Understanding supply chain uncertainties that might hinder an expansion of coffee husk-biochar production in Vietnam

A case study on the potential use of coffee husk-biochar as raw material for activated carbon production

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Preface

The following thesis was conducted during the spring of 2020 and represents the final part of our engineering studies within Industrial Engineering and Management. The thesis has been conducted in collaboration with Lund University and the United Nations Industrial Development Organization (UNIDO). Both authors have been involved in every part of the process and have contributed equally.

Throughout the project, we have gained many valuable insights regarding the difficulties of supply chains and how contextual settings affect both theory and practice. We have learned a lot about the Vietnamese coffee industry and its challenges, but also how it is improving and what is being done for its further development. With this, we have improved our analysing skills, learned how to tackle the challenges that a real world problem faces as well as improved our ability to conduct a larger scale project.

The thesis would not have been possible without the help and support from our university supervisor, Lina Frennesson. She has given us very valuable feedback throughout the whole project that greatly improved the result of the report. We are also very grateful to Alessandro Flammini at UNIDO who involved us in the project. Alessandro has been both a great support as well as a very valuable contact who has guided us through the project. We would also like to express our gratitude towards both Thao Le and Linh Hoang at the UNIDO office in Hanoi. Without their fantastic support, we would still be in Vietnam trying to figure out who to get in contact with. Lastly, we are very grateful for all the support that Hannes Zellweger at Sofies Zürich, Federico Tempestilli at Husk Ventures, Chung Tran at UNIDO as well as Trung Nguyen at VNCPC have given us. They have all greatly enhanced our understanding of the coffee supply chain as well as the biochar industry.

Rikard Grill

Erik Brundin

Lund, June 2020.

Abstract

Purpose - The purpose of this thesis is to increase the understanding of supply chain uncertainties that might hinder an expansion of coffee husk-biochar production in Vietnam, and understand how the coffee husk-biochar supply chain can be configured to address these uncertainties.

Methodology - A case study regarding the potential use of coffee husk-biochar as raw material for activated carbon was used to conduct this research. Through this approach, uncertainties that potentially could hinder an expansion of coffee husk-biochar production were found. Also contextual findings that could affect appropriate supply chain configurations and the responsiveness measures, needed to address these uncertainties, were identified. The found demand uncertainty from the activated carbon producer represented one level of demand uncertainty, and from those findings, further analysis was made of how other levels of demand uncertainty could affect the supply chain. To support this case study research, qualitative data was gathered from current coffee husk-biochar producers, an activated carbon producer, as well as other experts on the biochar subject.

Findings - This study shows that uncertainties in terms of both demand and supply are low in a supply chain where coffee husk-biochar is commercialized in Vietnam. The low demand uncertainty originates from investigating activated carbon producers as customers, but it was also found that it is unreasonable to prepare for other levels of demand uncertainty no matter to what market the biochar is sold. This is due to the characteristics of the biochar, which makes it a functional product that always should expect stable demand. Due to the found uncertainties, the responsiveness measures that are needed are a centralized production, low-cost transports and low levels of inventory. Only the low levels of inventory were found to be difficult to achieve among these measures. This is because of the need of annual production in combination with the short period of time where the coffee husk, which is the raw material, is generated. Small-scale farmers were found to be inappropriate producers of the coffee husk-biochar as they were found to have difficulties in both financing the production as well as having it utilized. Instead, large-scale farmers, external intermediaries or coffee processors which could use already existent flows and relationships, should be the producers.

Originality - Previous research has mostly focused on how both smoke issues and soil degradation can be solved by the production of coffee husk-biochar, as well as the technology needed for this production. Our idea was that biochar is a functional product, and that finding more application areas for the biochar could potentially scale up production, and thereby reduce the costs of producing biochar through economies of scale. Through this original supply chain management perspective, we were able to find uncertainties in the supply chain that might hinder the desired expansion of biochar production. We did also point out appropriate supply chain configurations that address the found uncertainties in the current context, and our study is original as this supply chain management perspective had not yet been used in this context.

Keywords - Supply chain uncertainties, supply chain responsiveness, biochar, Vietnamese coffee industry, activated carbon.

Paper Type - Master's Thesis.

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1. Introduction

Chapter 1 will present a background to the underlying problem the thesis is trying to address, as well as the UNIDO project that the thesis will try to contribute to. It will further explain the purpose of the thesis, as well as its limitations and focus areas.

1.1 Background

Vietnam is the world's second largest coffee producer with around USD 3 billion worth of exports each year according to the Vietnam Coffee-Cacao Association (2019), and the coffee industry accounts for more than 2% of the national GDP. The production covers over 650,000 hectares of land, where the majority is concentrated in the central parts of the country (Vietnam Coffee-Cacao Association, 2019). Of all coffee grown in Vietnam, 97% is the robusta sort while the remaining 3% is the more famous arabica, and a total of more than 10 million tonnes of coffee cherries was produced in Vietnam in 2018 (International Coffee Organization, 2019; Vietnam Coffee-Cacao Association, 2019).

Even if the coffee sector currently seems to be thriving in Vietnam, there are arising problems that need to be dealt with. The fact that the country has a very high output of coffee cherries per hectare, 12.8 tonnes per year, which is considerably higher than any other country in the world, is not just positive (Vietnam Coffee-Cacao Association, 2019). Zellweger et al. (2017) state that the high yields are due to too intensive farming with mainly chemical fertilizers, a method that has led to the degradation of the already poor nutrient soils. Zellweger et al. (2017) and Vietnam Coffee-Cacao Association (2019) also stress that changing weather patterns, such as longer dry periods and heavier, more irregular rainfalls, is a big threat to the Vietnamese coffee production. The weather can both reduce the harvest due to drought, but irregular rainfalls can also harm the drying process of the coffee cherries which traditionally have been dried in the sun. According to Vietnam Coffee-Cacao Association (2019), the combination of degraded soils and changing weather patterns are threatening to cost Vietnam up to 50% of its viable production areas by 2050.

Apart from arising problems, there are current problems within the coffee sector in Vietnam as well. Dry coffee waste, i.e. the outer parts of the cherry that surrounds the bean, is referred to as coffee husk. The coffee husk accounts for roughly 14% of the coffee production weight (Montilla-Pérez et al. 2008), meaning that every year almost 1.4 million tonnes of waste has to be disposed of in Vietnam. The coffee husk has therefore been spread on the soils as nutrients with limited positive effect, or burned, not seldom as a method to dry the coffee cherries instead of the common sun drying (Dzung et al., 2013; Vietnam Coffee-Cacao Association, 2019). To burn the coffee husk can solve the direct disposal problem, but it has also caused problems with the smoke such as effect on the taste of the coffee beans as well as health problems for the farmers (Luu Tien et al., 2018; Zellweger et al., 2017). According to Dzung et al. (2013), it is clear that the current use of the coffee husk is at best inefficient if used as soil nutrients, and at worst harmful for the farmers if burnt.

1.2 Introduction to UNIDO project

In order to mitigate the arising problems as well as addressing the current coffee husk problem, the United Nations Industrial Development Organization (UNIDO) has introduced a new small-scale pyrolysis machine, the PPV300, to the Vietnamese market. Pyrolysis is a smoke-free process that under controlled forms carbonize biomass, such as coffee husk, into biochar (Zellweger et al., 2017). Biochar is thus carbon made from biomass. The pyrolysis process also generates excess heat that, in the case of the PPV300, can be used for drying coffee cherries without the taste impact that the smoke otherwise has (Zellweger et al., 2017). It is an old technique, but applying it to coffee husk has not been done before at an industrial scale (Zellweger et al., 2017). The PPV300 is developed by a Swiss company and, with the support of UNIDO and the Swiss State Secretariat for Economic Affairs, the technology was transferred to a Vietnamese manufacturer in 2017 (UNIDO, 2019). The PPV300, which is the chosen machine unit for coffee husk-biochar production in this thesis, is designed to be operationable by small businesses or by smaller farmer cooperatives (Zellweger et al., 2017), but has yet to find its market segment. The biochar from the PPV300 is mainly intended to be used directly in the soil as soil amendment due to its water and nutrition holding capabilities that is achieved through high porosity (Draper, 2018). It will also reduce the need for fertilizers as well as improve the soil structure (Zellweger et al., 2017).

Despite its big potential, the PPV300 technology in Vietnam is still not fully mature, resulting in high production costs that often cannot be motivated by the farmers, and the demand for biochar in agricultural use has still been too low to sustain a business around it (UNIDO, 2019). By establishing new revenue streams from coffee husk-biochar and thus the PPV300, the chances increase of making the technology cheaper and more reliable, which can reduce business risk. Such an approach could therefore motivate farmers or other actors to invest in the technology. UNIDO (2019) have identified that potential new revenue streams could come from selling coffee husk-biochar as wastewater treatment, or, as the proven application as raw material for activated carbon. Activated carbon is biochar that has been further processed and refined to receive even higher porosity (Goncalves et al., 2013; Teshome, 2015), and the raw material for activated carbon production is thus biochar. The UNIDO project has so far mostly been focusing on the technology of the PPV300, but has yet to examine whether or not the potentially new revenue streams are viable applications for the biochar.

1.3 Contribution to the UNIDO project

Expansion of the biochar business will open up for new collaborations and supply chains, which implies that new roles and responsibilities will arise. Furthermore, Courtney et al. (1997) explain that emerging industries typically must handle big uncertainties and Simangunsong et al. (2010) stress that uncertainties are important to understand in supply chain management. It is also difficult to find clear and aligned descriptions of the Vietnamese coffee supply chain, an industry that highly impacts the potential biochar production, and supply chain theory is therefore deemed as highly relevant for the UNIDO project. This thesis is therefore a first step in exploring the potential supply chain uncertainties that might hinder an expansion of coffee husk-biochar production in Vietnam. The thesis will categorize supply chain uncertainties into *demand uncertainties* and *supply uncertainties.* These will be investigated through a case study of the identified application area as raw material for activated carbon production. Investigating this application area is therefore merely a tool to understand the supply chain uncertainties from producing coffee husk-biochar.

This will be done by examining the possibility of linking a coffee husk-biochar producer with activated carbon producers in Vietnam. A coffee husk-biochar producer could be either: (1) coffee farmers since they generate the coffee husk; (2) an intermediary; or (3) the activated carbon producers which potentially buy the husk to produce biochar first and then use the produced biochar as raw material for their activated carbon. Since there is no current market for coffee husk-biochar among activated carbon suppliers, the supply chain does not exist, meaning that the analysis should lead to suggestions of how it can be established. See Figure 1.1 for an illustration of a supply chain where coffee husk-biochar is used as raw material for activated carbon production. The dashed lines symbolizes the involvement of an additional actor in the supply chain, and the flows that would occur in this case. Coffee farmers and activated carbon producers will always be involved in a supply chain where coffee husk-biochar is used as raw material for activated carbon, and the flows from supply chains that only would involve them are therefore not dashed.

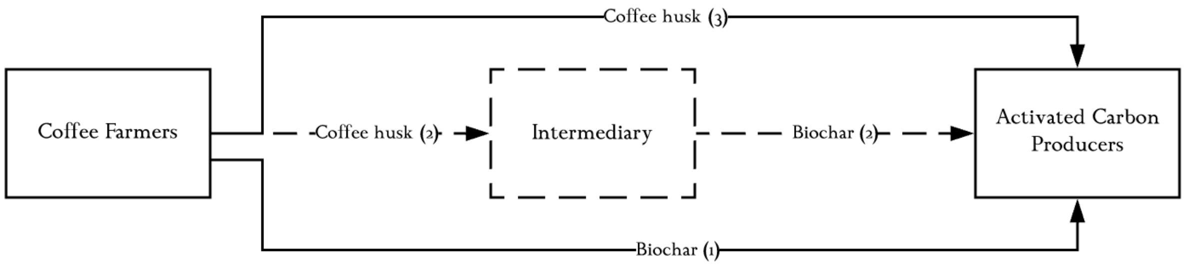

Figure 1.1 - A supply chain where coffee husk-biochar is used as raw material for activated carbon production.

Depending on which actor that takes on the role as biochar producer, the supply chain will have different configurations, i.e. have different paths that the initial raw material can take from point 'A' in order to reach point 'B' as a finished processed product. These configurations will have various uncertainties and, by exploring the different paths, an understanding of the expansional hinders will be gained.

These different supply chain configurations will be evaluated with the help of a framework developed by Chopra and Meindl (2013), to test their ability to link the coffee husk-biochar with the activated carbon producers. The framework focuses on supply chain uncertainties, and how these can be addressed through supply chain responsiveness, i.e. how well a supply chain can adapt to disruptions or unpredictable supply and demand. The matching of a correct level of responsiveness to the supply chain uncertainty is what Chopra and Meindl (2013) call achieving strategic fit, which is illustrated in Figure 1.2.

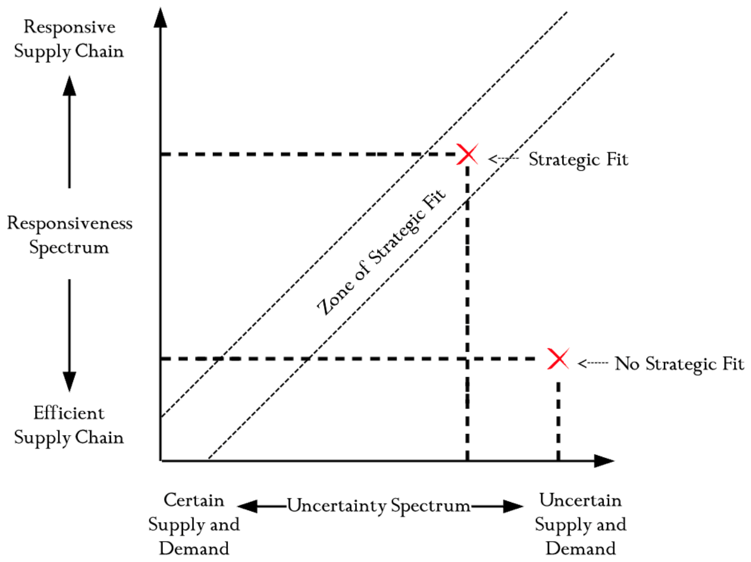

Figure 1.2 – The zone of strategic fit. Source: Chopra and Meindl (2013).

Due to the many potential factors that can affect the supply chain responsiveness, the thesis will focus on a limited number of factors identified by Chopra and Meindl (2013). These factors are *facilities*, *transportation* and *inventory*, and they will be investigated for further understanding of the supply chain responsiveness that is needed to adjust to the found uncertainties. The findings from the evaluated case will support UNIDO in understanding supply chain uncertainties that might hinder an expansion of coffee husk-biochar production, as well as how the supply chain could be configured to address these.

1.4 Purpose

The purpose of this thesis is to increase the understanding of supply chain uncertainties that might hinder an expansion of coffee husk-biochar production in Vietnam, and understand how the coffee husk-biochar supply chain can be configured to address these uncertainties.

1.5 Research questions

In order to fulfill the purpose of the thesis, the following two research questions will be answered.

RQ1: *What are the supply chain uncertainties if activated carbon is made from coffee husk-biochar?*

To explore possible hinders of using biochar from coffee husk as raw material for activated carbon, the uncertainties among the supply chain actors will be investigated. This will be done through analysing different supply chain configurations, with different types of actors as biochar producers.

RQ2: *How could the supply chain be configured to address the found uncertainties and fit into the current context?*

Uncertainties and their impact can, as mentioned, be addressed by responsiveness measures, and different supply chain configurations will have different opportunities of adopting these. Suggestions of how the supply chain could be configured will therefore be based on whether the actors can adopt the suggested responsiveness measures, as well as their incentives and potential hinders of being part of such a supply chain.

1.6 Focus and delimitations

Our research will focus on actors located in Vietnam, and the investigated supply chain configurations will therefore not include actors that are not present in the country. The flows from the activated carbon producers will not be included in the identified supply chain configurations, though demand parameters regarding activated carbon will be taken into account. Other material flows that typically occur in a supply chain are return flows, but these flows will not be investigated in this research.

In-depth product requirements or properties for the coffee husk or biochar will also be excluded from the report as the focus is supply chain responsiveness and uncertainties. Even though biochar could be made from other biomasses than coffee husk, along with the functionality of the PPV300 to do so, this thesis will focus exclusively on coffee husk. Product characteristics that affect the needed responsiveness such as production capacity or possible input material will however be investigated for the pyrolysis unit, as these are relevant for our recommendations.

1.7 Thesis outline

Chapter 1. Introduction
Chapter 1 will present a background to the underlying problem the thesis is trying to address, as well as the UNIDO project that the thesis will try to contribute to. It will further explain the purpose of the thesis, as well as its limitations and focus areas.

Chapter 2. Methodology
The methodology chapter will present how the research was conducted. We will present what method was used to structure the report, and how the data was gathered from external actors. Our choices of interview objects will be motivated in regards to how their knowledge and expertise contributed to answering the research questions.

Chapter 3. Frame of Reference
In Chapter 3, the frame of reference is presented. The first part will explain supply chain uncertainties, and the second part will then describe how they can be mitigated through responsiveness. After that, we will describe the coffee industry in Dak Lak, Vietnam, as well as elaborate on biochar and activated carbon to further outline the context of this thesis.

Chapter 4. Findings and Analysis

Chapter 4 will present the findings from the interviews, field visits and the literature review. It will present the found uncertainties depending on the type of actor that produces biochar, as well as the needed supply chain strategy and responsiveness the supply chain must have to address these. It will also present appropriate supply chain configurations according to these findings.

Chapter 5. Discussion

Chapter 5 will present discussions about the producers of biochar and the recommended supply chain strategy, as well as discussions regarding the framework from Chopra and Meindl (2013) which was used for the analysis.

Chapter 6. Conclusion

In Chapter 6, we will present the conclusions of our theis. We will answer the stated RQs and suggest how these answers contribute to practice and theory. As some research areas related to our thesis still are uncovered, we will also suggest areas for future research.

2. Methodology

The methodology chapter will present how the research was conducted. We will present what method was used to structure the report, and how the data was gathered from external actors. Our choices of interview objects will be motivated in regards to how their knowledge and expertise contributed to answering the research questions.

2.1 Research approach

We chose to conduct a case study for this research. Meredith (1998) and Bebensath (1997) have explained three benefits of using a case study approach, and our application of these benefits were: (1) We learned through observing actual practice; (2) We were able to explore questions of *what* and *how,* which Yin (2003) also explains is an important reason for choosing a case study design; and (3) Since the research areas we investigated were relatively unknown, we were able to use an early, exploratory investigation.

Our case study assisted in finding *what* supply chain uncertainties that exist, and *how* the supply chain could be configured to address these. There could however be difficulties by conducting case studies, and Voss et al. (2002) conclude that case studies has challenges such as: (1) It is time consuming; (2) Skilled interviewers are required; and (3) Generalisable conclusions must be drawn from limited cases, and a rigorous research must be ensured. We did however consider our achieved benefits to outweigh these difficulties.

2.2 Research design

2.2.1 Design of the case study

After choosing the case study approach, one must decide on whether the study should be made up of multiple cases or a single case (Baxter and Jack, 2008). The single case study is used when a single case unit and context is subject of research (Gustafsson, 2017). Baxter and Jack (2008) explain that the context could be for example a geographical location. If several case units are part of the research, with each having a separate context, the research format is a multiple case study (Baxter and Jack, 2018). We chose a single case study, as the single unit of analysis is the supply chain configuration needed to produce coffee husk-biochar, and sell this to activated carbon producers, in the Vietnamese context. Figure 2.1 is an illustration of the single and multiple case study, which is based on the descriptions by Baxter and Jack (2018).

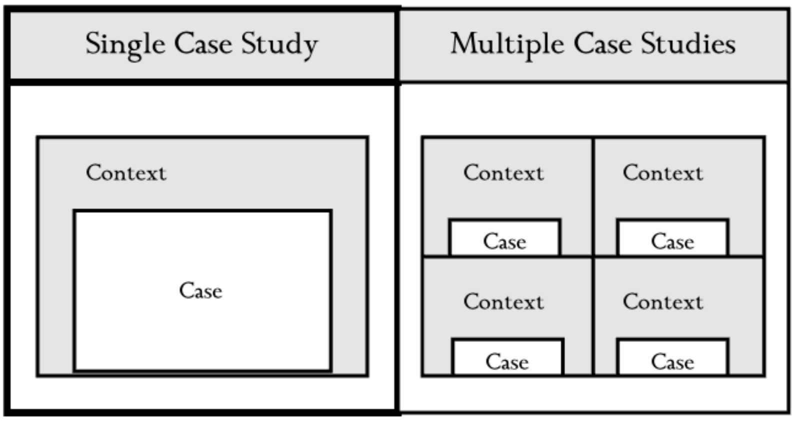

Figure 2.1 - An illustration of our chosen single case study design as well as the design for multiple case studies.

The RQs in this thesis guide towards research on *understanding of supply chain uncertainties that might hinder an expansion of coffee husk-biochar production in Vietnam.* To understand this, it must be understood what uncertainties that arise from the supply and demand in the coffee husk-biochar industry as well as how the supply chain could be configured to address these.

