is not relevant in your SECO? And why?). If satisfied with the answer I will continue with the next part.

Q4: Does your SECO analyze their sustainability? If yes, how? If not, why not?

In this part, it is important to distinguish methods or tools that analyze organizational sustainability and methods or tools that analyze SECO sustainability. I will ask follow-up questions, if the interviewee says yes, such as what does it analyze? Does it analyze only your organization or also those of partners? Does it analyze economic, social and environmental sustainability? What does it also analyze next your organization? If answered no, I will ask questions like; do you have a sustainability method that analyzes organizational sustainability? Do you analyze sustainability? Do you want to analyze sustainability in the future?

If asked Q5/5.1 to the academic SECO community, ask how which one they know and what they analyze.
Q5: Do you use methods to analyze the sustainability in your organization? *Can you provide names of the methods and what they analyze?*

This question is given as a comparison to Q5.1, but also a question to make sure that the interviewee knows the difference between organizational and SECO methods for sustainability. I do expect some answers here, but the answer is not important. I just want to make sure that the interviewee does not forget a method that analyzes sustainability in some kind of way and knows the difference between organizational and SECO sustainability. However, if the interviewee does not know any method it is also fine.

Q5.1: Do you use methods to analyze the sustainability in your SECOs? *Can you provide names of the methods and what they analyze?*

I do not expect an answer that contains a method that analyzes sustainability in SECOs. However, maybe a SECO has created something themselves and use it to analyze their sustainability. If the method is given, ask critical questions, such as does it analyze only your organization or also those of partners? Does it analyze economic, social and environmental sustainability? What does it also analyze next your organization? If none

given, I will ask a question, such as; Do you know if your partners analyze the sustainability in your SECO? Does your orchestrator analyze the SECO sustainability?

Q6: Do you want a (new) method that analyzes sustainability in SECOs? And why?

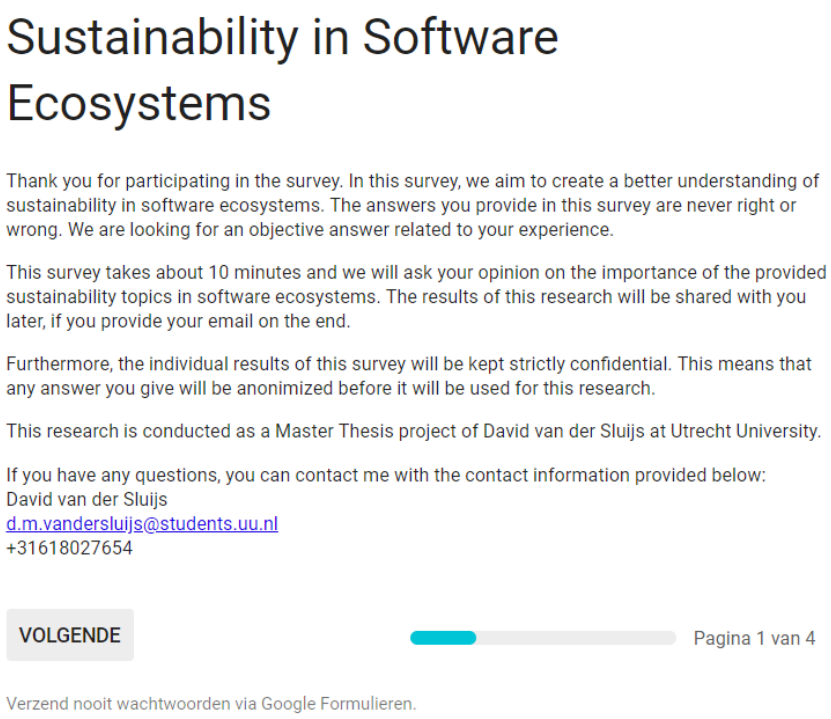
An open question and an answer that has good arguments is fine here. I do not want to guide the answer.

End Interview
Thank the interviewee for his time and round up the interview. Additionally, tell the interviewee that you will send a survey later that is related to this interview and you would like him to participate in the survey as well.

Appendix D. Survey Design

The survey design with the information provided for each page is found below (Figure D.1, D.2, D.3 and D.4).

Figure D.1: Introduction Survey.



Sustainability in Software Ecosystems

Thank you for participating in the survey. In this survey, we aim to create a better understanding of sustainability in software ecosystems. The answers you provide in this survey are never right or wrong. We are looking for an objective answer related to your experience.

This survey takes about 10 minutes and we will ask your opinion on the importance of the provided sustainability topics in software ecosystems. The results of this research will be shared with you later, if you provide your email on the end.

Furthermore, the individual results of this survey will be kept strictly confidential. This means that any answer you give will be anonimized before it will be used for this research.

This research is conducted as a Master Thesis project of David van der Sluijs at Utrecht University.

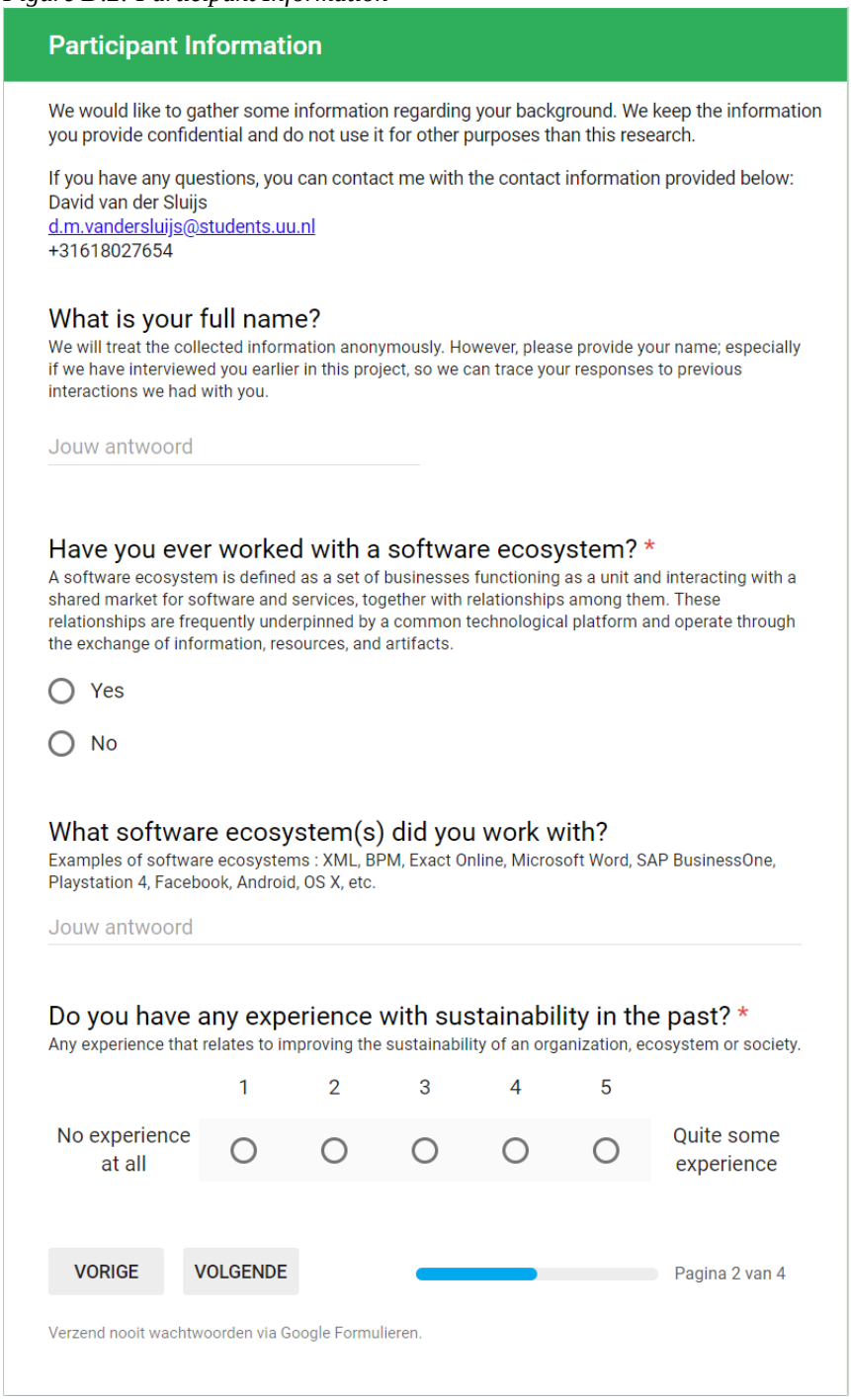
If you have any questions, you can contact me with the contact information provided below:
David van der Sluijs
d.m.vandersluijs@students.uu.nl
+31618027654

VOLGENDE

Pagina 1 van 4

Verzend nooit wachtwoorden via Google Formulieren.