2.2.2 Choice of subunits

To investigate our unit of analysis, the supply chain configuration needed to produce coffee husk-biochar and sell this to activated carbon producers, we also needed subunits that could provide data and increase the understanding of the case unit. The subunits in the chosen context were decided upon with the criterias that they could be involved in a supply chain where coffee husk is used as raw material for activated carbon. Eisenhardt and Graebner (2007) define *theoretical sampling* as a method where you choose units based on the belief that the units could add insight to the research area, which means we conducted theoretical sampling when choosing subunits. Since we only used a few samples in our research, we had to consider that these should be able to represent a much broader population. Seawright and Gerring (2008) stress that there is a risk that the choice of units is biased when trying to reflect a broader population with only a few samples. However, it was shown in their research that a biased choice often is more representative than a random selection. Our subunits were chosen both with the help of UNIDO, as well as from literature research where we identified potential participants in the supply chain.

Binh Minh Cooperative: Major actors in the industry are of course the coffee farmers, and the need of coffee farmers in the study was therefore highlighted. A coffee farmer cooperative who currently make use of the pyrolysis unit was chosen as a subunit, as they should have relevant insights. The coffee farmer cooperative is situated in the Dak Lak region in Vietnam and uses the pyrolysis unit to dry their coffee cherries from the pyrolysis excess heat. The biochar output is then used as a soil conditioner for their own crops. The role of Binh Minh in the investigated supply chain is marked in a grey tone in the following Figure 2.2.

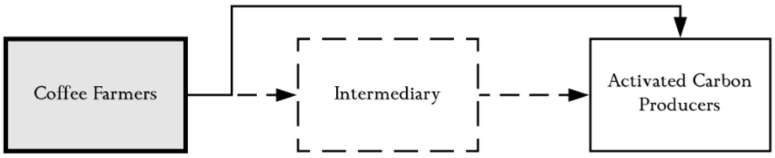

Figure 2.2 - The role of Binh Minh in a coffee husk-biochar supply chain.

Viet Hien: The pyrolysis unit PPV300 is manufactured by a company in the Dak Lak region, and this manufacturer was therefore also chosen as a suitable subunit because of its direct involvement in the industry. Viet Hien also produces biochar from coffee husk themselves for the biochar market, and is therefore identified as an example of an intermediary. The role of Viet Hien in the investigated supply chain is marked in a grey tone below in Figure 2.3.

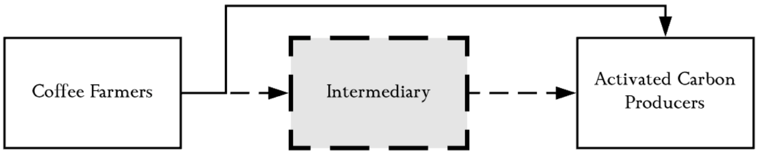

Figure 2.3 - The role of Viet Hien in a coffee husk-biochar supply chain.

Husk Ventures: Another user of the PPV300 is an intermediary enterprise in Cambodia, which uses rice husk and not coffee husk as input for the machine. They are therefore not directly involved in the coffee biochar industry in Vietnam, but they have important knowledge about the pyrolysis unit and process as well as the biochar industry as a whole. The role of companies similar to Husk Ventures, but located in Vietnam, in the investigated supply chain is marked in a grey tone below in Figure 2.4.

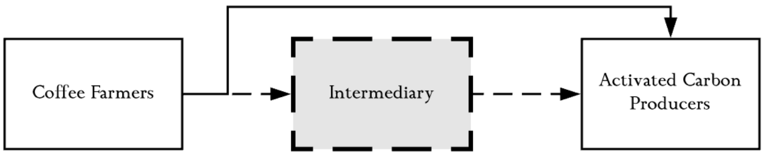

Figure 2.4 - The role of companies similar to Husk Ventures in a coffee husk-biochar supply chain.

The Activated Carbon (AC) Producer: Since possible supply chains involving coffee farmers and activated carbon producers should be evaluated, it was important to include an activated carbon producer as a subunit. The AC Producer is one of the global leaders in the activated carbon market, and produces many different kinds of activated carbon. Their activated carbon is mainly made from coconut-biochar. The role of an actor like The AC Producer in the investigated supply chain is marked in a grey tone below in Figure 2.5. *The AC Producer* is a pseudonym as this actor will be kept anonymous throughout this report.

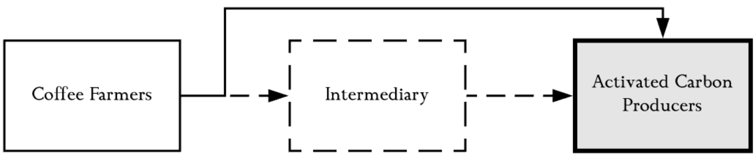

Figure 2.5 - The role of The AC Producer in a coffee husk-biochar supply chain.

2.3 Data collection and analysis

Case studies aim at understanding the real situation of a unit, in its environment where it interacts with other elements and not in isolation (Stake, 2006). As Stake (2006) states, *"Qualitative understanding of cases requires experiencing the activity of the case as it occurs in its context and in its particular situation. The situation is expected to shape the activity, as well as the experience and the interpretation of the activity."* (p. 3). It is therefore understandable that there are numerous ways of conducting data collection for case studies. According to Harrison et al. (2017) these could be interviews, observations or archive analysis which are used together to form an understanding for the case situation. The methods we used in this case study were interviews, observations in the form of field visits, mail correspondence and literature reviews.

2.3.1 Literature review

The literature review is the part where one identifies theories and previous research related to the chosen topic, and should together give a picture over the current state of knowledge in the research area as well as relevant theories to address the problem (Ridley, 2012). As a method of data collection, it is classified as *secondary* data collection since the gathered information is not directly produced for the purpose of the current work (Emerald Publishing, n.d.). The secondary data, i.e. the literature review, can itself consist of two different parts. The main literature research is done through published articles and books, while the second type of research, *grey* literature research, consists of unpublished papers, company reports or media coverage (Ridley, 2012).

We started by conducting a thorough review of the available information about the biochar industry in Vietnam and about the farmer setting. This helped us to gain a better understanding of the case and further enhanced the understanding of the underlying problem that needed to be solved as well as the difficulty of the situation. This included both published papers, but also media releases and company reports. The data research was conducted both through email conversations with involved project members at UNIDO who could guide us to more information, and through database searches. To find the most relevant data in the databases, we used keyword searches. The keyword used was, in the initial phase of the research, *"biochar"*, *"biochar Vietnam"*, *"coffee industry"*, *"coffee husk"*, *"coffee farmers"* and *"coffee farmers Vietnam"*, among others. The databases used were EBSCOHost, ResearchGate and Emerald, but also the regular Google search engine to find most of the grey literature.

The initial literature review also helped us understand what was needed to address the problem with expansion of the biochar industry. This showed to be literature connected to supply chain theory, and mainly supply chain uncertainty, supply chain responsiveness and how these two areas are linked together by different frameworks. Thus, further literature research was conducted on these topics to find theory that supported a solution to the purpose of the thesis. Apart from enhancing theories about possible supply chain solutions, the second phase in the literature review also gave new perspectives to the original problem due to the new insights. This research was, as the initial one, conducted through the mentioned databases. For the supply chain theory, exclusively published papers was used. From this, we also realized that further research had to be conducted about the actual coffee supply chain. This was done through both academic and grey literature, but also through primary data collection such as interviews, since the information about coffee supply chains in many cases was inconsistent and scattered. Keywords that were used for this later part of the literature review was *"supply chain uncertainty", "supply chain responsiveness", "supply chain redesign"* and *"coffee supply chain"*, among others. This research was used to write the frame of reference. For the methodology chapter, we used exclusively published papers, and used the same search engines to find literature about correct methodology.

The literature research also helped us to gain an understanding of what field visits should be conducted and which actors should be interviewed, i.e. what primary data collection that was required. Our primary data collection was focused on important research areas that lacked data, and areas where supply chain theory suggested that primary information from stakeholders was needed.

2.3.2 Field visits

From the secondary data review, we concluded that a number of field visits should be conducted. These were part of the primary data collection, that is, first hand data collection for the specific purpose of the thesis (Emerald Publishing, n.d.). During almost seven weeks in Vietnam and Cambodia, from 31st of January 2020 until 18th of March 2020, we conducted five field visits. We were in Cambodia to meet with Husk Ventures as they produce biochar, although from rice husk and not coffee husk, and their knowledge in this area is therefore good. The aim with the field visits was to enhance the case-contextual understanding and knowledge, identify uncertainties and add new dimensions to the literature. The field visits were also an essential part for understanding the interviews in its context as well as allowing us to interpret the interviews in a better way. The enhanced understanding from the visits also allowed us to gain new perspectives to ask for in the interviews which had not been possible only through literature.

The field visits covered at least one subunit in every identified position in the viable supply chains in order to understand all perspectives. Apart from the field visits to factories, sites and plantations, the actual travel in the Dak Lak region, Ben Tre region and major city areas such as Ho Chi Minh and Hanoi also added perspectives. A summary of the field visits is found in the following Table 2.1.

Table 2.1 - Information regarding field visits.

Field visit	**Purpose of field visit**	**Date**
Husk Ventures	Husk Ventures operates one of few PPV300 in the Asia Pacific region. The purpose was to understand limitations, capabilities and difficulties with the PPV300 from a private company's perspective.	17/2-20
The AC Producer	The AC Producer produces activated carbon and could therefore show us their facilities, explain their business as well as how their supply chain works.	11/3-20
Small scale coffee plantation in Buon Ma Thuot	The purpose was to understand and observe uncertainties with small scale coffee farms, as well as better understanding the coffee supply chain from one of the main actors (small scale coffee farmers).	24/2-20
Viet Hien	Understand and observe uncertainties with the machine production as well as biochar production from a private company's perspective.	25/2-20
Binh Minh, coffee farmers cooperative	Understand limitations with the PPV300 from a farmer's perspective as well as observe uncertainties with the supply of coffee husk.	25/2-20
Aeroco Coffee, large scale coffee farmer with processing equipment.	Aeroco Coffee processes its own coffee and with a different method than traditional farmers. The purpose was to understand another perspective of coffee farming, wet coffee processing, husk disposal as well as logistical limitations.	27/2-20

2.3.3 Interviews

The interview is the primary means of accessing the experience and subjective views of respondents, and allows the interviewer to open new dimensions to the problem or find clues on how the problem fits into its context (Whip, 1997), and is thus a primary source of information. Since this case study explored new possibilities for collaboration, the semi-structured interview technique was initially adequate in order to broaden the perspective and fully understand the interviewees. The technique is by Rubin and Rubin (2012) recommended when the interviewer wants to guide the conversation, but they still encourage to change direction of the interview if deemed necessary. Though, we also used unstructured interviews as we sometimes got the opportunity to ask questions that could not have been prepared before our scheduled field visits. Since several of the interviews took place closeby factories or farms we often got guided tours of the facilities before or after the semi-structured interview. During these tours, we asked questions whenever new information was revealed or something was unclear, and the method we used during these occasions was therefore unstructured interviews. As Stake (2006) suggested, in order to not misinterpret the unstructured interviews and observations, confirming questions was later emailed to the interviewees as well as follow up interviews with a third party to confirm the interpretations from the initial interviews. We did also, as suggested by Höst et al. (2006), document most interviews, with both full recordings and notes taken during the interviews in order to analyse them later.

We chose the interviewees with the goal of covering the views of all positions in the supply chain, as well as seeking information that we could not attain through the literature review. Though, since the UNIDO project still is limited, there were a limited number of actors that could contribute to the project. Therefore the interviewees were also chosen with the help of UNIDO and their contacts. The aim was that each actor both should be knowledgeable and be able to fit into the supply chain, but due to the limited number of actors we also conducted interviews with knowledgeable persons who could confirm statements and enhance our contextual understanding, without themselves being able to be part of the actual supply chain. Since many of the interviews were enabled and dependent on the help of UNIDO and their contacts, UNIDO influenced the choice of interviewees. At the same time, since UNIDO is leading the project, they could also ensure that many of the interview objects were the most knowledgeable in their field.

Due to the different backgrounds, the interviewees had both different perspectives and different knowledge. Depending on their background, a different questionnaire was used for each interview, even if several questions were the same to enhance the understanding from several perspectives or as to validate previous statements. Though, all the questions originated from theoretical findings in the frame of reference and applied onto the position that the interview object had in the possible supply chain. The interview questions were also categorized according to uncertainties and responsiveness, and are presented in Appendix A. It should be noted that due to the semi-structured or even unstructured way of interviewing, the initial questionnaire only set the frame for the interviews. The interviewees were offered the interview guide before the interviews and were informed about the purpose of the interview. Our interviews were limited to English in an often non-English speaking context, and we also had a limitation in time and geographical location. Those factors limited the number of interview objects as well as the requirements that could be set for the interviewee. It also limited in what order the interviews were conducted.

Perhaps the most limiting factor was the number of available interview objects for the "activated carbon producers". In cooperation with UNIDO, eight potential candidates as activated carbon producers were identified throughout the entire country. Out of these, only one was willing to participate in an interview, in which it was made clear that in practice there are only two actual producers in Vietnam. This strongly limited the number of interviews with activated carbon producers. In order to compensate for this, the perspectives of an activated carbon consumer were taken into account to verify the statements made by the single activated carbon producer. Table 2.2 compiles the interviewees, which are either part of the described subunits or people that have relevant knowledge related to our research area. Please see Appendix A for detailed interview guides.

Table 2.2 - Information regarding interview objects.

Interview object	Function and information	Interview duration	Date
Federico Tempestilli, COO of Husk Ventures (subunit).	Federico Tempestilli is the COO of Husk Ventures and part of the executive team. He has experience from charcoal and biochar production in Cambodia. The interview was about uncertainties regarding supply of husk, machine functionality and biochar demand.	60 minutes	17/2-20
Viet Hien (subunit), two representatives.	Interviewees was the director of Viet Hien, as well as an employee who also interpreted the director. The interview was about the pyrolysis machine, coffee husk supply, facilities, infrastructure in Dak Lak region, biochar demand, storage limitations and cost structures.	45 minutes	26/2-20
Binh Minh Cooperative (subunit), represented by the cooperative's Chairwoman	The cooperative has first hand knowledge about coffee husk supply, coffee husk limitations, biochar production and farming uncertainties, especially from a small scale-farmer perspective. They are the only farmers in Vietnam that have the PPV300 and thus the only source of information from a farmer perspective. The interview was about their use of the PPV300 and their distribution of coffee and biochar.	30 minutes	26/2-20
The AC Producer. (subunit), four representatives. General Director Vietnam, COO, COP and CTO.	Representatives presented a broad spectrum of expertise within the company, represented solely by executives. The interview was about the raw material demand, production patterns and uncertainties, supplier requirements and activated carbon segment variations.	40 min	11/3-20
Hannes Zellweger, Managing Director at Sofies Zürich	Hannes Zellweger has seven years experience at Sofies Zürich, which is a consultancy firm that focuses on sustainability. Hannes has long experience from introducing pyrolysis technology among coffee farmers and has been part of the UNIDO project for several years. The interview was about uncertainties in the coffee industry, coffee husk specifications, farmer preferences and biochar production.	40 min	4/3-20
Director of Invitek joint stock company (Activated carbon consumer)	Invitek is a company that uses activated carbon, and is thus a consumer of it. The company was represented by the company's director. The interview was about the activated carbon market, such as supply limitations and number of suppliers.	40 min	16/3-20

Five of the semi-structured interviews were recorded and transcribed, while one was not due to language barriers between the interviewee, the translator and us. In that interview, it was deemed better to rely on notes that were taken during the interview since the direct transcription would not depict the nuances that were given by non verbal communication and contextual setting. The answers from the non transcribed interview were cross checked by a third party interview as well as through clarifying emails to the translator.

2.3.3.1 Mail correspondence

Mail correspondence was also used as a source of primary data during the project. Both before, during, and after the visit to Vietnam, we corresponded with several persons. The correspondence was mainly focused on information sharing in the beginning and the end of the project, while directly after the interviews they focus mainly on cross checking findings or complementing the interviewee's answers. Information regarding the mail correspondence is depicted in Table 2.3.

Table 2.3 - Information regarding email conversations.

Mail correspondent	**Function and information**	**Date**
Hannes Zellweger, Managing Director at Sofies Zürich	In the email conversations, we firstly got introduced to the subject and problem. Later, we asked follow up questions to the previous interview. We also confirmed and cross checked statements made from other interviewees as well as discussed matters such as coffee husk supply and further supply chain uncertainties.	17/12-2019 until 11/05-2020
Former director of Viet Hien	The email conversation with Viet Hien was with the former director of the company, now retired. The conversation was about follow up questions from the previous interview, and further discussions about mostly supply chain uncertainties as well as coffee husk supply in the region.	26/03-2020 until 07/04-2020
Trung Nguyen, consultant at Vietnam Cleaner Production Center (VNCPC)	Consultancy firm that works closely with UNIDO on projects related to cleaner production. Trung has been involved in the UNIDO project for several years and has knowledge on the thesis project as well as general uncertainties connected to production in Vietnam. The email conversations were about the coffee supply chain and uncertainties.	10/01-2020 until 23/04-2020
Thao Le, Country Representative for UNIDO Vietnam, and Linh Hoang, Project Manager UNIDO Vietnam	The local UNIDO organization had valuable contacts, and besides assisting in arranging meetings, they acted as a focal point to help gather information from various sources that otherwise would have been difficult to access. The email conversation was about both these matters, most notably the information gathering from coffee processors.	21/01-2020 until 05/05-2020
Chung Tran, UNIDO Vietnam, Expert at Department of Environment	Knowledgeable UNIDO expert regarding the coffee industry. The email conversations were about the coffee supply chain and uncertainties related to it, and about the role of the coffee processor.	22/04-2020 until 13/05 2020
Professor Vu Duc Thao, Hanoi University of Science and Technology, pyrolysis and biochar expert.	Email conversations regarded biochar characteristics, price and biochar viability in different settings.	12/03-2020 until 26/03-2020

2.3.4 Data analysis

The data gained from the interviews were first categorized in order to fit into our purpose, which is to understand the uncertainties and how the supply chain can be configured to address them. We did therefore categorize and bundle specific quotes from our interviews into *supply chain uncertainties* and *responsiveness.* Supply chain uncertainties were then divided between *demand uncertainties* and *supply uncertainties*. Quotes within demand uncertainty were then further categorized into sources of demand uncertainty, which are *order characteristics, demand patterns* and *service level.* The quotes within supply uncertainty were instead further categorized into sources of supply uncertainty, which are *quality, production characteristics* and *supply reliability.* The uncertainty sources are based on the descriptions of uncertainties by Fisher (1997) and Lee (2002). While there are more than three sources of uncertainties each for both demand and supply according to Fisher (1997) and Lee (2002), we have categorized all their mentioned sources of uncertainties into these categories in order to fit the case context. The hierarchy of the uncertainty categories is shown in Table 2.4. Within each source of either *demand uncertainty* or *supply uncertainty,* we used quotes from interviews to identify more specific descriptions of the situation in the investigated case. One example is that we, in *Chapter 4.3.1.1 Order Characteristics*, found that there was a power imbalance because The AC Producer used short-term contracts with their many suppliers.

Table 2.4 - Hierarchy of uncertainty categories.

Supply Chain Uncertainty	
Demand Uncertainty	Supply Uncertainty
Order characteristics	Quality
Demand patterns	Production characteristics
Service level	Supply reliability

The *responsiveness* is according to Chopra and Meindl (2013) mainly influenced by six areas and the logistics related areas, which are applicable for our study, are the three areas: *facilities, transportation* and *inventory. Responsiveness* was therefore further categorized into these sub categories. The hierarchy of responsiveness categories is shown in Table 2.5. Just like with the uncertainties, we used quotes from the interviews to identify more specific descriptions of the situation in the investigated case within facilities, transportation and inventory.

Table 2.5 - Hierarchy of responsiveness categories.

Supply Chain Responsiveness
Facilities
Transportation
Inventory

To understand the importance of different uncertainties, we created three levels to evaluate the different uncertainty sources. Level 3 represents that the source implies uncertainty. Level 2 means that the source implies some degree of uncertainty, and Level 1 means that the source has few of the uncertainty characteristics. This enabled us to conclude an average level of uncertainty in the range from one to three, with configurations of either farmers or intermediaries as biochar producers having a separate overall uncertainty. We did also interpret that the framework from Chopra and Meindl (2013) encourage an equal weight from both demand and supply uncertainty, and the overall supply chain uncertainty was therefore concluded as the average of these. For descriptions of variables and their implications on each level, please see Table 2.6.

Table 2.6 - Variables of demand uncertainty and supply uncertainty and their respective levels.

	Level 1	Level 2	Level 3
Demand sources			
Order characteristics	Order characteristics are predictable during the year.	Order characteristics are slightly unpredictable.	Order characteristics are unpredictable.
Demand patterns	Demand patterns are predictable during the year.	Demand patterns are slightly unpredictable.	Demand patterns are unpredictable.
Service level	There is no strict service level and no emergency orders	The service level is somewhat important and emergency orders sometimes occur	The service level is important and emergency orders occur often
Supply variables			
Quality	Quality is stable and as expected.	Quality is sometimes varying and not always as expected.	Quality is varying and seldom meets expectations.
Production characteristics	The production is stable and is flexible.	The production is somewhat stable and slightly flexible.	The production is unstable and inflexible.
Supply reliability	There is a large supplier base and they always deliver as promised.	There is a somewhat large supplier base and they sometimes deliver as promised.	There is a small supplier base and they seldom deliver as promised.

It is important to note that the evaluation of uncertainties was structured with levels to show the reader how the analysis was made as well as to create a structured analysis for the authors. They were not meant to replace or resemble a quantitative research approach, but rather create transparency and structure. The responsiveness section was, unlike the original framework which evaluates the actual responsiveness, structured to present what level of responsiveness that is needed in order to meet the uncertainties. Our descriptions of the situation in the investigated case, which were based on the quotes from interviews concerning *facilities, transportation* and *inventory* showed the feasibility of the needed responsiveness. One example is that we, in *Chapter 4.4.1.1 Facilities*, showed that many farmers are needed to invest in a PPV300 and also utilize it, which would force them to centralize facilities.

2.4 Research process

This research has been divided into three essential phases, which all contain three sub-phases each. A summary of these phases can be seen below in Figure 2.6.

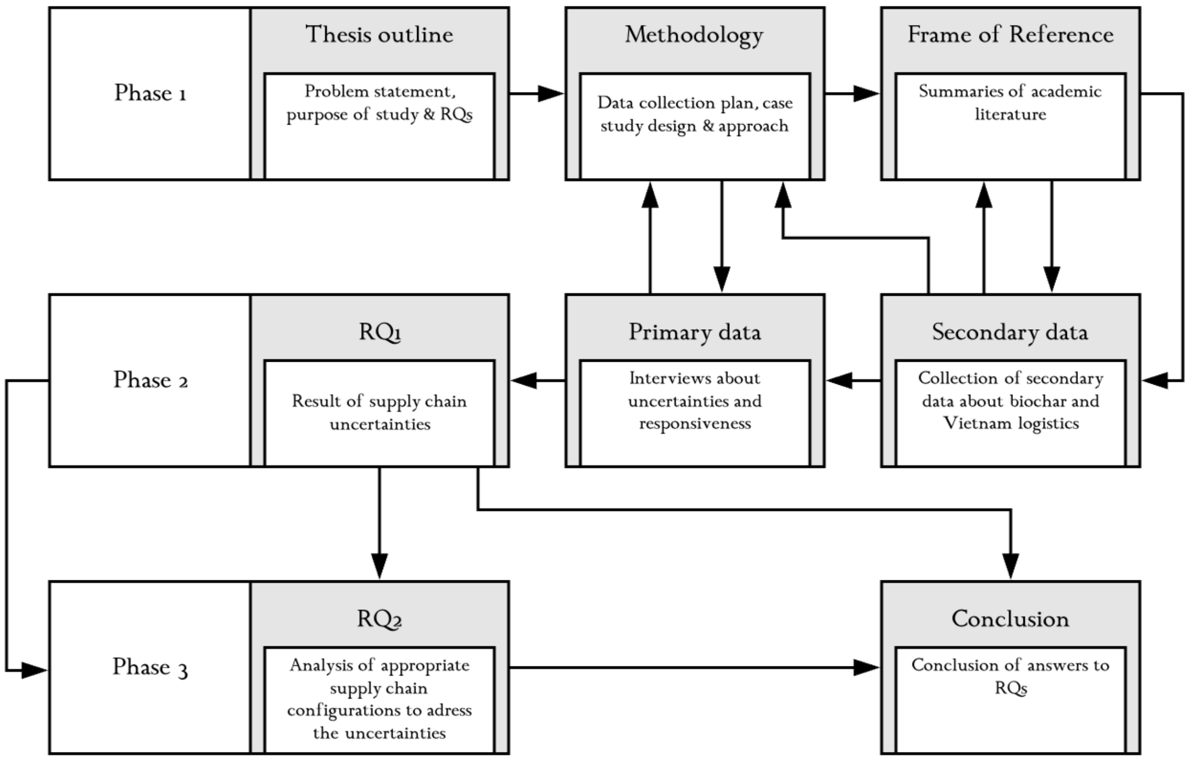

Figure 2.6 - The research process of this thesis.

Phase 1 - Research base

January - February 2020

The research was initiated in January, when the purpose, problem statement and RQs were decided upon. These aspects were chosen after discussions between ourselves, and discussions between ourselves and previous participants of the biochar project in Vietnam. Based on the purpose and RQs, the methodology could be outlined. This included learning what type of study that was relevant based on the RQ characteristics as well as the purpose of the study. It did also include planning on how to collect the relevant data that could support in answering the stated RQs. When the data plan as well as interview guides were finalised, relevant academic literature were summarized in a *Frame of reference.* These references were chosen for the purpose of introducing the reader to the subject, as well as to serve as a base for analysis in *Phase 3.* When the mentioned sub-phases were finalised they served as a solid research base for the upcoming phases.

Phase 2 - Data collection

February - March 2020

After the research base was established, the data collection was carried out. The first sub phase included collecting secondary data, from previous UNIDO project participants and internet sources, about the Vietnamese coffee husk-biochar industry and logistics in Vietnam. This data collection was based on reports from previous work in the UNIDO project and reports concerning the logistics context in Vietnam. That means some of the data from the secondary data was gathered for the purpose of the UNIDO project, but not for the purpose of our specific research. From these learnings, the data collection plan and interview guides could be updated, because it guided towards an understanding of what data that was needed from the interviews. Some of the learnings were also included in the *Frame of reference* since it was believed they constituted an important knowledge base for the reader.

After the collection of secondary data sources, we held interviews with relevant actors of the supply chain. The data gathered from interviews was continuously analysed, so we could make important changes to the data collection plan and interview guides for future interviews. When all data was gathered, the answer to RQ1 could be concluded. This included outlining demand uncertainties and supply uncertainties.

Phase 3 - Analysis and conclusion

April - May 2020

The objective of the third phase was to use the findings from RQ1, to conclude how the supply chain could be configured to address the uncertainties and fit into the context. This included outlining needed responsiveness as well as appropriate supply chain configurations. Finally, we concluded supply chain uncertainties that might hinder an expansion of coffee husk-biochar production, and how the supply chain can be configured to address these, through summarizing the answers to RQ1 and RQ2.

2.5 Research quality

In order to give credibility to the study, it is according to Yin (2003) important to validate the study. The ultimate goal, according to Becker-Ritterspach (2009), should be to match the research goal with the research method, data collection method, the sampling method and the data analysis. By matching these steps, the research will be validated. According to Yin (2003), by following the framework in Table 2.7, the matching between the mentioned criterias will be achieved in a structured way. In the table, Yin (2003) has concluded four quality criterias: construct validity; internal validity; external validity; and reliability. The four criterias will be further elaborated on.

Table 2.7 - Core quality criterias to evaluate the quality of the study (Yin, 2003) and summary over actions taken.

Criteria	**Purpose**	**Case study tactics**	**Application in this study**
Construct validity	Apply correct operational measures for the case study.	- Use multiple sources of evidence - Establish chain of evidence - Have key informants review draft of case study	- Early involvement of knowledgeable actors - Multiple interviews - Multiple field visits
Internal validity	Show casual relationships from findings.	- Do pattern-matching - Do explanation-building - Address rival explanations	- Open ended interviews - Wide background among interviewees
External validity	Show that the results can be analytically generalizable .	- Use theory in single-case studies - Use replication logic in multiple-case studies	- Rich theoretical background - Documentation and motivation about field visits and interviews
Reliability	Prove that the study can be repeated with the same results.	- Use case study protocol - Develop case study database	- Interview guide - Documented research approach

2.5.1 Construct validity

Construct validity aims at establishing proper operational measures for the concepts that are included in the research (Yin, 2003). The methods used in this research mainly focused on establishing a variety of information sources, both recommended by previous researchers as well as new sources deemed trustworthy due to their business knowledge. Much of the data collection has been done through interviews which Yin (2003) states is a good source of information, but also risky due to its subjective nature. That risk was mitigated by having several interviewees with a broad knowledge spectra in order to triangulate information and strengthen the claims. Field visits were also conducted to enhance understanding and gain new sources of information. The case itself has been reviewed by our university supervisor and several of the subunits have also been reviewed by UNIDO who have a long history within the pyrolysis project. An early involvement of several actors led to a thorough process in defining the case and its goals due to many perspectives and discussions.

2.5.2 Internal validity

The goal with establishing internal validity is to show the cause-and-effect relationship in the study (Yin, 2003), i.e. to prove that the data is correctly interpreted. In order to avoid false inferences, it is important to be open to rival explanations and follow pattern-matching logic (Yin, 2003). This study reduced the risk of false inferences by cross-checking theory findings with interviewees by having open-ended questions, several field visits and patterns were looked for in the data. The conclusions are also openly presented in order for the reader to follow the logical reasoning.

2.5.3 External validity

External validity aims at showing that the results of the study are generalizable (Yin, 2003). While quantitative research seeks to generalize its results by statistical means, the qualitative research should seek to generalize its result to a broader theory (Andrade, 2009). Andrade (2009) suggests that interpretive researchers should aim at generalizing theories rather than testing them. This research aims at suggesting actions according to a theoretical framework, and by that also enrichen the theory by trying it in a new setting. Though, Yin (2003) argues that single case studies are harder to achieve external validity, which is also true for this study since it was conducted in a specific setting with several limitations. By having a rich theoretical background and clear motivations for subunits and field visits, the study will be better comparable with similar settings and thus, to some extent, generalizable.

2.5.4 Reliability

Reliability is the term used for ensuring that, if the same research process would be repeated, it would generate the same results (Yin, 2003). Though, Andrade (2009) argues that for qualitative research, reliability might not lead to the exact same results and conclusions if the process were repeated since case studies are interpretive in their nature. Rather, Andrade (2009) argues that to ensure reliability the researchers should present a chain of evidence to ensure quality in the results, rather than ensuring that the result is finite. This was ensured by a clear research process, motivations to both interviews and field visits as well as a structured and transparent analysis. Interview guides are presented (Appendix A), and most interviews were recorded and fully transcribed. The transcriptions will further strengthen the validity by ensuring that critics better can understand the context from which the interpretations are made, and will also increase transparency. Though, since this study was conducted in a setting with language barriers, one interview was not recorded and transcribed due to its contextual setting where body language and physical equipment on site played a major role. Also, since the field visits often revealed new information, much of the information gathering was done ad-hoc and could neither be recorded. To ensure the reliability of this information gathering, notes were taken directly after the dialogues, clarifying emails were sent to the informants and an interview with a third party was conducted to ensure statements and interpretations.

3. Frame of Reference

In Chapter 3, the frame of reference is presented. The first part will explain supply chain uncertainties, and the second part will then describe how they can be mitigated through responsiveness. After that, we will describe the coffee industry in Dak Lak, Vietnam, as well as elaborate on biochar and activated carbon to further outline the context of this thesis.

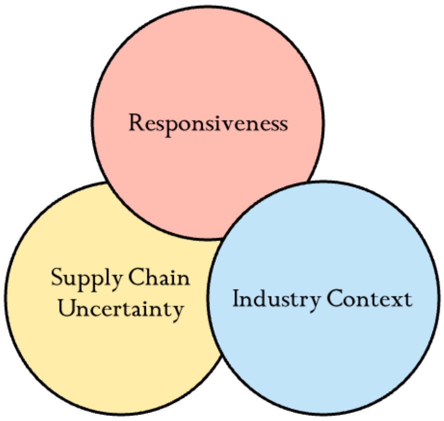

Figure 3.1 - Areas of literature research

As support for the analysis and understanding of areas related to the research questions, a literature research was conducted. The most relevant research is summarized in this chapter to establish knowledge and understanding before empirical findings and analysis is presented. In Figure 3.1 above, the main areas of literature research are illustrated.

3.1 Supply chain uncertainty

As supply chain uncertainties are important to track in emerging industries, along with their importance in supply chain management, this concept will be further explained. Also sources of both demand uncertainty and supply uncertainty will be exemplified.

3.1.1 Introduction to uncertainty

Companies commonly view themselves as part of a supply chain that competes against other supply chains, rather than as an isolated company (van der Vorst and Beulens, 2002; Rice and Hoppe, 2001). This has led to the managing of supply chains rather than single companies, and Cooper et al. (1997) as well as Simatupang and Sridharan (2005) confirm that the reason for managing the total supply chain is that successful collaboration between supply chain members will both enhance the performance of the individual firms as well as better meet the end customer needs. Though, Simatupang and Sridharan (2005) highlight that the entities in the supply chain will still have their individual interests, wants and needs. The implications could be that different goals among the supply chain members could create *supply chain discontent* that will either harm the overall efficiency, or, in the worst case, disable the cooperation (Simatupang and Sridharan, 2005). This means, according to Chopra and Meindl (2013), that an uniform strategy must be formed throughout the entire supply chain. The supply chain strategy constitutes the actual operations of a firm and its extended partners to meet a specific objective (Happek, 2005). The supply chain strategy establishes how to work to fulfill the goals of the organizations (Happek, 2005). This includes how to cooperate with different business partners and how the internal processes should be executed (Happek, 2005; Fisher, 1997; Lee, 2002). Finding a common strategy across the supply chain and aligning this between its members is difficult, but at the same time recognized as the most important issue associated with supply chain management (Chopra and Meindl, 2013; Chaharsooghi and Heydari, 2011).

According to Davis (1993), van der Vorst and Beulens (2002), and Simangunsong et al. (2010) among others, the main problem with managing supply chains is to control the *uncertainty* that they are facing. Uncertainty is according to van der Vorst and Beulens (2002) defined as;
"Decision making situations in the supply chain which the decision maker does not know definitely what to decide as he is: indistinct about the objectives; lacks information or understanding about the supply chain and its environment; lacks information processing capacities; is unable to accurately predict the impact of possible control actions on supply chain behaviour; or, lacks effective control actions." (p. 413)

The uncertainty will stimulate decision makers to create safety stocks, time buffers and extra capacity in order to hedge themselves against the uncertainty (van der Vorst and Beulens, 2002). This leads to inefficient use of resources and creates waste, which will hinder operational performance and thus limit the competitive advantage (van der Vorst and Beulens, 2002). It is therefore important for the supply chain to firstly identify the sources of uncertainty, and thereafter manage them (Simangunsong et al., 2010). By breaking down the walls between the actors in the supply chain, i.e. managing the total supply chain rather than single companies, there is an opportunity to reduce decision making uncertainty within the whole system (van der Vorst and Beulens, 2002). Gupta and Maranas (2003) state that, apart from the operational and efficiency risks with uncertainty, underestimating the uncertainty and its impact can also lead to missed opportunities that higher levels of uncertainty provide, such as lost sales.

3.1.2 Sources of Uncertainty

Simangunsong et al. (2010) identified 14 different sources of uncertainty, which have arisen over time as businesses and supply chains have developed into more advanced entities. Though, in order to limit the scope as well as adjusting the research to the case context, an earlier version from van der Vorst and Beulens (2002) will be used. Their identified uncertainties originate from the food supply chain which has many similarities to the case, such as seasonal production, and could easily be applied onto a rural setting where the more recent uncertainties, such as advanced IT-systems, are not as prominent.

In general, according to van der Vorst and Beulens (2002), uncertainties could be divided into three categories depending where the uncertainty originates from:

1. *Inherent characteristics,* which are the uncertainties identified by both Fisher (1997) and Davis (1993) as demand uncertainty, supply uncertainty, and process/manufacturing uncertainty. These are the predictable uncertainties that one could expect from the nature of the business, such as problems with the yield, machine problems, demand fluctuations or the characteristics of the product such as perishability. From here on in this thesis, process/manufacturing uncertainty will be included in supply uncertainties due to their close relationship in the thesis context.

2. *Chain characteristics,* such as the chain configuration or chain information systems. These uncertainties originate from the internal supply chain structure and might cause delays, unnecessary parties involved and flexibility problems.

3. *External phenomena,* such as changing markets, competitors or government regulations. These uncertainties are outside the control of the supply chain, and are characterized by sudden changes in the normal patterns due to uncontrollable factors. Since these external phenomenons are outside the control of the subunits, it would require an extensive research to understand to what extent they will affect the supply chain, and will thus not be included in the research from here on.

It shall be noted that while the uncertainties are put into specific categories, many uncertainties originate from several sources (Simangunsong et al., 2010). For example, supply uncertainty could be due to timing, quality or availability of the products. Davis (1993) also stresses that uncertainties arise due to poor cooperation within the supply chain. Davis (1993) exemplifies that, if one actor strongly limits its stock, an uncertainty arises towards its neighbouring actors, which in turn have to compensate with different buffers. This will in the end increase the total uncertainty in the supply chain, which is why it is important to also view the uncertainty management from a supply chain perspective in order not to sub optimize.

3.1.2.1 Mitigating actions

Once being aware of the uncertainties in the supply chain, there are several different courses of action that could be applied to reduce them (van der Vorst and Beulens, 2002; Simangunsong et al., 2010). According to Simangunsong et al. (2010), the actions could either aim at reducing the uncertainties at their source, or coping with them with the help of different safety measures. A coping action could be, for example, to deal with unpredictable orders from the customer by having a large safety stock. To instead discuss with the customer to put more stable orders, by using different incentives would be to reduce the uncertainty at its source.

A strategy with mitigating actions suggested by van der Vorst and Beulens (2002), Bhatnagar and Sohal (2005) as well as Kamalahmadi and Parast (2016) is *supply chain redesign*. The redesign strategy is broad and addresses the structure of the supply chain, and aims at reducing much of the uncertainty at its source. It deals with areas such as members involved in the chain, the members functions and roles, the chain configuration as well as facility location, meaning that it deals with the uncertainties originating from chain characteristics. The strategy also addresses the governance structure in the supply chain, such as responsibilities among actors, and who should assign these responsibilities within the chain (van der Vorst and Beulens, 2002). This could for example concern the choice of what actor that takes on the role as producer of a specific product, and how the other companies in the supply chain should act to support this operation (Stocchetti and Scattola, 2011). The goal with the strategy is thus to redesign the supply chain in order to exclude causes of uncertainty and construct a chain structure that from the beginning takes the inherent uncertainties into consideration. That is, the supply chain redesign strategy will mainly reduce *demand* and *supply* uncertainties (Simangunsong et al., 2010).

Chopra and Meindl (2013) have developed a framework that aims at redesigning the supply chain according to the supply and demand uncertainty, i.e. the *inherent uncertainties*. Supply and demand uncertainties are prominent in food supply chains (van der Vorst and Beulens, 2002), which have many similarities to the thesis case. The framework does also address the uncertainties by suggesting configuration solutions related to *chain characteristics*, meaning that it covers two out of the three uncertainty categories. The framework is thus deemed relevant for the thesis case, as the not included category *external phenomena* is outside of the scope for this thesis. Chopra and Meindl (2013) state in their framework, which is supported by additional theory by Sharifi et al. (2006) as well as Ambe and Badenhorst-Weiss (2011), that there are three steps to follow when designing and aligning a supply chain, where the first step will be described in this chapter;

1. *Understanding the Supply Chain Uncertainty*
2. *Understanding the Supply Chain Responsiveness*
3. *Achieving Strategic Fit*

The three steps are a basic way of adjusting the supply chain to the experienced supply chain uncertainty, as proposed by both Fisher (1997) and Lee (2002). Chopra and Meindl (2013) call the adjustment of supply chain responsiveness to the supply chain uncertainty *strategic fit*. The framework directly addresses the inherent uncertainties in the first step, while the chain characteristics are taken into consideration in the third step, as chain configurations are suggested there. By deciding an appropriate chain configuration, some uncertainties can be reduced at their source and the remaining uncertainties can then be coped with through responsiveness measures.

3.1.3 Understanding the Supply Chain Uncertainty

3.1.3.1 Demand Uncertainty

Demand uncertainty is the uncertainty that arises when a business or an industry is unable to accurately account for demand fluctuations (Gupta and Maranas, 2003). This could, according to Gupta and Maranas (2003), lead to the loss of market shares, or, too high inventory levels as a result of wrongful predictions. In other words, the inability to understand the customer demand for a company's products or services can lead to either loss of market share or failure in managing the costly risk exposure of the company (Gupta and Marans, 2003).

The first step in the strategic fit framework in understanding the demand uncertainty is for a company to understand the needs of its customer segment (Chopra and Meindl, 2013). By understanding the customer segment, the implied demand uncertainty will be identified. For example, are low prices important or do the segment value high availability? The implied demand uncertainty is the uncertainty that the targeted segment causes, not the uncertainty from the full demand for the product (Chopra and Meindl, 2013). For example, the same product will experience very different uncertainty if it is supplied as emergency orders or as part of a continuous replenishment program.

Examples of sources of demand uncertainties that should be evaluated are *order characteristics, demand patterns* and *service level* (Fisher, 1997; Lee, 2002), and these are explained below in Table 3.1.