Figure D.2: Participant Information



Participant Information

We would like to gather some information regarding your background. We keep the information you provide confidential and do not use it for other purposes than this research.

If you have any questions, you can contact me with the contact information provided below:
David van der Sluijs
d.m.vandersluijs@students.uu.nl
+31618027654

What is your full name?

We will treat the collected information anonymously. However, please provide your name; especially if we have interviewed you earlier in this project, so we can trace your responses to previous interactions we had with you.

Jouw antwoord

Have you ever worked with a software ecosystem? *

A software ecosystem is defined as a set of businesses functioning as a unit and interacting with a shared market for software and services, together with relationships among them. These relationships are frequently underpinned by a common technological platform and operate through the exchange of information, resources, and artifacts.

- ◯ Yes
- ◯ No

What software ecosystem(s) did you work with?

Examples of software ecosystems : XML, BPM, Exact Online, Microsoft Word, SAP BusinessOne, Playstation 4, Facebook, Android, OS X, etc.

Jouw antwoord

Do you have any experience with sustainability in the past? *

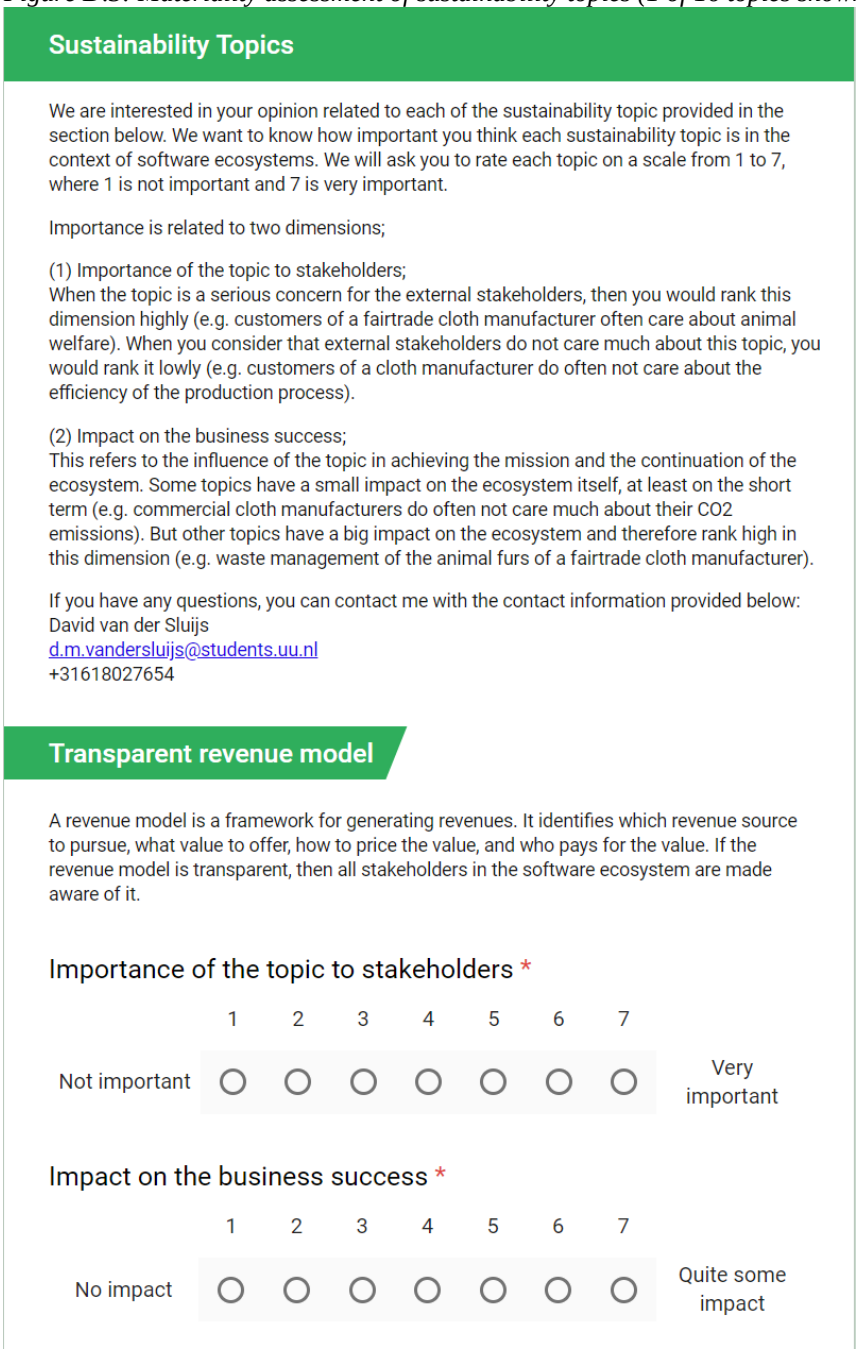
Any experience that relates to improving the sustainability of an organization, ecosystem or society.