Table 3.1 - Examples of sources of demand uncertainty. Source: Authors' interpretation of Fisher (1997) and Lee (2002).

Source of *demand* uncertainty	**Explanation**
Order characteristics	The predictability and level of required lead time, order quantity and the variety of product ordered. If, for example, your customers have a lot of suppliers of a specific material this may indicate an uncertainty regarding your order quantities as they could be distributed to another one of their many suppliers.
Demand patterns	Refers to seasonalities and other differences in the expected demand. For example a strong sales peak during summer may be possible to plan for, but the fluctuations makes the planning more complicated as different levels of capacities in production and inventory is needed during the year. This is an uncertainty that must be handled.
Service level	The required service level regarding for example delivery, packaging and expectations on emergency orders to be fulfilled. It can also include the customer expectations on product availability or holding excess stock.

To further understand the uncertainty in the demand, the *product characteristics* from Fisher (1997) could be studied. According to Fisher (1997), a product can be either *functional* or *innovative*. Functional products often satisfy basic needs and are available in a wide range of retailers, such as common groceries or standard commodities. Innovative products are more specialized and have more varieties to it, such as fashion apparel or different energy supplements before and after workout (Fisher, 1997). Fisher (1997) argues that since functional products fulfill basic needs they will have stable and predictable demand, while innovative products are often untried by the market and thus having a more unpredictable demand, i.e. greater demand uncertainty.

3.1.3.2 Supply uncertainty

When understanding the demand uncertainty, the *supply uncertainty* introduced by Lee (2002), needs to be taken into consideration in order for a full understanding of the uncertainty. The supply uncertainty could be defined as either a stable or an evolving process (Lee, 2002). The stable process is when the supply uncertainty is low and thus predictable with few disruptions, including a mature manufacturing process. The evolving process is when the supply is still under development, with a limited supplier base and not mature manufacturing process which indicates disruptions and a greater need of fine tuning (Lee, 2002).

Examples of sources of supply uncertainty are *quality, production characteristics*, and the *supply reliability* (Lee, 2002). These sources are explained below in Table 3.2.

Table 3.2 - Examples of sources of supply uncertainty. Source: Authors' interpretation of Lee (2002).

Source of *supply* uncertainty	**Explanation**
Quality	Relates to how well expectations of quality of the goods are met and how varying the quality is.
Production characteristics	Relates to how seldom or often production needs to pause due to either planned or unexpected disruptions, such as process changes, maintenance or breakdowns since this lowers capacity. It also includes how flexible the production can be, such as ease to changeover and ability to vary the output.
Supply reliability	The number of available suppliers, what their capacity is, and how reliable they are in terms of agreed service level. It does also include how external factors such as weather or industry context can affect the reliability of supply.

3.1.3.3 Total uncertainty

The overall supply chain uncertainty, found from combining the implied demand uncertainty with the supply uncertainty, can then be placed on a continuous scale to enable understanding of what level of responsiveness that is needed (Chopra and Meindl, 2013), see Figure 3.2.

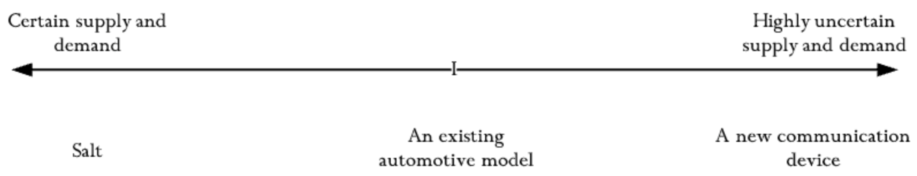

Figure 3.2 - Supply chain uncertainty spectrum. Source: Chopra and Meindl (2013).

The area between the extremes indicate that the product has either predictable supply and uncertain demand, uncertain supply and predictable demand or somewhat uncertain supply and demand.

3.2 Responsiveness

To understand how uncertainties can be mitigated by the corresponding level of responsiveness, the term responsiveness and factors that affect the responsiveness will be explained. The factors that affect the responsiveness are *facilities, transportation,* and *inventory.*

3.2.1 Understanding the Supply Chain Responsiveness

The second step in the strategic fit model is to map the current supply chain responsiveness, although the analysis in this thesis will have that replaced by suggestions of needed responsiveness to match the uncertainty. Holweg (2005) defines responsiveness as *"the ability to react purposefully and within an appropriate time-scale to customer demand or changes in the marketplace, to bring about or maintain competitive advantage"* (p. 605), and Minnich and Maier (2006) define cost-efficiency, which indicates a low level of responsiveness, as *"focus is on cost reduction and no resources are wasted on non-value added activities"* (p. 1). However, Minnich and Maier (2006) highlight that there are situations where an increased efficiency will lead to an increased responsiveness, such as improved manufacturing processes, and stress that responsiveness and efficiency often are interdependent.

To understand the level of responsiveness in a supply chain, one must consider the basic factors that affect the responsiveness (Chopra and Meindl, 2013). The main logistics-oriented factors that affect responsiveness, and thereby the supply chain, are *facilities, transportation* and *inventory* (Chopra and Meindl, 2013; Eicker and Cilliers, 2017). These factors should just like the uncertainties be evaluated in order to comprehend the total supply chain responsiveness and, as in this thesis, how they need to be adapted to address the uncertainties.

3.2.1.1 Facilities

The *facilities* are a major part of how responsive the supply chain can be. For example, the facilities do to a large extent decide what role the production should have, such as if it is specialized or more flexible, and it affects the actual capacity of the production site (Chopra and Meindl, 2013). When a new facility is considered, the basic consideration to make is how to make sure it supports in meeting customer needs (Melo et al., 2009). This can be done through measuring the related distances that need to be travelled and other costs that can be related to the chosen facility (Owen and Daskin, 1998; Melo et al., 2009). Costs could easily be related to the decision regarding whether to have the facilities centralized or decentralized. Centralization is connected with the goal of being cost-efficient, which is achieved if the organization manages to decrease inventory as well as to decrease costs for employees and facilities (Graungaard Pedersen et al., 2012; Giannoccaro, 2018). Employee costs and fixed costs can be reduced due to economies of scale and lower inventory levels can be achieved through the aggregated demand variances (Graungaard Pedersen et al. 2012). Centralization is also considered efficient as facility-related activities can be handled in an uniform standard, along with the possibility to resolve incongruent objectives in the supply chain (Giannoccaro, 2018). Incongruent objectives is a source of supply chain discontent mentioned by Simatupang and Sridharan (2005), and should therefore be resolved if possible.

Schmitt et al. (2015) have shown that a centralized approach can achieve lower costs when a supply chain experiences demand uncertainty and also mitigate the risks related to the uncertainties. During supply uncertainty, the costs are instead similar when using a centralized or decentralized approach (Schmitt et al., 2015; Snyder and Shen, 2006). It is however shown that the cost variance is higher in a centralized system than in a decentralized system during supply uncertainty, which is explained by the risk diversification in decentralization (Schmitt et al., 2015; Snyder and Shen, 2006). Schmitt et al. (2015) showed that a decentralized system also could be preferred when having both demand and supply uncertainty, since the effect from risk-diversification is stronger in this case than the effect from risk-pooling. If choosing the decentralized approach, Schmitt et al. (2015) explain that important risks to consider are a possible misalignment of incentives and asymmetric information among the decentralized units which can affect the supply chain. Both misaligned incentives and asymmetric information are sources of supply chain discontent, as mentioned by Simatupang and Sridharan (2005). The decentralized approach of facilities is in general chosen when one wants to achieve responsiveness through being closer to the customers (Graungaard Pedersen et al., 2012).

3.2.1.2 Transportation

Being close to customers decreases *transportation* lead times and thus being a means of increased responsiveness. The major decision regarding transportation is the tradeoff between speed (responsiveness) and cost, where decisions such as design of the transportation network and the mode of transport are very important factors (Chopra and Meindl, 2013). Transport operations are also important since they are the most expensive part of logistics (Selviardis and Spring, 2007; Goetschalckx, 2011; Holter et al., 2008). This operation could be outsourced, and advantages with outsourcing are according to Selviardis and Spring (2007): (1) that an external logistics provider will increase the flexibility since no bigger investments are needed in equipment (e.g. trucks); (2) it is more flexible to handle demand fluctuations; and (3) it is possible to piggyback on the logistics provider to achieve economies of scale, since the provider will serve more customers. Though, Selviardis and Spring (2007) stress that by outsourcing, the company may also lose responsiveness towards the customer by relying on a third party. It is neither guaranteed that outsourcing will lead to cost savings despite economies of scale and less investments, due to the cost structure and margins from the logistics provider.

3.2.1.3 Inventory

Inventory levels are another important area to consider for the responsiveness towards customers. In general, having buffer inventory will improve the possibility of reducing lead times to customers as well as attain higher service levels, and thereby achieving responsive customer service (Berman and Sapna, 2001). This is because having too low inventory levels may result in stock-outs which in term will affect the customer service (Johnson and Ruankaew, 2017; Koumanakos, 2008). Having stock-outs may be very costly to the company as the result can be that the customers choose another supplier unless the products are available immediately on request (Koumanakos, 2008). Even so, Koumanakos (2008) claims that having too big of a buffer may consume space, be costly and increase the risk of having to scrap inventory due to obsolete goods. There is also a risk that the buffer inventory acts as a cover for poor management, inaccurate forecasting and lacking process improvement. Though, when dealing with seasonal products, such as biomass that arises during a short period of time but is needed throughout the full year, there are no alternatives than to store it for longer periods (Rentizelas et al., 2009).

When dealing with seasonal biomass products that require storing, there are several issues to address, mostly relating to quality and costs. Storing biomass on the field where it arises is the cheapest solution, but weather conditions may deteriorate the quality of the biomass as well as creating potential health issues for farmers if fungus and spores are formed (Rentizelas et al., 2009). The field storing might also hinder farming activities. Storing the biomass protected from weather indoors or in silos helps to keep the quality, but will still impose problems and potential danger if stored moist (Rentizelas et al., 2009). According to Rentizelas et al. (2009), the moist biomass may both deteriorate and has also the potential to self-ignite (Dumfort et al., 2018). Wet biomass, even if stored indoors, does also reduce in mass due to deterioration. Wästerlund et al. (2017) showed losses of around 3-6% during a roughly five months storing period of moist wood chips. It is therefore important to dry the biomass to below 20% of moisture before storing it to reduce problems related to quality, health and safety, since the biomass below this moisture content does not develop any degrading microbes that cause the above mentioned problems (Dumfort et al., 2018). Though, both drying activities and indoor storing are costly activities that have to be weighed against the advantages they offer (Rentizelas et al., 2009).

3.2.1.4 Total responsiveness

When understanding the responsiveness after evaluating *facilities, transportation* and *inventory*, the supply chain responsiveness should be placed on a continuous scale. See Figure 3.3 for an illustration of the scale of responsiveness, which is based on the original work by Chopra and Meindl (2013). This level of responsiveness can then be compared to the corresponding level of uncertainty.

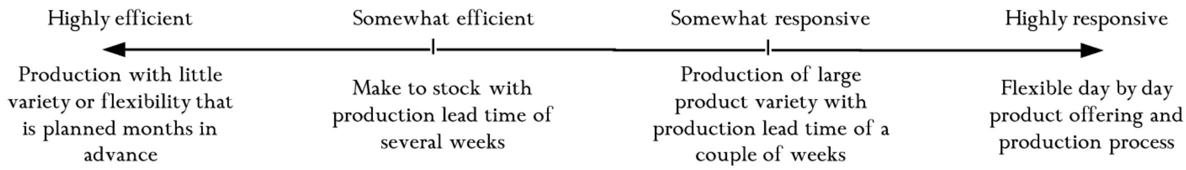

Figure 3.3 - The level of responsiveness the supply chain can achieve. Source: Chopra and Meindl (2013).

3.2.1.5 Additional considerations regarding responsiveness

If having the possibility to affect the responsiveness, it should be considered where the supply chain is in its life cycle (Randall et al., 2003). Randall et al. (2003) mean that the supply chain will have different needs of responsiveness during different stages of its life cycle, and stress the importance of the supply chain strategy at market entry. The reason for their market entry focus is that companies are more reluctant to change their supply chain later during the life cycle, even if theory suggests they should. Randall et al. (2003) confirm that, in general, markets with low growth rates, high contribution margins, large product variety as well as great demand uncertainty are suited for entering the market with a responsive supply chain. The reason for this is that when the market has reached low growth rates, Randall et al. (2003) states that the only segments that are left to target are the niche segments that could be reached by high responsiveness. In line with this, they suggest that if the market has high contribution margins, the responsive supply chain will better be able to adjust to changes and constantly be able to be up to date with customer needs, and this is especially true during high product variety. Lastly, if there is demand uncertainty, Randall et al. (2003) could partially support that firms would more likely enter with a responsive supply chain. If the circumstances are the opposite, Randall et al. (2003) states that it is more common that a firm enters with an efficient supply chain since this in these situations generates the most advantages.

3.2.2 Achieving strategic fit

The final step in the strategic fit model is to redesign the supply chain so that the level of responsiveness is adequate to the level of uncertainty that the supply chain faces. Chopra and Meindl (2013), Lee (2002) and Fisher (1997) suggest that a high degree of uncertainty shall be matched by a high level of responsiveness, and that a stable demand and supply should be met with a low level of responsiveness (cost-efficiency). Selldin and Olhager (2007) confirmed in their research that a match in general will have a positive impact on cost and delivery dependability. Selldin and Olhager (2007) could however not distinguish that a low uncertainty supply chain combined with a cost-efficient supply chain strategy would have better cost performance in practice than high uncertainty supply chains combined with a responsive supply chain strategy.

If the level of responsiveness corresponds adequately to the level of uncertainty, it will fit into what Chopra and Meindl (2013) refer to as the *zone of strategic fit*. Figure 3.4 illustrates the zone of strategic fit and thereby the desired range of responsiveness that should be attained across the supply chain to properly match the current uncertainty. Depending on the current level of responsiveness, the redesign needed to reach the zone of strategic fit can range from smaller adjustments to larger restructurements in the supply chain.

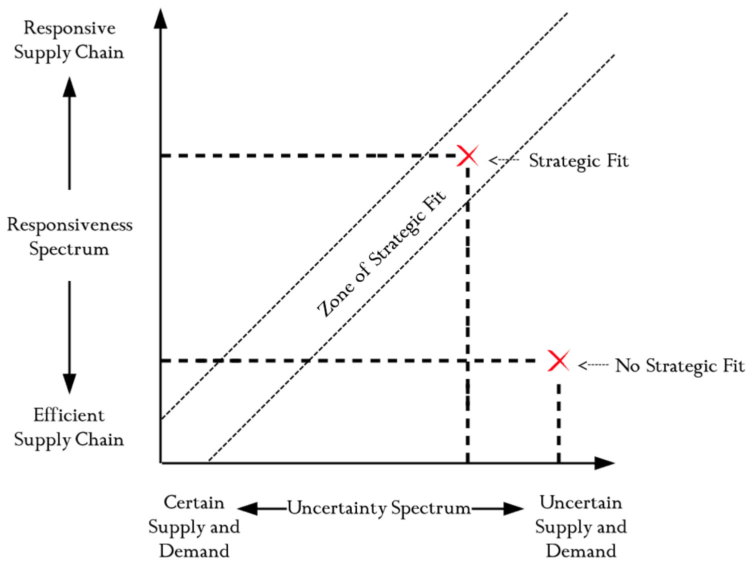

Figure 3.4 - Zone of strategic fit. Source: Chopra and Meindl (2013).

It is important to note that being outside the strategic fit zone can mean that a supply chain underperforms, but it can also overperform, such as delivering shorter lead times than demanded. Even though you succeed by mitigating the uncertainties by overperforming, the costs for it is too high and a good match has not been achieved between responsiveness and uncertainties, and should thus be avoided (Minnich and Maier, 2006). Additionally, Lee (2002) suggests that the same level of responsiveness could be very different depending on where the uncertainty originates from. In practice, there are situations where the supply chain experiences stable demand and uncertain supply, or vice versa. There are therefore situations with the same level of total uncertainty which will have to be addressed very differently (Lee, 2002). Lee (2002) states that there are four main supply chain strategies that could be followed, depending on how the different uncertainties relate to each other, to achieve strategic fit. These are illustrated in Figure 3.5 below.

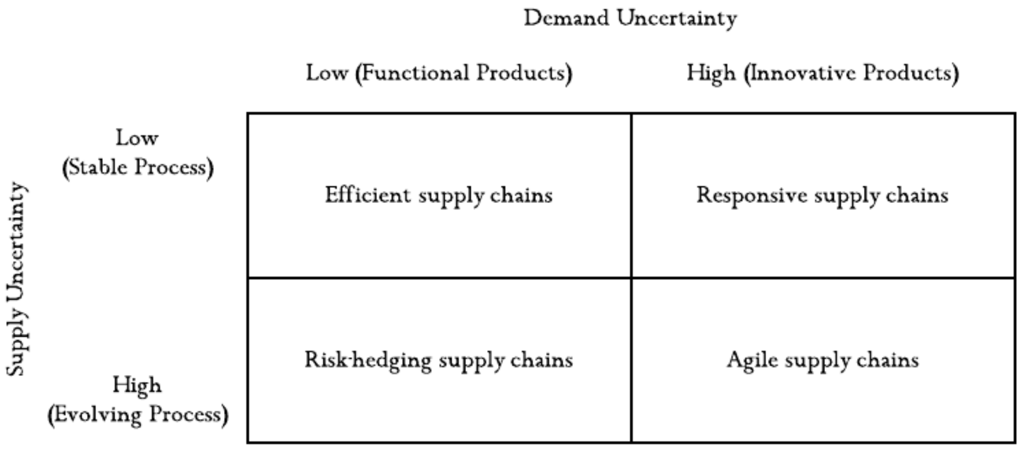

Figure 3.5 - Different supply chain strategies according to demand and supply uncertainties. Source: Lee (2002).

The four strategies in Figure 3.5 are described be Lee (2002) as following;

Efficient supply chains aim to supply the product at the lowest possible cost. This strategy is based on the stable demand and supply, which allows the company and its competitors to compete on price since the predictable flows allow for long term planning and economies of scale. This could be achieved by low inventory, or by maintaining a high average utilization rate in the production since no buffer capacity should be needed to meet the predictable demand. It should also aim towards shortening lead time as long as it does not increase costs.

Responsive supply chains aim to respond quickly to unpredictable demand in order to minimize stock outs and lost sales. This is done by the deployment of excess buffer capacity in the production and significant buffer stocks of parts or finished goods. The lead times should also be as short as possible to customers, even if it incurs costs. The strategy is costly, but originates from the assumption that a lost sale during unstable demand is more costly than the buffer capacity. Forced markdowns and possibly obsolete inventory should be expected with the responsive strategy due to the buffer inventory. Since the supply is stable, no significant bugger stocks of raw material or similar is needed.

Risk-hedging supply chains aim at mitigating a supply risk, while the demand is stable. This is done mainly by pooling and sharing resources in the supply chain in order to spread out the risk among several actors, such as sharing facilities for safety stock to reduce cost per entity, having several suppliers or increasing safety stock of unfinished products or raw material. Since the demand is stable, there is no need for excess safety stock for finished products, and lead times to customers should not be shortened if it incurs costs.

Agile supply chains aim at mitigating uncertainties from both supply and demand. This is done by combining the risk-hedging and responsive strategy, i.e. by pooling resources and safety stocks, shortening lead times and buffer capacity in the production in order to quickly adjust to fast changing circumstances.

The strategy is expensive and should expect obsolete stock, and is therefore mainly suitable for products with high price margins that can compensate for this and the excess capacity.

3.2.2.1 Uncertainty absorption across the chain

Apart from the considerations depending on what type of uncertainty that the supply chain faces, Minnich and Maier (2006) stress that the uncertainty can look very different up- versus downstream in the supply chain. Thus, to achieve the desired level of responsiveness, the supply chain might have different roles for its entities, meaning that the uncertainty could be divided in many different ways across the supply chain depending on potential responsiveness for each actor and their desired strategy (Chopra and Meindl, 2013).

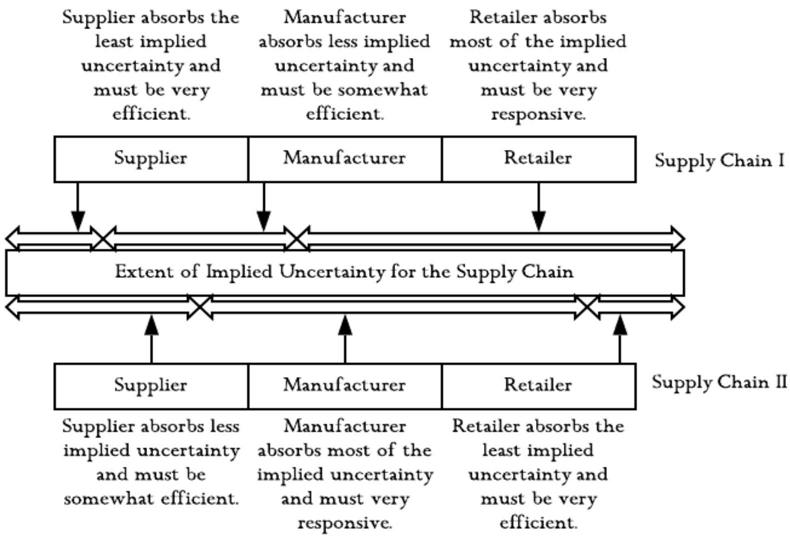

Figure 3.6 - The level of uncertainty met by assigning different levels of responsiveness to the supply chain entities. Source: Chopra and Meindl (2013).

As seen in Figure 3.6, from Chopra and Meindl (2013), the same level of uncertainty could be met in a theoretically infinite number of ways. Actors that absorb a lot of the uncertainty must however be compensated for their costly responsiveness to ensure their participation in the supply chain (Chaharsooghi and Heydari, 2011). This allows for different supply chain entities to follow different strategies, but still with the consistent goal of meeting the same implied uncertainty from the end consumer. There might therefore arise a supply chain leader who is coordinating the actions (Stadtler, 2005; Cooper et al., 1997). Stadtler (2005) mentions that there is often a company in the supply chain that, due to its financial power or knowledge, takes the leader role and by that establishing a hierarchy in the supply chain.

Lastly, van Ackere et al. (1993) and Mason-Jones and Towill (1998) stress that the demand volatility that the uncertainty causes will amplify across the chain. That means that by having more actors in the supply chain, there is a greater risk that the upstream actors will face very large fluctuations that are hard to handle due to that the demand variation will increase with each transfer in the supply chain (Mason-Jones and Towill, 1998). The root cause to the problems are that information is either withheld, scattered or distorted, and will cause increased inventory, communication difficulties as well as fluctuations in orders across the chain, referred to as the bull-whip effect (van Ackere et al., 1993; Mason-Jones and Towill, 1998). It is thus highly important to take the redesigned structure itself into consideration, since involving more actors can cause more uncertainties than what the initial redesign mitigates.

3.3 Industry context

In order to comprehend the uncertainties that will affect the case, it is important to have a deeper understanding of the industries that the case is affected by. These industries are the coffee industry and the activated carbon industry.

3.3.1 Farmer setting

Coffee has been grown for more than 150 years in Vietnam, and in particular in the Dak Lak region which by now is the biggest coffee region in Vietnam (Hoang and Nguyen, 2019). Hoang and Nguyen (2019) explain that the reasons for this are the size of the region, the high production capacity due to favourable climate conditions as well as the quality of the coffee that is produced there. The coffee farmers in the Dak Lak area are mainly small-hold coffee farmers, as these make up 90% of total farms (Hoang, 2017), with operational areas of 1-5 hectares (Nguyen and Sarker 2018; Nguyen and Bokelmann 2019). About 300 000 family workers and 100 000 hired workers harvest coffee in this area, which is about 203 746 hectares in size (Nguyen and Bokelmann 2019). According to Nguyen and Sarker (2018), coffee farmers have an average monthly income of USD 250-500.

3.3.2 Coffee production

The most produced coffee type in Vietnam is robusta, which accounts for up to 97% of the total production (Vietnam Coffee-Cacao Association, 2019). This is due to its resistance and adaptability to the region (Hoang and Nguyen, 2019). The harvest of the robusta coffee in Dak Lak normally takes place between November and January, but is dependent on the weather (UNIDO, 2019). The actual harvest lasts approximately one month (Nguyen and Bokelmann, 2019).

After the picking of the coffee cherries, the bean shall be separated from the rest of the cherry, and this is called dehusking. The cherry is depicted in Figure 3.7. There are two different methods to separate the bean, wet processing or dry processing (Draper, 2018). The robusta cherries are mostly processed through dry processing in Vietnam (Strauss Group, n.d).

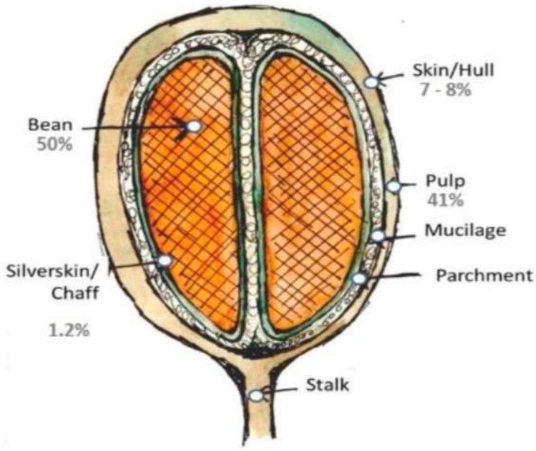

Figure 3.7 - An illustration of a coffee cherry (Draper, 2018).

Dry processing starts by the process of drying the whole coffee cherry either in the sun or by other external heat sources, which will make the separation of the bean easier (Draper, 2018). When the whole cherry is dried, it is put through a milling machine that separates all the layers from the bean (NCA, n.d). Due to the outer layers being dried, they are often crushed into smaller pieces when put through the milling machine. The outer dried layers, separated from the bean, make up what is referred to as husk. A picture of the husk can be seen below in Figure 3.8.

Figure 3.8 - Picture of dried coffee husk (Authors' picture)

Since the husk is not used for the coffee making, it has to be disposed of after the processing (Draper, 2018). Due to the short harvest season, a large amount of husk arises in a short period of time. The fresh coffee cherries are either sent to processors for drying and dehusking, or are dried and dehusked at the farmers (Draper, 2018). The farmers either spread the husk back to their coffee fields as fertilizers, or burn it as a method of drying their coffee cherries (Zellweger et al., 2017), and the processors either burn the husk as the farmers, sell it as fertilizer or make it into compressed fuel pellets.[1] For every tonne of fresh cherries that are

[1] Hoang, Linh; Project Manager UNIDO Vietnam. 2020. E-mail correspondence 5th of May.

picked approximately 500 kilos are waste (Dzung et al., 2013), which will reduce to around 140 kilos in weight when dried (Montilla-Pérez et al. 2008). In the final dried state, the beans and husk will have a moisture level of 12-13% (Hoang and Nguyen, 2019).

3.3.3 Coffee supply chain

The coffee is after harvest sold to either buying agents, traders or coffee processors (Nguyen and Bokelmann, 2019; Hoang, 2017). Nine out of ten farmers sell the coffee to buying agents, whereas the rest sell to traders or coffee processors in descending order (Nguyen and Bokelmann, 2019). As found in the study by Hoang (2017), farmers will have to pay higher transportation costs when selling to actors further downstreams the supply chain and skipping buying agents, whereas selling to buying agents implies the lowest transportation costs. One reason for this is that companies further downstreams the supply chain is located further away, and transports are therefore longer. Descriptions of the involved supply chain actors will follow and the supply chain is illustrated in Figure 3.9.

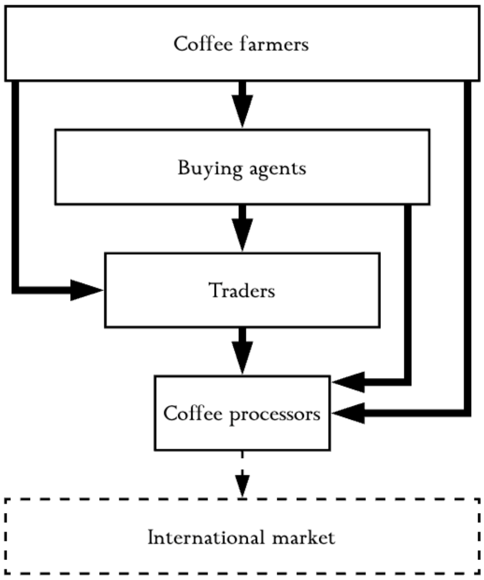

Figure 3.9 - An illustration of the coffee supply chain in the Central Highlands of Vietnam, based on descriptions by Nguyen and Bokelmann (2019) and Hoang (2017)

Buying agents: These actors act as a middle man between the farmers and companies that further process the beans. They arrange transports, and help farmers get the coffee to market through their bigger network of actors further downstream in the supply chain (Nguyen and Bokelmann, 2019; Hoang, 2017). Important factors that affect the big involvement of buying agents are trust and strong relationships between buying agents and coffee farmers. Also their, sometimes, credit bound relationship to the farmers where the buying agents assist farmers with credits during other parts of the year, is an explanation to their common involvement (Nguyen and Bokelmann, 2019).

Traders: The traders buy coffee from several buying agents or directly from farmers and sell them to processors or other companies that sell to international markets (Hoang, 2017).

Coffee processors: These companies conduct different activities that range from dehusking of coffee cherries, quality testing and sorting of the beans before they go on export or are sold to the local market (Nguyen and Bokelmann, 2019). The coffee will arrive to processors either as fresh cherries, dried cherries or as coffee beans. Farmers have dehusked the cherries if they arrive as beans and the processor will dehusk them if they arrive as cherries. Nguyen an Sarker (2018) mentioned that around half of the 137 farmers they surveyed in Dak Lak owned their own dehusking machine.

A small scale processor could handle 350 - 1000 tonnes of beans each year, corresponding to around 2000 - 5500 tonnes of fresh cherries.[2] The coffee processor market is large, with hundreds of companies throughout the country although most are located in the Central Highlands (International Coffee Organization, 2019). After the processors are finished, the beans will either be sold to the international market, or domestic companies that make the final preparations for the bean for the domestic market.

3.3.3.1 External influencers of the coffee supply chain

The coffee industry is highly dependent on the world market price for coffee since almost 84% of the coffee goes on export (Tran, 2019). According to Tran (2019), if the prices are deemed as unfavourable by the farmers, they will stock up coffee and await better prices. Since the price of coffee is fluctuating, with the biggest importers of Vietnamese coffee being Germany, USA and Italy, the stock levels of coffee will fluctuate as well (Tran, 2019). When the farmers have deemed the price for the beans or cherries as favourable, they will be sold for further processing, such as being cleaned and quality checked.[3] This is not done by the small scale farmers in Dak Lak, but mainly by small-scale processors.

Another factor that affects the current supply chain among the small-scale farmers are according to Nguyen and Bokelmann (2019) poor infrastructure in the region. Transportation in Vietnam is expensive compared to neighbouring countries and, in addition, the Dak Lak region has a disadvantageous position in terms of logistics compared to the rest of the country (Nhân Dân, 2019). An example of this is that the better margins the farmers would get by bypassing the intermediaries are not high enough to cover the increased cost of transport (Nguyen and Bokelmann, 2019). Regardless of transporter, the transportation in the region is done by road, either by the farmers' tractors or by larger trucks depending on transporter and size of the load.[4,5]

The high use of road transport is also true for the rest of the country where 75% of transportation is done by road (Banomyong et al., 2015). While railway is available and connects south and north Vietnam, it is deemed unreliable and inflexible by operators (Banomyong et al., 2015). Banomyong et al. (2015) also state that there are only few airports used for cargo freight, and that inland water way transport is limited to areas mainly around the Mekong Delta in the south, or the Red River in the north. This leads to the high use of road transport, which is deemed as highly flexible and the first choice by domestic consignors in Vietnam (Banomyong et al., 2015). Even if it is deemed as the first choice, the transport sector has many problems.

[2] Viet Hien; former director. 2020. E-mail correspondence 30th of March.
[3] Nguyen, Trung: consultant at VNCPC. 2020. E-mail correspondence 23d of April.
[4] Zellweger, Hannes; Managing Director at Sofies Zürich. 2020. Interview 6th of March.
[5] Chairwoman at Binh Minh Cooperative. 2020. Interview 26th of February.

Many of the trucks in the domestic fleet are old with similarly old equipment, and the labour force is insufficient (Blancas et al., 2014). According to Blancas et al. (2014), truck companies call for better regulations regarding equipment, qualifications and emission testing to name a few, and less focus on rates regulations. Lastly, a large portion of the road network is still unpaved, weight limitations on highways hinders efficient transport and low quality of the roads leads to reduced speed (Blancas et al., 2014).

The overall infrastructure in Vietnam is also lagging behind. The trend since 2000 is, according to Banomyong et al. (2015), that despite good infrastructural preconditions, such as a large road network and railway between major cities, the country has not been able to get its logistical capabilities to keep up with the economical growth nor to develop its infrastructure. The result is further stressed by the facts that: more than 72% of Vietnamese businesses call for improved quality in logistical services; almost 64% stress the need for improved reliability; and 45% find both deadlines and responsiveness as areas that need to be improved (Dung and Oanh, 2019). Apart from poor infrastructure, the root to problems are stated to be low quality of human resources as well as the ability to corporate management (Dung and Oanh, 2019).

3.3.4 Biochar and activated carbon

3.3.4.1 Pyrolysis process

Pyrolysis is a method to thermally decompose biomass through applying heat in a container without access to air (Buysman et al., 2017). From this process the outputs of biochar, heat and tar are generated (Buysman et al., 2017; Draper, 2018; UNIDO, 2019). Biochar is thus the carbonized form of biomass. The waste generated from the coffee farmers can be used as an input material for a pyrolysis process (Draper, 2018).

3.3.4.2 PPV300 characteristics

The pyrolysis unit that is subject for scrutiny in this report is the PPV300, which is manufactured by the Dak Lak-based company Viet Hien. An illustration of the PPV300 can be seen in Figure 3.10.

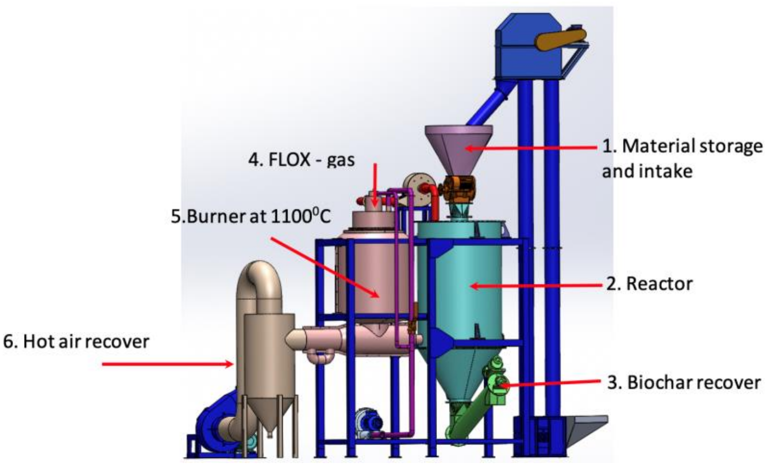

Figure 3.10 - The pyrolysis unit PPV300. Source: UNIDO (2019).

As UNIDO (2019) describes it, the machine runs on external gas the first two hours of operation to elevate the temperature, but will then generate its own fuelling gas through reactions with the biomass in the *reactor*. Around 50% of the heat generated from operating the machine will be excess heat that can be used for drying, for example, coffee cherries. Input material, biomass, with a moisture level up to 54% has been proven successful for operations with the PPV300, but it is recommended not to exceed 40% (Draper, 2018).

The biochar output per hour is about 30 kg when using the full capacity input of 100 kg coffee husk per hour (Zellweger et al., 2017). Depending on the input material for pyrolysis, the output biochar will have different carbon levels, porosity and ash content, and it will also demand different temperatures during the pyrolysis (Ronsse et al., 2012). When using coffee husk as input, the biochar output from the PPV300 has a carbon content of about 80% (UNIDO, 2019). According to UNIDO (2019), the PPV300 could be running 24 hours per day for six consecutive days when operating with coffee husk. After six days, it requires regular maintenance. This means that the yearly production, assuming a 90% utilization, will be at most approximately 200 tonnes of biochar. The cost for one tonne of biochar in the Vietnamese market, produced with the PPV300, is approximately USD 350-400[6], which could be compared to the common fertilizers that cost approximately USD 170 per tonne (UNIDO, 2019).

3.3.4.3 Activated carbon and its needs

Biochar has many application areas, most of them deriving from the biochar's porous structure which gives it capabilities such as water retention and filtration capabilities as an adsorbent (Kwiatkowski and Kalderis, 2019). UNIDO (2019) mentions that application appropriateness for biochar can be indicated through its porosity, since porosity is an indicator of how effective a material is in its filtration capacity. The demand for biochar is big and it is estimated that the annual market growth rate for biochar will be 13.2% from year 2020 til year 2025 (Grand View Research, 2019b).

Activated carbon, which is produced from biochar, has an even higher porosity than biochar (Buysman et al., 2017). The higher porosity is achieved through exposing the biochar to either physical or chemical activation, and when this step has been done, the biochar has become activated carbon (Teshome, 2015). Paraskeva et al. (2008) explain that the *physical activation* achieves this through introducing the biochar to an activating agent such as air, steam or carbon dioxide. The *chemical activation* is according to Paraskeva et al. (2008) instead dependent on an impregnation of the biochar. Chemical activation is usually preferred prior to physical activation due to the lower temperatures needed during activation, and also the higher porosity that is achieved (Paraskeva et al., 2008).

Activated carbon is mainly used in water treatment, air purification, the pharmaceutical/medical industry, the automotive industry and in food and beverage processing. The demand for it is expected to rise steadily globally and with a significant growth in Asia-Pacific for the coming years (Grand View Research, 2019). Depending on its area of use, the activated carbon will have different requirements such as size, shape and porosity. To achieve this, larger pieces could be ground to desirable size, or, different biomasses could be used since the various biomasses will generate activated carbon with different product properties.[7]

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[6] Viet Hien. 2020. Interview 26th of February.
[7] The AC Producer. 2020. Interview 11th of March.

3.4 Analytical Framework

The analytical framework that was used throughout the report is displayed below in Figure 3.11.

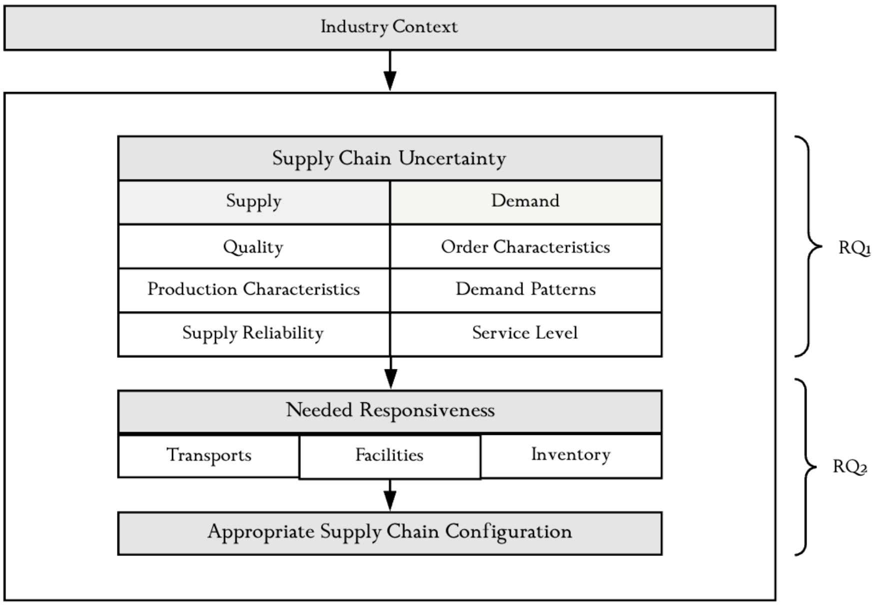

Figure 3.11 - Analytical framework used throughout the report

First, the industry context which affects supply chain uncertainty, needed responsiveness and appropriate supply chain configurations were investigated. By combining the contextual understanding with the theoretical supply chain understanding, the dimensions of uncertainty and responsiveness illustrated in Figure 3.11 were identified. These dimensions were later used during the interviews with the stakeholders identified from the context research. At this stage, RQ1 was answered, since a deeper understanding of supply chain uncertainties was achieved.

The responsiveness needed to address the identified supply chain uncertainties was thereafter analysed. Appropriate supply chain configurations were then recommended according to findings regarding uncertainties and the viability among different actors to conduct the needed responsiveness measures. When that was concluded we had answered RQ2, since we had suggested how the supply chain could be configured to address the found supply chain uncertainties.

4. Findings and Analysis

Chapter 4 will present the findings from the interviews, field visits and the literature review. It will present the found uncertainties depending on the type of actor that produces biochar, as well as the needed supply chain strategy and responsiveness the supply chain must have to address these. It will also present appropriate supply chain configurations according to these findings.

4.1 Introduction to findings and analysis

While uncertainty is a very broad term, we have chosen to narrow it down to a set of variables to fit the case, as well as using these variables in the context of the strategic fit framework of Chopra and Meindl (2013). Though, to identify the limited uncertainties, it must also be clear from what perspective the uncertainties are looked upon. For example, a phenomenon might be regarded as an uncertainty if looked upon from a customer perspective but not when seeing it with the eyes of the supplier. It is therefore important for the findings and analysis to state the perspectives, and in this case, configurations, that will be looked upon.