	1	2	3	4	5	
No experience at all	◯	◯	◯	◯	◯	Quite some experience

VORIGE VOLGENDE Pagina 2 van 4

Verzend nooit wachtwoorden via Google Formulieren.

Figure D.3: Materiality assessment of sustainability topics (1 of 16 topics shown).



Sustainability Topics

We are interested in your opinion related to each of the sustainability topic provided in the section below. We want to know how important you think each sustainability topic is in the context of software ecosystems. We will ask you to rate each topic on a scale from 1 to 7, where 1 is not important and 7 is very important.

Importance is related to two dimensions;

(1) Importance of the topic to stakeholders;
When the topic is a serious concern for the external stakeholders, then you would rank this dimension highly (e.g. customers of a fairtrade cloth manufacturer often care about animal welfare). When you consider that external stakeholders do not care much about this topic, you would rank it lowly (e.g. customers of a cloth manufacturer do often not care about the efficiency of the production process).

(2) Impact on the business success;
This refers to the influence of the topic in achieving the mission and the continuation of the ecosystem. Some topics have a small impact on the ecosystem itself, at least on the short term (e.g. commercial cloth manufacturers do often not care much about their CO2 emissions). But other topics have a big impact on the ecosystem and therefore rank high in this dimension (e.g. waste management of the animal furs of a fairtrade cloth manufacturer).

If you have any questions, you can contact me with the contact information provided below:
David van der Sluijs
d.m.vandersluijs@students.uu.nl
+31618027654

Transparent revenue model

A revenue model is a framework for generating revenues. It identifies which revenue source to pursue, what value to offer, how to price the value, and who pays for the value. If the revenue model is transparent, then all stakeholders in the software ecosystem are made aware of it.

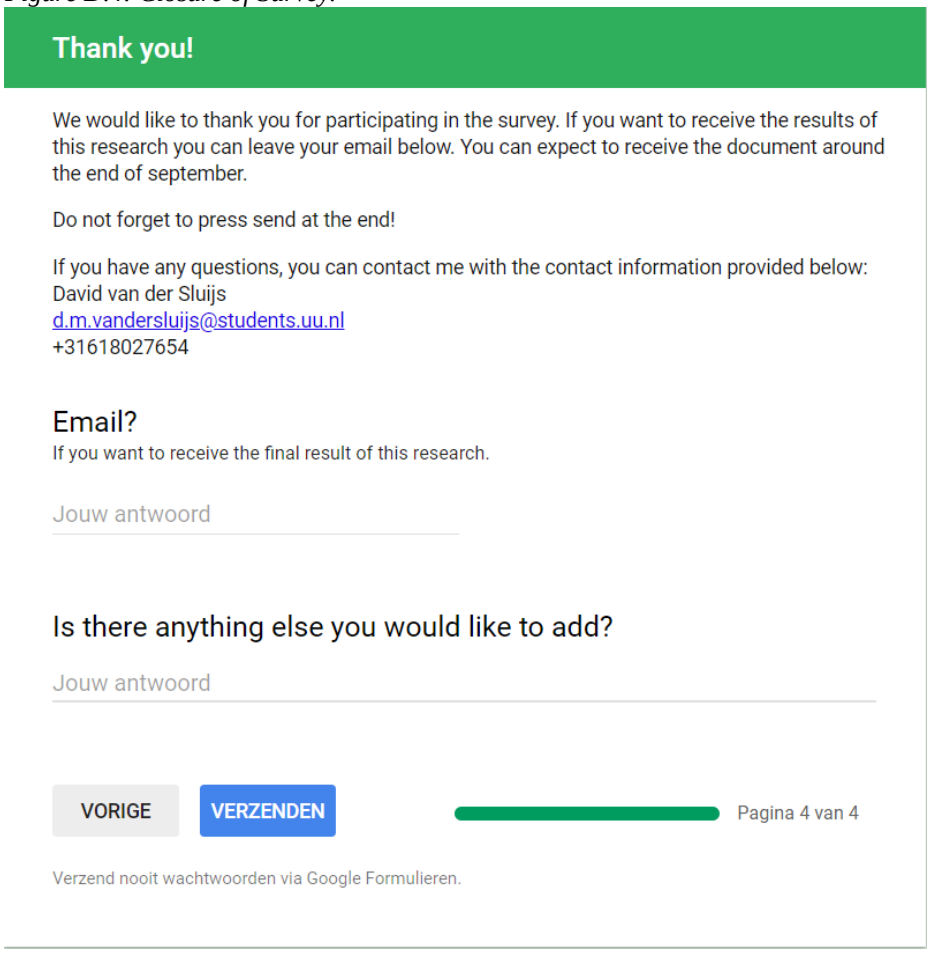
Importance of the topic to stakeholders *