There are theoretically three different supply chain configurations that could be viable in the current case:

1. ***The farmers themselve produce biochar and sell to activated carbon producers.***
   Farmers are defined as an actor that grows and harvests the coffee themselves, as well as performs little to non value adding activities with the cherries. That is, the farmers might dry and dehusk the cherries, but further quality checking, sorting, roasting or exporting of the beans are activities performed further down the value chain. The average single coffee farmer in Vietnam has an monthly income of USD 250-500, and the average farm size is one to five hectares, where we assume that three hectares are the standard size.

2. ***The farmers supply coffee husk to an intermediary who produces biochar and sells to activated carbon producers.***
   The intermediary is defined as an actor that is not growing or cultivating coffee themselves. That means that the intermediary could be an already established actor in the coffee supply chain, such as a processor who is performing value adding activities to coffee but not growing it themselves, or it could be a new actor without previous involvement in the coffee supply chain such as a completely new company. The relevance of a coffee processor, that comes from the fact that some of these actors also dehusk coffee cherries and thereby generate coffee husk, was found late during the project. We did therefore not have the opportunity to focus on this specific type of intermediary during interviews, and investigate uncertainties from their perspective. Even so, they were found to have high relevance for this case and will therefore be further elaborated upon in Chapter 4.5, *Appropriate producer of coffee husk-biochar* and Chapter 5, *Discussion*.

3. ***The farmers supply coffee husk directly to the activated carbon producer who handles the whole production.***
   This means that the activated carbon producer firstly would have to carbonize the coffee husk bought from the coffee farmers before they further process the carbonized husk, the biochar, into activated carbon.

Though, from our findings, the third alternative will not be investigated due to the limited data from the single activated carbon producer we interviewed. This would only lead to a too speculative analysis. For example, right now they only buy already carbonized biomass, and buying coffee husk to carbonize themselves would therefore imply that they would have to transform their business. Instead, the initial two configurations will be investigated: one where the farmers act as coffee husk-biochar producers; and one where the farmers act as coffee husk suppliers to an intermediary who instead produces the biochar.

This means that configurations 1 and 2 in Figure 4.1 below will be investigated, but configuration 3, which is crossed over, will be left out from the findings and analysis.

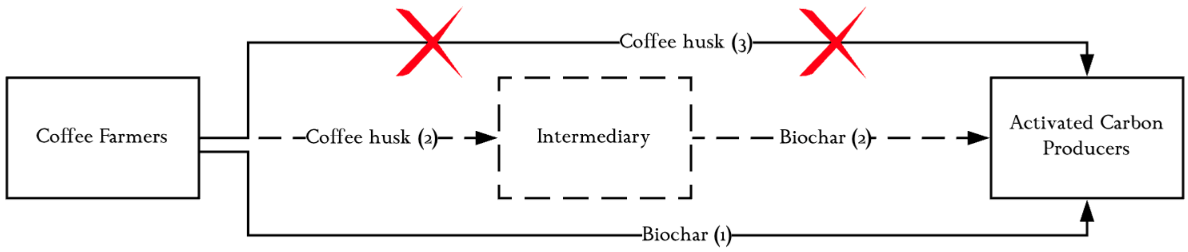

Figure 4.1 - Investigated configurations.

It shall also be stated that during our interview with The AC Producer, it became clear that the activated carbon market in Vietnam is dominated by two actors, of which we interviewed one of them. This has implications on the analysis. The framework originally states that it is the *implied* demand uncertainty that should be investigated, but since there is an oligopoly market, there is in practice no segments to target, but rather that the implied demand uncertainty is equivalent to the overall demand uncertainty.

The perhaps greatest uncertainty in the investigated case is whether or not coffee husk-biochar actually is viable as input material for activated carbon during current market demand, current price of the biochar, and current production equipment at The AC Producer. Though, since this uncertainty cannot be mitigated by any responsiveness, the analysis and findings will assume that the activated carbon producers *can* and *want* to use coffee husk-biochar, even though this has not been verified. This allows for a structured analysis where the current case will portray one demand uncertainty scenario, which will be complemented by other scenarios to analyse how the supply chain best should be configured to support coffee husk-biochar production expansion. The case of the activated carbon is, as stated, not used primarily to evaluate the precise requirements to establish a business, but rather as a tool to evaluate further expansion of the biochar production from a supply chain perspective. Therefore, it is deemed necessary to make these assumptions.

Lastly, the analysis will be based on the use of the PPV300 for the coffee husk-biochar production, even though it was found that carbonization could be done with much simpler equipment. Though, this simpler equipment does not possess the other benefits the PPV300 have, that addresses health issues from smoke in production as well as excess heat that can be used for other purposes. For this reason, the PPV300 will be the base for the findings and analysis, but it should be noted when reading that the operations could be simplified and more accessible.

4.2 Contextual findings

To understand the findings and how these are evaluated, it is important to first present the findings regarding the context in which the uncertainties will take place. These are not uncertainties in themselves, but have a great effect on how the operation will have to be organized, which in turn could affect uncertainties and supply chain configurations.

4.2.1 The utilization of the PPV300 must be as high as possible

It was found during the interviews and field visits that the largest cost for the PPV300 is the gas required in the start up-phase to get a high enough temperature to start the pyrolysis.[8] The relatively high start cost meant that if the machine could not produce almost at full capacity for a longer period of time, it would be better economically to not produce and wait until the supply allowed for full production. At the same time, the cost of the machine must be depreciated over as many tonnes of biochar as possible to keep the biochar price down, a crucial part in the project since the current price of coffee husk-biochar is higher than both chemical fertilizers as well as the coconut-biochar sourced by the investigated activated carbon producer. We did not receive an exact figure on the price of the coconut-biochar they bought as raw material, but their response indicated that it was much lower than the price Viet Hien could offer for their biochar. The current price from Viet Hien is around USD 400 per tonne[9], whereas the highest known biochar price to date according to a Vietnamese biochar expert was approximately USD 300 per tonne[10]. It is therefore assumed that the price of the competing biochar originating from other biomasses are considerably cheaper. In addition, The AC Producer mentioned that at least approximately 100 tonnes a month of a specific type of biochar would be needed for them to sustain a business around it as well as they have a continuous production throughout the year and thus need continuous supply.[11]

The cost structures for the production, in combination with a demand from The AC Producer that widely exceeds the production capacity of one machine, leads to the finding that at least an equivalent of six machines should be running on full capacity all year round if targeting the specific investigated activated carbon producer. Though, even if the demand would be lower, the cost structures still conclude that at least one machine should be running on full capacity all year around. This in order to reduce the overhead cost, such as depreciation and facilities, per tonne produced biochar to improve the chances of reaching the market. The alternative to a continuous production is instead investing in more machines that can produce

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8 Husk Ventures. 2020. Interview 17th of February.
9 Viet Hien. 2020. Interview 26th of February.
10 Professor Vu Duc Thao. 2020. E-mail correspondence 26th of March.
11 The AC Producer. 2020. Interview 11th of March.

the same amount over a shorter period of time. Since this will impose a higher depreciation cost per tonne due to the machines being idle most of the year, this is not deemed as a viable option.

To illustrate, if calculating that the PPV300, which costs USD 40 000, is operational for 10 years:

4 month production per year

- Yields 670 tonnes of biochar over 10 years → Depreciation cost of USD 59 per tonne

12 month production per year

- Yields 2000 tonnes of biochar over 10 years → Depreciation cost of USD 20 per tonne

These calculations are simple and do not try to be exact, not addressing interest, price of the biochar nor maintenance, but resembles the fact that a high utilization can generate great savings per produced tonne.

Though, according to Flammini et al. (2019), there are additional methods to decrease the costs of the pyrolysis machine. For example, by utilizing the excess heat for either electricity production during the time when there is nothing to dry with it, the energy savings could be allocated to the biochar price (Flammini et al., 2019). Flammini et al. (2019) also exemplifies that if governmental actions would create financial incentives for reducing air pollutants, as the PPV300 does, it would also be an alternative method of keeping the price of the biochar down and thus making it more attractive. Nevertheless, since none of these alternatives exists today and since it always is desirable to make the product more economically attractive for customers, a high utilization is deemed as desirable.

4.2.2 A great amount of husk needs to be stored over longer periods of time

Most of the husk will also arise during a short period of time once per year during the harvest season, with only a smaller portion of the cherries being stored and dehusked later during the year.[12,13] Nguyen and Bokelmann (2019) supports this as they mention that the coffee cherries could be stored for a couple of weeks or be dehusked right away after harvest to avoid that the cherries decompose. This leads to the finding that big amounts of coffee husk must be stored to sustain this production for a full year, if following our suggestion rather than having more machines that could produce as much biochar in a shorter period of time. Producing during a shorter time would also imply higher inventory levels of biochar would be needed if it is demanded during the whole year, which means more capital tied up in inventory since the finished product is more valuable than the raw material.

4.2.3 The coffee supply chain is highly complicated

The coffee supply chain has proven to be highly complicated to understand and depict. While it on paper resembles a straight forward supply chain where coffee cherries is harvested by farmers and then further stepwise processed downstream in the supply chain by designated actors, the reality is more complicated.

[12] Zellweger, Hannes; Managing Director at Sofies Zürich. 2020. Interview 6th of March.
[13] Tran, Chung; UNIDO Expert, Department of Environment. 2020. E-mail correspondence 13th of May.

Firstly, the presumably simple question where the husk arises has been highly difficult to assess. While the current coffee supply chain literature either takes it for granted that the husk arises at the farmers when using the dry method or not addressing the issue at all, it was found from the former director of Viet Hien that, quoting, "around 50% of the farmers dry at the farm themselves and the other 50% sell their coffee cherry to small processors to dry it"[14]. Also Nguyen and Sarker (2018) supported this, as only 76 out of 137 (55.5%) farmers they surveyed in Dak Lak owned their own machine for dehusking or roasting. At the same time, another knowledgeable source stated that "small-scale processors prefer buying beans already dehusked" and "after drying, the dried cherries will be dehusked by the farmers so the beans can be sold to the processing companies".[15] A third source claimed that only 20% of the coffee cherries are dehusked at the farmers (Hoang, 2017), meaning that there is no straight answer to the questions.

Apart from not being able to fully state where the husk arises, the incentives structures are also difficult to assess regarding the husk. One source stated that the price for the cherries that are not dehusked are higher than the dehusked ones (beans), since there is a market for the husk, and the low value husk would in this case arise at the processors.[16] Another source said that the farmers do not want the husk[17], indicating that the incentive structure should be for the farmers to always sell the cherries that are not dehusked. This would aswell reduce their workload. Though, a third source as well as literature stated that farmers currently use the husk for drying coffee cherries or spreading it on the fields as fertilizers (Dzung et al*.,* 2013; Vietnam Coffee-Cacao Association, 2019), and further literature claimed that 26% of the husk is separately collected at the farmers by private companies without further stating for what purpose (Nguyen and Sarker, 2018). Apart from making it hard to assess the incentives, it also makes it very difficult to assess the amount of husk that would be available in terms of actual supply since the husk could be a crucial part for some actors in their business model.

Secondly, the available literature sometimes is making little or no distinction between coffee processors and coffee exporters (Nguyen and Bokelmann, 2019; Nguyen and Sarker, 2018; Vietnam Supply Chain, 2015; Hoang, 2017), and findings from interviews, mail conversations and literature define the coffee processor's role differently[18,19]. Additionally, there is no common definition of the different supply chain actors, and literature and experts seem to use a different definition of the different actors (Hoang, 2017). This makes it difficult to understand the core business and incentives of the actors, as well as determining the scale of their operations. The processors, who are by many defined as sometimes conducting the dehusking of the coffee cherries and sometimes not, have been difficult to fully assess (Hoang, 2017).[20] Though, from the literature as well as interviews, we conclude that there are several processors in the region with an average size of 350-1000 tonnes capacity of beans per year.[21] However, these claims were stated regarding beans (already

[14] Viet Hien; former director. 2020. E-mail correspondence 30th of March.
[15] Nguyen, Trung: consultant at VNCPC. 2020. E-mail correspondence 23d of April.
[16] Hoang, Linh; Project Manager UNIDO Vietnam, 2020. E-mail correspondence 5th of May.
[17] Viet Hien. 2020. Interview 26th of February.
[18] Viet Hien; former director. 2020. E-mail correspondence 30th of March.
[19] Nguyen, Trung; consultant at VNCPC. 2020. E-mail correspondence 23d of April.
[20] Viet Hien; former director. 2020. E-mail correspondence 30th of March.
[21] Ibid.

dehusked cherries), and it is unclear if this capacity corresponds to the equivalent of fresh cherries that are needed for the mentioned amount of beans.

There are also actors that have been found to possess capabilities that would be defined as both an intermediary as well as farmers. Either they could be a large-scale farm which conducts further processing of the coffee cherries, or, as we observed during the field visits, they can act more as a processor but with dedicated farmers connected to the company (Nguyen, 2015). Vietnam's largest coffee company, Trung Nguyen Coffee, has a supply chain consisting of both contracted farmers as well as their own farms, which all share the processing facilities controlled by Trung Nguyen Coffee (Nguyen, 2015). As the literature suggests that the majority of farmers are small-scale farmers, it is assumed that the number of larger scale farmers with processing capability is limited, though without being able to confirm the exact number. As the existence of this type of actor was found late during the project, no specific uncertainties have been sought for this actor, which will be called *Large-scale farmer* from now on. Even so, they will be elaborated upon in Chapter 4.5, *Appropriate producer of coffee husk-biochar*, as they could have high relevance for this case.

Lastly, it could be stated that the supply chain also is highly dependent on long-term relationships and structures, not seldomly related to different financing structures towards the farmers (Dzung et al., 2013).[22] For example, both processors and buying agents seem to lend money to the farmers during larger parts of the year, which later are repaid during the harvest period (Nguyen and Bokelmann, 2019). These financial obligations seem to make the supply chain rather static and difficult to change. Additionally, depending on the capabilities of both farmers and processors, the coffee cherries or beans might undergo different amounts of processing at each stage which are hard to assess. There might therefore be exceptions in the supply regarding the responsibilities of the actors. For example, there might be situations where the processors only do some simpler cleaning and sorting, which needs further processing by yet another actor downstream, or it can be that the farmers can process the coffee to the extent that the processors are not needed. The conclusion from this is that even if a general supply chain has been illustrated in Chapter 3, there are many exceptions to it and structures that have not been possible to assess due to cultural factors.

4.3 Understanding the Supply Chain Uncertainty

Supply chain uncertainty is made up by demand and supply uncertainty. Demand uncertainty can arise from *order characteristics, demand patterns* and *service level*, whereas supply uncertainty can arise from *quality, production characteristics* and *supply reliability.* The level of uncertainty from each source, assessed on a scale from 1 to 3, will be presented first together with a short summary of the findings that has led to that specific conclusion. These findings will then be elaborated upon for each source to explain how they lead to the stated level of uncertainty. We suggest that the reader returns to Chapter 2.3.4 Data Analysis for further elaborations on how the uncertainty were assessed as well as further considerations for the following chapter.

[22] Viet Hien; former director. 2020. E-mail correspondence 30th of March.

4.3.1 Demand Uncertainty

The investigated sources of demand uncertainty are, as mentioned, *order characteristics, demand patterns* and *service level.* Findings on these sources come from the interview with The AC Producer, conducted on the 11th of March 2020. Each source will be given a level of uncertainty, in line with Table 2.6, based on the quotes and observations that have been collected. Due to the oligopoly market for activated carbon production, the demand uncertainties are assumed to be generalizable for larger scale activated carbon production.

4.3.1.1 Order characteristics

The overall uncertainty from order characteristics is deemed as **level 2**. This level considers the negative impact from *power imbalance* between The AC Producer and their suppliers, as well as the positive impact from *low product variety* in orders from The AC Producer. Elaborations of how the level was decided will follow.

Power imbalance

The AC Producer were found to use a big supplier base, partly because of the farmer structure in Vietnam, with many small-scale farmers and few larger ones, but it was also a means of reducing supplier risk. They expressed that: "We use a lot of suppliers. We don't want to end up being at the mercy of one supplier so we need sustainability in our supply chain so we're looking for numerous suppliers". Another uncertainty for suppliers to The AC Producer is that contracts with the suppliers are negotiated over 2-4 weeks of supply. This allows for quick changes in orders and suppliers if they are not satisfied. Since the coffee market, with its small-scale farmers, is similar to the coconut market, which The AC Producer currently buys raw material from, the same power structures and risks would be applicable. There should therefore be the same risk with altering order quantities and uneven power balance for coffee farmers if they would be suppliers to The AC Producer. The findings that The AC Producer has a big supplier base and use short-term contracts increase the demand uncertainty, as The AC Producer can bargain or alternate ordered quantities unless they are fully satisfied. This is especially true since they presumably possess a lot of power over the market due to their scale and oligopoly market. The AC Producer is a global company with production facilities all over Asia, whereas their suppliers at most are regional in their reach, which resembles the difference in size of organizations.

Though, it was also stated that there is a competition for the biochar from other markets, meaning that even if there is an uneven power balance, The AC Producer does not possess full power over the market. Neither did they misuse their assumed power concerning lead times and these will therefore unlikely cause any uncertainty issues. The AC Producer is currently supplied by a large number of small scale coconut farmers, and understands the scale of the operations most of their suppliers have. As described during the interview: "The biochar market is probably the most informal market that exists. You're dealing with farmers mostly, and the farmer will not have a proper supply chain setup". They therefore indicated that their expectations of flexible responsive lead times would follow accordingly and be low.

Low product variety

It was mentioned that The AC Producer prefers to purchase bigger pieces of biochar that they later refine to smaller ones, because this allows for a broader product offering since the size of the activated carbon piece gives it certain capabilities. They have worked with their suppliers over a longer period to make sure that they can meet these required quality and size specifications. Their suppliers do also mainly use very simple equipment, such as carbonizing the biomass in a barrel, indicating that their equipment will not be able to offer great varieties of product output. This postponement of size diversification, means the variety of raw material bought by The AC Producer will be low.

4.3.1.2 Demand patterns

The uncertainty originating from demand patterns is deemed as **level 1.** This level considers that there are *no seasonalities in demand,* which is positive as this will give lower fluctuations and the supplier can therefore have a more stable capacity. Elaborations of how the level was decided will follow.

No seasonalities in demand

The AC Producer had a "more or less" stable demand from their own customers and were not dependent on seasonalities for their products. They did therefore have their production running 24 hours per day, all year long, and they concluded that: "Orders to our suppliers are stable over the year". Though the biomass that The AC Producer uses, coconut, is seasonal, the farmers know that they want continuous supply throughout the year and can therefore adjust their inventory to this pattern. By this, there is a low risk of uncertain demand patterns, and in combination with the increased demand of activated carbon in Asia-Pacific, the stable demand pattern is deemed long lasting.

4.3.1.3 Service level

The total uncertainty originating from demanded service level is deemed as low and therefore a **level 1**. This level considers the positive impact from the *high flexibility towards suppliers* of The AC Producer, as well as the fact that *emergency orders are unusual.* Elaborations of how the level was decided will follow.

High flexibility towards suppliers

Suppliers to The AC Producer will not be forced to adapt to specific standards regarding delivery and packaging, as priority is to make it easier for them as long as it is cost-efficient and fulfills basic quality requirements, such as the biochar being dry. They expressed it as: "We are open to getting supplies in different forms. We would look at what is the most cost-effective and what helps to make it easier for the supplier. We don't want to be too specific, if they have a suggestion we are open to modify what we do". There was neither a strict requirement on precise on-time deliveries, as The AC Producer seemed to accept that orders could sometimes be a bit late. Again, they highlighted their understanding for the small scale farmers ability to perform according to big company standards, as well as understanding the potential hinders in Vietnam, such as rainy seasons. This indicates low uncertainty since the risk that The AC Producer suddenly changes procedures that suppliers must adapt to is limited.

It is neither expected that suppliers adapt to a certain stock policy and keep buffer stocks to ensure constant availability of raw material for The AC Producer. The personnel at The AC Producer said: "We do not expect our suppliers to have buffer stock. We will keep enough material in stock to protect ourselves against risk". Indirectly, suppliers will only have to keep as much stock as it takes to deliver to the agreed contractual volumes. Presumably, they will also hold some safety stock in order to hedge against risks, but this is no requirement. Instead, The AC Producer will hold the necessary safety stock for potential abruptions in the supply chain and is therefore being flexible towards its suppliers by absorbing much of the uncertainty in the supply chain.

Emergency orders are unusual

The suppliers are neither expected to handle possible emergency orders from The AC Producer, as they indicate that they plan long-term with stable orders. When discussing this matter, they did also press the fact that their own production and demand from customers is stable and emergency orders are therefore unnecessary. They could put pressure on the suppliers to perform, but only according to what is specified in current contracts. The small-scale operations of the farmers that make up The AC Producer's supplier base will also make it impractical with emergency orders as, like The AC Producer said: "The farmers will not have a proper supply chain setup".

4.3.1.4 Concluded demand uncertainty

In conclusion, The AC Producer was very flexible and had few requirements on their suppliers apart from the quality of the product. They were aware that they were dealing with small scale farmers and accepted that deliveries could be late, as well as different packaging and had no requirements on stock policies. Though, the short term contracts and the decentralized supplier structure which allows for quickly changed or terminated contracts are a big uncertainty for the suppliers, even if the contracts usually are renewed.