	1	2	3	4	5	6	7	
Not important	○	○	○	○	○	○	○	Very important

Impact on the business success *

	1	2	3	4	5	6	7	
No impact	○	○	○	○	○	○	○	Quite some impact

Figure D.4: Closure of Survey.



Appendix E. Systematic Literature Review Results

Method 1: Business Model(s)

Purpose/Intention of the method: A business model describes the rationale of how an organization creates, delivers and captures value by interacting with suppliers, customers, and partners (Popp & Meyer, 2010).

PDD of the method:
In figure C.1 the PDD of the analysis of business models is found. Table C.1 explains the related activities and table C.2 explains the related concepts.

Figure C.1: PDD of the analysis of business models.

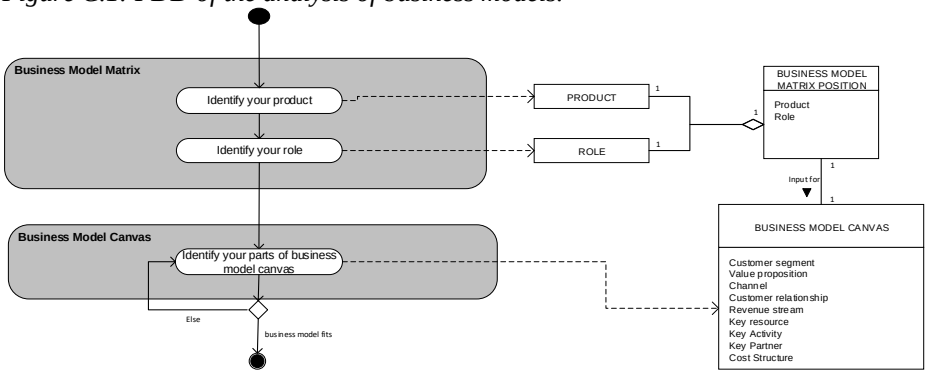


Table C.1: Activities related to the business model PDD.

Activity	Sub-activity	Description
Business Model Matrix	Identify your product	You should identify the product you offer. In the case of SECO, it is always an intellectual property.
Business Model Matrix	Identify your role	Identify your role in the product.
Business Model Canvas	Identify your parts of business model canvas	Fill in the business model canvas to position yourself using their metrics.

Table C.2: Concepts related to the business model PDD.

Concept	Description
Product	The product you offer as an organization or SECO.
Role	The role of a certain actor in the software vendor's business model.
Business Model Matrix Position	The position of an actor in the software vendor's business model (Popp & Meyer, 2010).

Business Model Canvas	The Business Model Canvas gives a description of a software vendor's business model (Popp & Meyer, 2010).

Analysis Dimension(s): Economic

Metrics: A SECO is an intangible product. This results in the following options as roles according to the business model matrix (Popp & Meyer, 2010):

As a creator: Inventor, Developer, and Author
As a distributor: IP Distributor
As a lessor: IP Lessor
As a broker: IP Broker

The Business Model Canvas gives a description of a software vendor's business model. In the description below you find metrics analyzing a business model.

- **Customers Segments;** an organization serves one or several customers.
- **Value proposition;** it seeks to solve customer problems and satisfy customer needs with value propositions.
- **Channel;** value propositions are delivered to customers through communication, distribution, and sales channels.
- **Customer Relationships;** customer relationships are established and maintained with each customer segment.
- **Revenue Streams;** revenue stream result from value propositions successfully offered to customers. At this part a pricing scheme is added, so tools can be compared on revenue models.
- **Key Resources;** key resources are the assets required to offer and deliver the previously described elements by performing a number of key activities.
- **Key Activities;** see key resources.
- **Key Partners;** some activities are outsourced and some resources are acquired outside the organization.
- **Cost Structure;** the business model elements result in the cost structure.