The concluded demand uncertainty from The AC Producer from the three different uncertainty sources are presented in the following Table 4.1.

Table 4.1 - Concluded demand uncertainty

	Level 1	Level 2	Level 3
Demand variables			
Order characteristics		X	
Demand patterns	X		
Service level	X		

The concluded demand uncertainty is therefore considered low, as it scores only 1.3 on average on the scale from 1 to 3.

4.3.2. Supply Uncertainty

The investigated sources of supply uncertainty are, as mentioned, *quality, production characteristics* and *supply reliability.* Findings on these sources of uncertainty originate from interviews with subunits and external experts, as well as from mail correspondence and our own observations during field visits. Each finding will be given a level of uncertainty, in line with Table 2.6, according to the quotes and observations that have been collected. The levels of these findings will then contribute to the average level of supply uncertainty for coffee farmers and intermediaries individually, as specific findings may indicate different uncertainties depending on the type of actor.

4.3.2.1 Quality

It is assumed that with clear instructions regarding the storing of the husk, the overall uncertainty regarding quality is low and therefore a **level 1** for both farmers and intermediaries. The clear instructions should concern keeping stored goods dry, as the *quality of biochar and coffee husk is stable if kept dry.* Elaborations on how this level was chosen will follow.

Quality of biochar and coffee husk is stable if kept dry

We observed that Binh Minh Cooperative had limited dedicated storing areas for coffee husk and biochar, where it was stored under a roof without walls, whereas Aeroco Coffee that was visited had big facilities and dedicated areas for coffee husk. Wet coffee husk can begin to decompose and lose its carbon content[23], as well as pose safety issues, and this risk increases if there is no proper storage facility or if the storing method is inappropriate. Sofies Zürich warned about this through saying that: "I think the problem is leaving something moist in bags for longer than 1 day, it will start to rot. Once it's dry, you can store it for a while".[24] Also, dry and wet biomass will require a different setup by the PPV300, meaning that it could affect the final quality if mixing both dry and wet input material. Lastly, the PPV300 should preferably not handle raw material husk with a moisture level above 40%, a level that could be hard to calculate and thus increasing uncertainty. However, by connecting the PPV300 to a drum dryer, as done at Binh Minh Cooperative, the excess heat from the pyrolysis could be utilized to dry the biomass. There was no report on decreased quality of the biomass by drying it in the drum dryer, but additional equipment was needed. Even though the issue of wet husk could be solved by manually drying them or more easily by storing them dry, clear instructions about the core problem are needed, as their quality is lost if they are wet for too long and start to rot.

The biochar is not affected in the way that it can get spoiled by poor rainfalls or poor handling. It is however not recommended to expose it to rain as it might be desired to control the moisture of the biochar to a certain level, as for example Husk Ventures indicate that their customers prefer a moisture level of 20%. As biochar acts as a sponge and attracts water, the moisture level might get much higher than this if left out in the rain and it could also be expensive to transport due to a higher weight. Another alternative is that the biochar needs to be dried before it is shipped out, meaning that the lead time will be prolonged. Overall, the quality of the biochar was not an issue experienced by either Viet Hien, Husk Ventures or Binh Minh

[23] Zellweger, Hannes; Managing Director at Sofies Zürich. 2020. Interview 6th of March.
[24] Ibid.

Cooperative. Though, it should be stated that the production periods varied between the interviewees. Both Binh Minh Cooperative and Viet Hien who produced biochar had not yet had production up and running for a full year, meaning that they could not report on quality issues that might arise when storing the raw material for longer periods of time.

4.3.2.2 Production characteristics

It was found that *production characteristics* are a source of supply uncertainty that deserves attention. In conclusion, the uncertainties from production characteristics are medium high, and therefore a **level 2** for the farmers. The interviewed intermediaries showed signs of having abilities to quickly solve arisen problems, such as more experienced personnel working with the machine all year long. Though, since most of the uncertainties arise from the machine and procedures, the uncertainty is still deemed as medium high and thus a **level 2**. The main findings that influenced the levels are that there might be *potential disruptions due to machine characteristics,* there might be *potential disruptions from safety procedures* and *production with the PPV300 can be inflexible*. These findings will be elaborated upon below.

Potential disruptions due to machine characteristics

It is an uncertainty that the PPV300 has been, and continuously will be subject to redesign. The machine manufacturer confirmed this as they stated that: "Yes, the machine is very different now compared to the last years. We changed it three times, big upgrades. We may continue to change some parts and redesign some parts. Like the burner and the screw conveyor."[25] These continuous redesigns implies that the machine still needs time before it can produce biochar without disruptions. For example, during our visit to Husk Ventures, we observed that they were still in need of short-term measures to cope with issues and thereby enable the machine to work properly. This could mean customers that have already bought the machine will experience issues with, for example, rust or overheating as these are aspects Viet Hien has addressed with design changes. We would not expect this uncertainty to disappear until the design changes concern finer details of the machine operations, and users of the machine must therefore be prepared for disruptions until the design has reached a more mature stage.

The PPV300 has a non modular design that does not allow the machine to be taken apart as smaller parts. It can therefore be difficult to solve issues that have appeared inside the machine. This can lead to long disruptions as the disassembling operation can be dangerous and time consuming due to heavy parts that require machinery to handle. Husk Ventures explained that: "A challenge we had was a small welding activity on the screw conveyor. It was very difficult because it is very hard to disassemble the machine. It is perhaps not difficult in terms of skills you need to have for the repair, but it is very time consuming and it can be dangerous".[26] Though, minor repairs were deemed easy and quick to fix in-house. Intermediaries could have better opportunities than farmers to fix issues as they have no other business obligations and therefore have more time to allocate to this matter.

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[25] Viet Hien. 2020. Interview 26th of February.
[26] Husk Ventures. 2020. Interview 17th of February.

Potential disruptions from safety procedures

It was found from UNIDO (2019) as well as interviews that the safety procedures in the production could be improved, especially since there is no formalized training program for the machine operators. For example, there are high levels of dust and very hot parts on the machine which can cause fires as well as health problems. The maintenance or repairs is also sometimes impractical and dangerous due to heavy parts that require heavy equipment to be handled. Yet there were no reports on injuries from the field visits due to machine handling, and UNIDO stated, in our mail correspondence, that a safety manual is under development. Though, the findings point at an insecure working environment that, especially under circumstances with few trained workers, poses a threat to keeping the production running.

Production with the PPV300 can be inflexible

Due to the contextual factors, with a high start-up cost for the PPV300 in combination with the need of reducing costs, the machine will in practice have to be up and running for six consecutive days as soon as the production is started. The machine does also have different requirements depending on biomass it uses, such as time between maintenance and time it takes to transform it into biochar. This means that material cannot be mixed if the quality of the biochar should be guaranteed, meaning that the same material needs to be used for the whole production cycle. This makes the machine inflexible, but as the most probable scenario is that the producer always is using the same material, the inflexibility is not of great importance.

4.3.2.3 Supply reliability

Our findings conclude that the supply of coffee husk for biochar production has *dependence on external risks* that can hinder a reliable supply. It shall be noted that the supply uncertainties from the intermediaries takes some supply uncertainties from the farmers into consideration, since farmers supply the husk that the intermediary uses as raw material. In conclusion, both the intermediaries and farmers face the same type of external risks. Though, since intermediaries have better ability to both hedge themselves and source from a large network of suppliers makes their uncertainty regarding supply reliability low, and therefore a **level 1**. Farmers are deemed to be more vulnerable and their uncertainty for supply is deemed to be medium high and thus a **level 2**. Apart from the *dependence on external risks*, the supply reliability was affected by the finding that *habits might limit supply* as well as the positive finding that it is *possible to achieve long-term storing* of coffee husk and biochar.

Dependence on external risks

It is a clear uncertainty that the supply of coffee husk-biochar may be affected by external risks, as it is highly dependent on the coffee industry. Coffee growing is vulnerable to the changing weather patterns, which have been more unpredictable the last couple of years (Vietnam Coffee-Cacao Association, 2019). Too little or too much rain may affect the supply of coffee and thereby coffee husk. Unattractive prices for coffee may also cause farmers to hold on to their beans and husk a couple of weeks until the price is right, which Viet Hien indicated as they said: "All of the farmers keep the coffee beans in the husk until the day they need to sell it".[27] As Vietnam Coffee-Cacao Association (2019) has indicated, production costs of coffee in Vietnam have increased whereas world coffee prices are at low levels. This combination may increase the risk that

[27] Viet Hien; former director. 2020. E-mail correspondence 30th of March.

farmers will switch to other crops, as coffee farming during these circumstances is less lucrative than before, which would limit the supply of husk as well. Though, since the switching costs are high for farmers and require an investment horizon of several years before new crops generate income, the supply is still deemed to be high (Marsh, 2007).

The external risk is deemed more prominent at single farmers, cooperatives or at larger scale farms, since the farmlands are located closely together. This means that they are more vulnerable to the same risks. Intermediaries could perhaps easier adapt to the external risks that the coffee industry faces, since they could hedge themselves and buy coffee husk from many different farmers and regions. In combination with Dak Lak being home to a very large number of farmers, the uncertainty for running out of suppliers is low for intermediaries.

Habits may limit supply

In addition to external risks, culture among farmers or their habits may limit the supply of coffee husk. Uptil now, there has been no widespread culture to store the husk, and the farmers may be reluctant to get involved in a new business area according to UNIDO (2019). If someone else would like to source the husk from farmers, convincing is needed and Sofies Zürich stated: “Are they interested in selling it? Sometimes they just don't want to. But I don't think they store it, you really never see piles like they have as with rice husk”.[28] Though, as Viet Hien had already established connections with farmers, they were able to buy husk during the harvest period and concluded that there was a rich supply of husk during harvest periods. Viet Hien did instead say: “Almost all farmers want to sell, because they do not need it”.[29]

Possible to achieve long-term storing

When the coffee cherry is dried correctly, that is to 12-13% moisture, the husk can be stored for long periods of time if later stored correctly and it does thus not increase the supply uncertainty. Viet Hien confirms that: “They can be stored for as long as you may want as long as they avoid rain”.[30] It is also supported by Dumfort et al. (2018) who state that below 20% moisture, the biomass will not start degrading. The intermediaries have better opportunity for correct handling of the husk, as farmers have been observed to have limited opportunities for dedicated storing, but they are still in the hands of the farmers who provide the raw material. Though, they can refuse to buy damaged husk and use a larger supply network, meaning that the risk of not being able to store the husk is somewhat mitigated. The refined product of coffee husk, biochar, was proven to not be a sensitive storing unit, and could therefore easily be stored long-term.

[28] Zellweger, Hannes; Managing Director at Sofies Zürich. 2020. Interview 6th of March.
[29] Viet Hien. 2020. Interview 26th of February.
[30] Ibid.

4.3.2.4 Concluded supply uncertainty from coffee farmers

The concluded supply uncertainty from coffee farmers, based on the three different uncertainty sources, are presented below in Table 4.2.

Table 4.2 - Concluded supply uncertainty from coffee farmers

	Level 1	Level 2	Level 3
Supply variables			
Quality	**X**		
Production characteristics		**X**	
Supply reliability		**X**	

The concluded supply uncertainty from coffee farmers is, when considering the findings, 1.7 on the scale from 1 to 3.

4.3.2.5 Concluded supply uncertainty from intermediaries

The concluded supply uncertainty from intermediaries, based on the three different uncertainty sources, are presented below in Table 4.3.

Table 4.3 - Concluded supply uncertainty from intermediaries

	Level 1	Level 2	Level 3
Supply variables			
Quality	**X**		
Production characteristics		**X**	
Supply reliability	**X**		

The concluded supply uncertainty from intermediaries is, when considering the findings, 1.3 on the scale from 1 to 3.

4.3.3 Concluded Supply Chain Uncertainty

4.3.3.1 Coffee farmers as coffee husk-biochar producers

The supply chain uncertainty that occurs from having coffee farmers as producers of coffee husk-biochar, is the average of the demand uncertainty and the supply uncertainty that occurs from having this supply chain configuration.

This gives a total supply chain uncertainty from this configuration, as presented below in Table 4.4.

Table 4.4 - Concluded supply chain uncertainty from configuration with coffee farmers as coffee husk-biochar producer.

Demand Uncertainty	**Supply Uncertainty**	**Supply Chain Uncertainty**
1.3	1.7	1.5

The concluded supply chain uncertainty of 1.5 is illustrated on the uncertainty spectrum below in Figure 4.2.

Figure 4.2 - The concluded supply chain uncertainty, on the uncertainty spectrum, when coffee farmers produce biochar.

4.3.3.2 Intermediaries as coffee husk-biochar producers

The supply chain uncertainty that occurs from having intermediaries as producers of coffee husk-biochar, is the average of the demand uncertainty and the supply uncertainty. This gives a total supply chain uncertainty from this configuration as presented below in Table 4.5.

Table 4.5 - Concluded supply chain uncertainty from configuration with coffee farmers as coffee husk-biochar producer.

Demand Uncertainty	**Supply Uncertainty**	**Supply Chain Uncertainty**
1.3	1.3	1.3

The concluded supply chain uncertainty of 1.3 is illustrated on the uncertainty spectrum below in Figure 4.3.

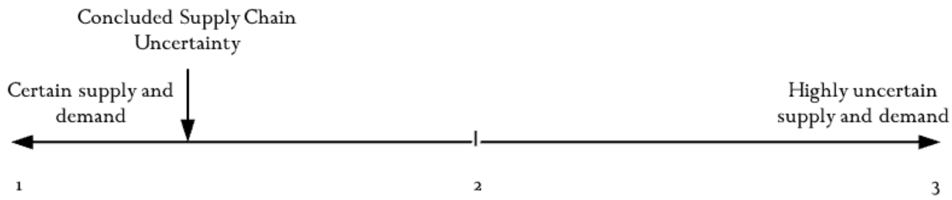

Figure 4.3 - The concluded supply chain uncertainty, on the uncertainty spectrum, when an intermediary produces biochar.

4.4 Needed Supply Chain Responsiveness

As a reminder, responsiveness is defined as *"the ability to react purposefully and within an appropriate time-scale to customer demand or changes in the marketplace"*, and we make the interpretation that this also includes mitigating supply uncertainty. Figure 4.4 illustrates the needed responsiveness for both the farmers and intermediaries to achieve strategic fit. This section will present how the actors would need to cope with the found uncertainties with an appropriate level of responsiveness according to the zone of strategic fit.

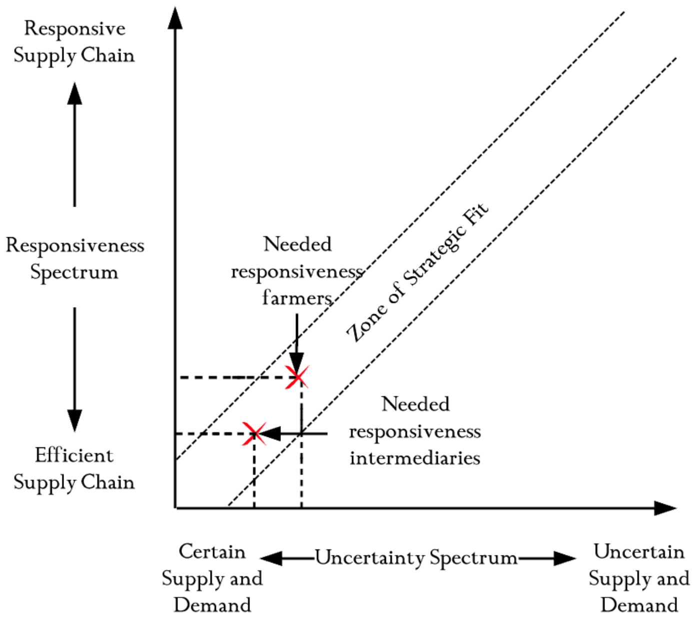

Figure 4.4 - Desired level of responsiveness according to the found uncertainties.

4.4.1 Choosing an appropriate supply chain strategy

As can be concluded from Figure 4.4, the required responsiveness to meet the uncertainty is fairly low both in the case of farmers and intermediaries. Adjusting to the correct level of responsiveness is not a straightforward task, since it also has to take into consideration where the uncertainties originates from, since the framework concludes the aggregated uncertainty. In order to find where the responsiveness should be focused, for example if it should be towards suppliers or customers, the framework from Lee (2002) will be used. The supply chain strategy should be based on both the level of uncertainty, but also where the uncertainty originates from. The resulting recommendations from the framework evolve around different methods on how to cope with the uncertainties. Lee (2002) suggests that, under the current circumstances with both low demand and supply uncertainty, the focus should be on an *efficient* supply chain, as illustrated next in Figure 4.5. Following this strategy during these circumstances should, as mentioned by Selldin and Olhager (2007), have a positive impact on cost and delivery dependability.

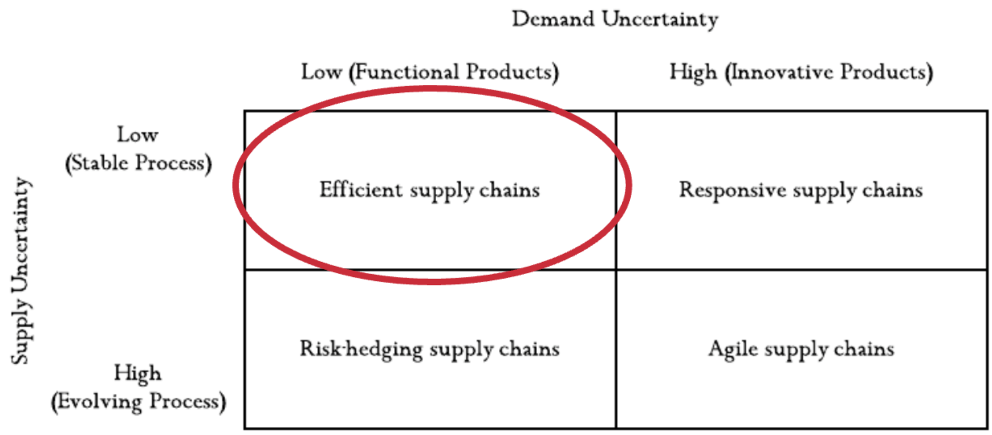

Figure 4.5 - Chosen supply chain strategy from Lee (2002)

An efficient supply chain is, as Lee (2002) and Fisher (1997) state, one where the company should be focused on cutting costs through efficient use of resources and competing on price. This strategy resonates well with the finding that in order for the coffee husk-biochar to be considered by the activated carbon producer, it would quite drastically need to reduce its price. As decisions regarding *facilities, inventory* and *transports* are the biggest influencers of the supply chain responsiveness, suggested measures in these areas, as well as an analysis of potential contextual hinders to these measures, will follow.

4.4.1.1 Facilities

Schmitt et al. (2015) and Snyder and Shen (2006) have concluded that facilities could benefit from being decentralized when having either uncertain supply or having both uncertain supply and demand. Both farmers and intermediaries would as concluded imply rather low supply uncertainty and, as demand uncertainty is low in this case, decentralization should not be sought from this point of view. As they also mention that decentralization could cause asymmetric information, misaligned incentives as well as incongruent objectives which all result in discontent and inefficiencies in the supply chain, centralization seems like an appropriate choice. This seems viable in this context, as an evolving and immature industry like the biochar industry naturally could cause asymmetric information between involved supply chain partners, as roles and responsibilities may be undefined.

The chosen efficient strategy also suggests that facilities should be centralized, and all our findings indicate that neither farmers nor intermediaries would be hindered, by the context we have investigated, from adopting the approach of centralizing the facilities. These findings are that *many farmers are needed* and that *machine operations benefit from centralization,* and these will be elaborated upon. The first finding does thus direct only farmers, whereas the second directs both farmers and intermediaries.

Many farmers are needed

From the research we found that many farmers would be needed to invest in one machine. We base this suggestion on the fact that a farm in Dak Lak in general has a monthly income of around USD 250 - 500, while the PPV300 according to Viet Hien costs USD 40 000. This implies that around ten yearly incomes of one farmer would be needed to invest in one machine. If considering the income of the average farmer, many farmers would realistically be needed to get together to make such an investment. In a survey by

Nguyen and Sarker (2018), 96.4% out of 137 farmers in Dak Lak confirmed that they would be willing to invest more than 10 million Vietnamese Dong (around USD 430 at today's exchange rate, June 2020), if that would improve their farming or lead to higher sustainability. Assuming the farmer would be willing to invest as much as USD 500, it would still require that 80 farmers together invest in the PPV300. This can be compared to Binh Minh Cooperative which consists of 30 farmers.

Another financial consideration that affects the viability of either centralizing or decentralizing is the capacity utilization of the PPV300. Using up to 90% of the capacity should be desired to reduce the cost of the produced biochar, and thereby follow an efficient strategy, as a big portion of the cost for the produced biochar otherwise will be represented by machine depreciation costs. A calculation of the number of average farms needed to utilize 90% of the machine capacity is therefore presented below in six steps.