Modeling language: Natural Language

Tools: Business Model Matrix and Business Model Canvas

The list of publications that scientifically contribute to the method: (De Reuver, Bouwman, & Haaker, 2013; Meertens e.a., 2012, 2012; Popp & Meyer, 2010)

Number of Citations: 76

Method 2: Sustainable Collaborative Relationships

Purpose/Intention of the Method: In order to create a healthy and sustainable software ecosystem, a keystone platform developer needs to elicit and analyze the objectives and decision criteria of both its organization and external developers for participation .(Sadi, Dai, & Yu, 2015).

PDD of the method:
The method is derived from the paper of Sadi et al. (2015). Figure C.2 shows the PDD of the sustainable collaborative relationship method, and table C.3 and C.4 do explain the activities and concepts shown in figure C.2.

Figure C.2: PDD of the Sustainable Collaborative Relationship method.

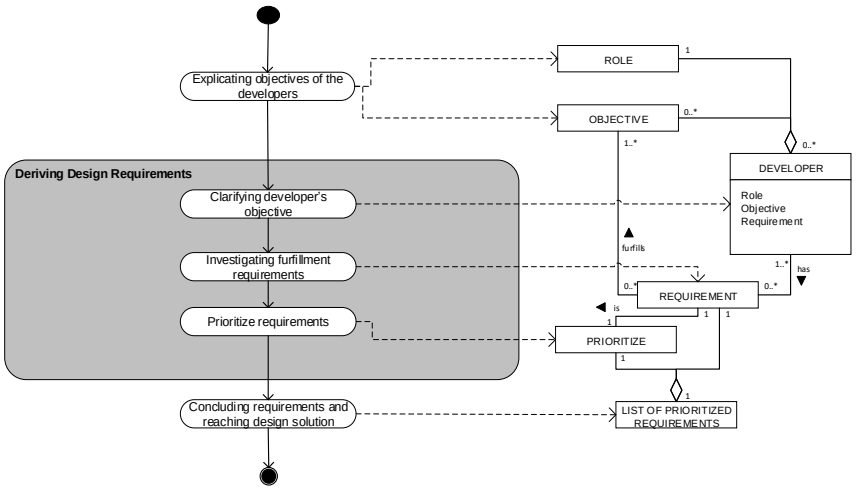


Table C.3: Activities related to the Sustainable Collaborative Relationship method.

Activity	Sub-activity	Description
Explicating objectives of the developers	-	Explicating the objectives of the developers for the SECO.
Deriving Design Requirements	Clarifying developer's objective	Further refined objectives, so that they can be used as requirements.
Deriving Design Requirements	Investigating fulfillment requirements	Investigating the list of requirements, so that it fulfills the objectives.
Deriving Design Requirement	Prioritize requirements	Prioritize requirements based on the needs of developers.

Concluding requirements and reaching design solutions	-	Creating a list of requirements that can be used as input to create new design solutions for important features of the SECO.

Table C.4: Concepts related to the Sustainable Collaborative Relationship method.

Concept	**Description**
ROLE	The role of a developer in the SECO.
OBJECTIVE	The objectives a developer wants to achieve in the SECO.
DEVELOPER	The developers that participate in the SECO.
REQUIREMENT	The requirements that come forth out of the objectives of the developers.
PRIORITIZE	The prioritization of the requirements.
LIST OF PRIORITIZED REQUIREMENTS	The list of requirements prioritized, so that it can be used to create design solutions for the SECO.

Analysis Dimension(s): Social

Metrics:
The metrics are based on the main steps of the method (Sadi e.a., 2015);

- **Different Type of Application Developers;** categorize them according to their behavior by understanding their motivations, expectations, and criteria for deciding to join an ecosystem
- **Explicate and analyze the technical and non-technical requirements;** to refine and analyze the obtained information about each group of application developers as a source for deriving the requirements of an appropriate collaborative environment.
- **Derive alternative solutions for designing an appropriate collaborative environment that fulfills the elicited requirements;** what courses of action should be taken to design or improve the configuration of the collaborations among the keystone software company and the application developers

Modeling language: iStar (i*) goal-oriented social modeling technique

Tools: iStar template

The list of publications that scientifically contribute to the method: (Sadi e.a., 2015)

Number of Citations: 3