1. *One coffee farmer in Vietnam averages 3 hectares of land. Each hectare yields 12.8 tonnes of fresh coffee cherries per year. 12.8*3 = **38.4 tonnes per year per farmer** is produced.*

2. *Out of every fresh kilo of fresh coffee cherries, **14% of the weight will become dry husk*** (Montilla-Pérez et al. 2008).

3. *The PPV300 requires 100 kg of biomass, coffee husk, per hour, and can run 24 h per day, 6 days a week. The calculations will assume 90% utilization rate, as for example disruptions and additional maintenance might hinder full utilization.*

4. *This would mean that the PPV300 requires 0.9(utilization)*52(weeks)*6(days)*24(hours)*100(kg) = **673.2 tonnes biomass, dry husk, each year.***

5. *673,2 tonnes of biomass would mean 673.2/0.14 = **4808.6 tonnes of fresh coffee to sustain production.***

6. *4808.6 tonnes needed with a 38.4 tonne production per farmer equals an equivalent of **125 average farmers** would be needed to use the capacity up til 90%.*

That is, to afford the machine, 80 average farmers would be needed, and to sustain the production, 125 average farmers would be needed.

Machine operations benefit from centralization

Another consideration regarding the use of either centralized or decentralized production facilities, is the increased need for flexible personnel and education of the PPV300 if decentralizing. As Sofies Zürich mentions, a farmer may benefit from reducing the number of activities per worker to reduce workload and the need for more training of individual employees, and centralization is therefore beneficial. Also Husk Ventures preferred a centralized solution, and said: “If you replicate the unit and decentralize, you have to replicate all the resources there. You need to replicate the management for every unit because it has to be self managing".[31]

Also the machine characteristics can affect whether it would be beneficial to have production in one or several places. From speaking with Viet Hien and Husk Ventures we found that the PPV300 might need quite much space to operate due to generated heat and related operations. Husk Ventures made a rough estimation, that around 200 square meters could be needed for the use of the machine as they explained that: "You need space for the supply, so you can move around, if you do maintenance you need space for the forklift".[32] If the business can support more than one machine, it could be beneficial to centralize with many machines in one place rather than spreading them out, as the machines most likely can be closer to each other than to other things.

4.4.1.2 Inventory

The efficient strategy suggests that inventory levels should be kept as low as possible in order to reduce costs, both for raw material as well as for finished products. The stable demand and supply indicates that there will be limited need for safety stock, and thus they should ultimately be kept low. Though, our previous finding that *a great amount of husk needs to be stored over longer periods of time* makes it difficult to follow the efficient strategy regarding inventory management on the supply side. Regardless of actor, the need of a large raw material inventory creates the need of both larger facilities and more capital tied up than what the suggested efficient strategy requires. It can therefore be investigated whether the raw material inventory could be distributed among the actors in the supply chain to share this additional cost. Having long-term storing might however be difficult for farmers, as Hoang (2017) mentions that more than 90% of the 139 farms she studied in the central highlands lacked an appropriate storage area. Farmers may therefore have a difficult task sharing this burden.

The visited intermediary in Vietnam, Viet Hien, had much better ability for long-term storage, but since they had not yet had the production up and running for a full year, their precise storage capability was not definite. Even though it could be possible for intermediaries to transfer stock responsibility in the form of coffee husk upstream the supply chain to share this burden, or for the farmers to decentralize their stock if other farms have storage areas, the stock costs will still be present in the supply chain as a whole.

Though, the finished goods inventory made up of biochar could, in contrast to the raw material, be limited. Since the demand is predictable and stable, only low levels of inventory would be needed to meet the needs of The AC Producer. The predictable production would also allow for regular shipments that would keep the finished goods inventory at a low level. This is true regardless of biochar producer.

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[31] Husk Ventures. 2020. Interview 17th of February.

[32] Ibid.

4.4.1.3 Transports

The efficient strategy suggests that the lead times of transports, if possible, should be kept short, but not at the expense of increased costs. As supply and demand uncertainties were found to be low, long term planning where only full truck loads are being shipped at favourable rates should be possible. Since the customer also is willing for different options regarding packaging and delivery, bulk shipments could be arranged to create more efficiency. These shipments should of course be outsourced to a transport company, as the possible loss of responsiveness Selviardis and Spring (2007) mention is less important in the efficient strategy than the potential cost savings from the achieved economies of scale.

Apart from this, our findings showed that it could be costly for farmers to transport goods in Vietnam as *transportation costs could hinder farmers from being efficient*. We did however not find any major hinders for an intermediary to arrange cheap transports and thereby being efficient. Another finding that may affect transports in the region is that *reliability of transports is varying* and both findings will be elaborated upon below.

Transportation costs could hinder farmers from being efficient

During our field visits and interviews with Binh Minh Cooperative, we found that they will arrange a limited share of their transports of goods. They transported everything below five tonnes with a three-wheeled tractor to a local processor, whereas amounts above five tonnes got picked up by processing companies. As the three-wheeled tractor might be used also for distributing biochar, the transports of biochar could potentially be slow from the farmers, and the reach might be limited. Hoang (2017) mentions that farmers have the opportunity and contacts to send their goods longer distances, but the costs these longer transports can imply are sometimes too big for the farmers to endure.

Reliability of transports is varying

Most interviewees stated that they consider the transports to be reliable as for example Sofies Zürich said: "I would say compared to other countries, it works really well in Vietnam. They are very punctual. They are also business oriented. So if you are ready to pay for additional transport services, they will do it."[33]
This is contradicting the suggestions from Dung and Oanh (2019), which states that many professionals are disappointed with reliability and deadlines. Reasons for their disappointment could, as mentioned by Blancas et al. (2014), be that roads may be unpaved or have weight limitations along with low standards on vehicles and equipment. A consequence from this is that reliability has potential of improvement as many businesses in Vietnam obviously wish for better performance. This needs consideration, as low reliability can cause varieties that must be mitigated through costly responsiveness measures.

[33] Zellweger, Hannes; Managing Director at Sofies Zürich. 2020. Interview 6th of March.

4.5 Appropriate producer of coffee husk-biochar

In this section we will analyse what type of actor that is reasonable to have as a biochar producer when, such as in the case of supplying to activated carbon producers, considering the context and having low demand uncertainty. This is part of our suggestion of how the coffee husk-biochar supply chain can be configured to address its uncertainties and reduce them at their source.

4.5.1 Farmers

If farmers would be the producers of biochar, we conclude that they either would have to be of considerably bigger size than the average farm or be part of very large cooperatives to enable the production. These options make up a very small fraction of the farms in Dak Lak, but the average farm is not an option due to mainly two factors. Firstly, the economics of the PPV300 are hard to match with the finances of average farms, as the price of it corresponds to almost ten years of earnings for the average farmer. Realistically, many average farmers would have to gather to finance the machine unless a farmer would have considerable savings, which is unlikely. This is partly supported by the fact that not all farmers were willing to invest more than roughly USD 430 in improved farming methods. As still an absolute majority were willing to invest that amount, it is assumed that the investment willingness will decline with both higher investment sums, but also since the PPV300 is not within their core business nor area of expertise.

Secondly, from the findings regarding the price of the PPV300 as well as the price of the coffee husk biochar, it should be desired to use as big part of the capacity as possible to decrease the cost per each ton of produced biochar. It would take the husk from about 125 farmers to achieve high utilization of the machine, unless it is accepted that the machine is unused for the major part of the year, i.e. outside of the coffee harvest season, which we concluded is a suboptimal option. It might however be difficult to make 125 average farmers get together to produce biochar, as farmers in the region have limited cooperation between each other, along with the fact that they are geographically scattered. Coordinating the large number of farmers requires that a farmer takes on a serious leader role. It is uncertain whether this is in any farmer’s interest or ability, and it would also interfere with the daily farming operations. In addition, since the transport costs are already a constraining factor on the farmers' operations, there could be difficulties arranging the full truck loads to keep the cost down per tonne.

The analysis shows that it is highly unlikely that average farmers would be willing to get involved in the biochar business due to the economical and organizational constraints. An option would be farmer cooperatives, as the visited one which already produces biochar. Having a cooperative of around 30 members would drastically reduce the investment per farmer, and a larger supply of husk would from start be available. Though, there would still be a large shortfall of husk, meaning that the cooperative would have to organize the supply of almost additionally 100 average farmers to sustain a yearly production to reduce the biochar price. We did also find higher levels of uncertainty related to the farmer cooperatives than visited intermediaries. Though, this analysis does not address the other benefits that the PPV300 brings, such as reducing the smoke and its possibility to use its excess heat for drying. The cooperative would be able to dry their beans as they produce the biochar, an operation that otherwise costs between VND 400-800 per kg of coffee (Hoang, 2017). By allocating the savings from the drying, the price of the biochar could be reduced which is an option that the visited intermediaries to date did not use. However, although this might reduce the price for the biochar, it does not compensate for the increased depreciation per tonne unless the cooperative source husk outside their own supply to sustain a yearly production.

4.5.2 Intermediaries

While the PPV300 is a considerable cost for the average farmer, or would require extensive cooperation between a large number of actors to utilize it, an intermediary is deemed to have better opportunities to both finance and utilize the machine than a farmer. The intermediary is also deemed as having better prerequisites to establish such a large supply network due to that the biochar would be their main operation. An intermediary could also optimize its location in contrast to the farmers who are bound to their farmlands, and the intermediary would not have to focus on generating its own raw material through farming operations. This would speak in favour of the intermediary. Though, the intermediary as a newly founded company, as the one visited in Cambodia, would presumably not have the same opportunities to fully utilize the PPV300 and allocate savings from its excess heat unless expanding their business to include different drying services. They would also have to, as concluded, store great amounts of husk, meaning that large facilities are needed and thus absorbing a large portion of the costs. As found, the option of sharing the stock among upstream farmers is not deemed as viable.

Though, the potential storage problem could be solved by using the advantage that the intermediaries could locate their business more freely. This means that they should consider cooperating with coffee processors. Our findings indicated that between 20-50% of the coffee cherries are not dehusked at the farmers, but rather at external processors, meaning an alternative is to buy husk from these instead of the farmers. Apart from solving the storage problem, it would offer the opportunity to centralize close to one or a couple of larger processors that could provide the raw material from a focal point instead of dealing with hundreds of farmers. This would for example use the already established business relationships between the processor and farmers as well as the established logistics between them, meaning that many of the uncertainties that come when dealing with a large number of actors can be mitigated. As the findings show that the farmers have an ambiguous attitude towards the husk and new type of businesses, the advantage of piggybacking on an existent supply chain should not be underestimated, as it could be difficult to set up this for a new company.

Though this would not be directly comparable due to different raw material, this setup would replicate the setting found at Husk Ventures in Cambodia where the company was located in the same factory as the rice husk arose in, and bought it directly from the rice company. This would further increase the efficiency in the coffee husk case, but requires the cooperation from one or more coffee processors. If being placed in the same facilities, it is beneficial if the intermediary also is allowed to source from other processors to avoid the supply risk that is generated from the dependence of a single supplier. If it is not possible to rent part of a facility owned by a processor, locating as close to processors as possible is recommended to limit transportation. There is also the possibility for the intermediary to utilize the PPV300’s excess heat by engaging in the processor's drying activities. This would create synergies between the actors, but still allow the intermediary to be flexible in supply and choice of location. The suggested supply chain configuration is illustrated below in Figure 4.6. It should be noted that a coffee processor also is a type of intermediary, but the *intermediary* in this figure still refers to an external intermediary that produces the coffee-husk biochar.

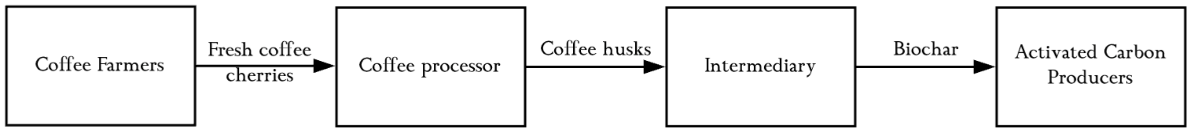

Figure 4.6 - A supply chain configuration where an external intermediary produces coffee husk-biochar. Please note that also buying agents could be involved in this supply chain as a connector between coffee farmers and coffee processors.

Though, this supply chain configuration would imply one more type of actor is needed in the supply chain which potentially could increase costs. It could also increase the total uncertainty in the supply chain, since the uncertainty is amplified further up in the supply chain. This would mean that the farmers, who are at the top of the supply chain, but also the ones with least abilities to address the uncertainties, would theoretically be even more affected by the uncertainties. Such an outcome would either affect their other operations, such as the field work needed outside the harvest season, or, they would prioritize their other operations meaning that it would affect the husk supply. However, as the setup is intended to utilize the already existent supply chain where the husk arises at the processor, the risk that the farmers are affected is deemed as limited.

A perhaps bigger threat with the additional actor, and the relatively high dependence on it, is the potentially conflicting interests that might arise. It is important to remember that when adding another actor into the supply chain, there is a higher risk that the new actor is more powerful than the intermediary. Thus, the new actor could take the supply chain leader role which might limit the intermediary to arrange a very efficient biochar production. Therefore it is important for a potential intermediary to take these risks into consideration when choosing partners to cooperate with, especially if they are in a more dominant position (Stadtler, 2005).

In the end, the setup of having an intermediary, close to coffee processors, as producer is preferred over having farmer cooperatives as producers since: (1) Less overall transports are needed in the system as the coffee processor already make the long transports that contain coffee cherries; (2) The right, presumably efficient, flows of material already exist, and it is likely that fewer parties would need convincing of this solution than if new cooperatives would be created or many farmers would need to act as suppliers; and (3) The intermediary producer could have the biochar production as core business, and avoid coffee production as distraction, and could therefore focus on making processes more efficient.

4.5.3 Coffee processors

The main uncertainties that surround the intermediary if located near a processor are the potentially amplified uncertainty as well as the potential conflicting interests between the supply chain actors. Both of these could be mitigated by the processor itself being the intermediary that produces biochar by limiting the actors and thus also avoiding conflicting interests with a new biochar producer. The processor would also utilize many of the advantages mentioned for the intermediary, such as using the existing supply chain and that they have established relationships with the important buying agents, or in some cases, directly with farmers. They would therefore neither have to establish new sales channels to the same extent, as for example an external intermediary, since they could also start by selling biochar through the same channels they have sourced their coffee cherries from. Additionally, they could also use the excess heat for drying coffee cherries as part of their original business. A reduced need of energy for drying beans gives the opportunity to allocate less costs to the produced biochar as it creates value that decreases costs in other areas. This is therefore aligned with the objective of reducing costs for the biochar, assuming the processor can make full use of the excess heat. Well established processors are also assumed to have more solid finances than both farmers and potentially newly founded companies. The suggested supply chain configuration is illustrated below in Figure 4.7.

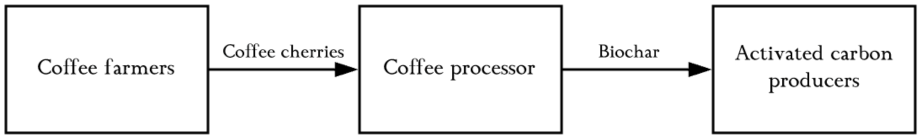

Figure 4.7 - A supply chain configuration where a coffee processor buys coffee cherries from farmers, dehusks them and then produces coffee husk-biochar from the coffee husk. Please note that also buying agents could be involved in this supply chain as a connector between coffee farmers and coffee processors.

Moreover, since the harvest season is short, so is the processing season. While the processors might conduct some additional businesses, such as trading with coffee between other actors or engaging in the tourism industry, the actual processing does only take place during a few months per year.[34] This means that both facilities, machines and similar overhead costs must be allocated to this short period of processing. If the processor either themselves engage in the biochar business, or if they rent out their facilities to an intermediary, it should be a desirable option as long as it generates a profit. Apart from the potential synergy by using the excess heat, it should theoretically be desirable from an economical perspective to increase their sources of income.

Though, the processor would also possess several of the disadvantages as the farmers, such as adding another large business area to their core one, as well as potentially not having the same opportunities to source as freely as an independent intermediary. Since they already have invested in fixed assets, they will not have the same opportunities, as the intermediary has, to adjust their business to an efficient strategy. It is neither found exactly how many processors there exist who generate enough husk themselves to sustain the production of one machine per year.

It is thus difficult to state if a processor, in the end, would be a better alternative as the biochar producer than an external intermediary. However, it can be concluded that their involvement in the supply chain configuration would be a favourable option, as they already have important relationships and distribution channels in place. The sometimes not logical setup in the coffee supply chain, with more actors than what a conventional supply chain would deem as necessary, is to a large extent due to relationships and financial obligations. Becoming part of that supply chain may therefore be difficult, which leads to the necessity of

[34] Tran, Chung; UNIDO Expert, Department of Environment. 2020. E-mail correspondence 13th of May.

the involvement of a business oriented actor like the processor, who since long have been part of the supply chain.

4.5.4 Large-scale farmer

As discussed in the contextual findings, it has become clear that there are also actors who cannot be classified as either processors or farmers, since they either are farmers so large that they also process their coffee, or processors with so close connections to specific farmers that one cannot distinguish them from each other. This type of actor would possess the benefits of being able to use the excess heat from the PPV300, have a proper supply chain and necessary relations for the husk, and is assumed to have the resources to make the necessary investments. As visited farms and literature stated, the common procedure for farmers is to grow additional crops in the coffee fields, such as pepper, the actor could continue to utilize the PPV300 for drying other crops besides the coffee. This might not be the case for pure processors who could be fully designated to process coffee. The suggested supply chain configuration is illustrated below in Figure 4.8.

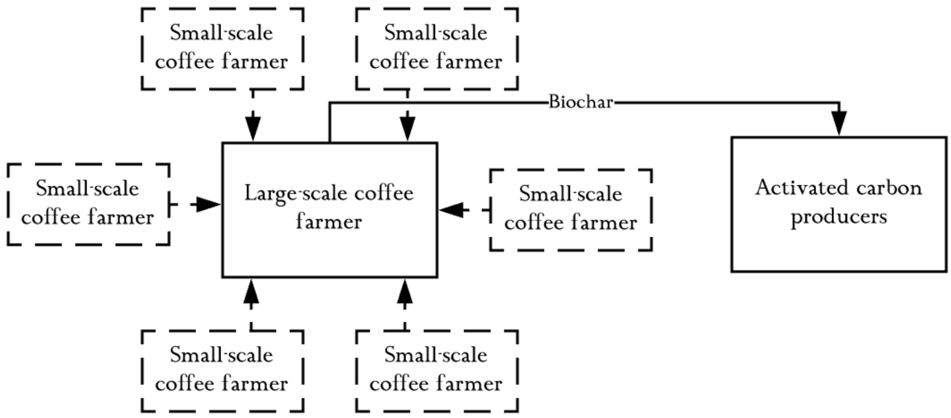

Figure 4.8 - A supply chain configuration where a Large-scale farmer produces coffee husk-biochar.

This hybrid actor would presumably still be in need of sourcing additional husk from additional farmers to sustain production for a full year, and would not be as flexible as an intermediary due to fixed assets. It would also interfere with their core business during harvest and current use of the husk, as in the case of the small-scale farmers. Even so, they would have greater ability and larger workforce to handle the new business area than the small-scale farmers. They would also, as with the processors, add another source of income during the remaining parts of the year by producing biochar which should be economically beneficial. Lastly, since they also are closely connected to the farms, they would be able to use the biochar themselves if the demand is fluctuating, meaning that they can reduce the need of fertilizers as well as limit their water usage.

While this type of actor possesses both advantages and disadvantages from the previously discussed alternatives, there are both advantages and disadvantages that could have been foreseen. This, since the absolute majority, 90%, of farmers are small-scale, meaning that there both is a limited number of these actors, as well as limited descriptions in the literature about their characteristics.

4.5.5 Recommended actors

In conclusion, there are several actors that according to the analysis would be able to take the role as biochar producer, although small-scale farmers or farmer cooperatives are not deemed appropriate due to their limited abilities. The three other actors, an intermediary without previous direct involvement in the coffee supply chain, a coffee processor, or a hybrid between farm and processor (Large-scale farmer), do all possess different advantages and disadvantages. How to evaluate their abilities would though require a much deeper study of each actor and their respective preferences. What could be concluded is that these three actors, regardless of their availability, preferences or willingness to adopt a new type of business, would all be suitable from a supply chain perspective to attain an efficient strategy that would keep the price of the biochar as low as possible.

4.6 Sensitivity analysis

Regardless of the actor chosen for the supply chain, the analysis has so far originated from the case findings with both low demand uncertainty and low supply uncertainty. Though, since the overall purpose is to increase the understanding of supply chain uncertainties that might hinder an expansion of coffee husk-biochar production and configure the supply chain to handle these, it is important to also widen the perspective outside the single case studied. To give the supply chain stability, other levels of uncertainty need to be tested in order not to adjust it according to a unique case that presumably is not representative for the uncertainties the biochar will face from other markets.

Randall et al. (2003) state that the initial supply chain implemented is the most important due to companies' reluctance to make changes later on. This means that the initial supply chain might have to take as many scenarios into consideration as possible if there is a risk that there are not resources, or will, to make changes later on. This could be both to take into consideration the later product life cycle demand which most likely will be different to the initial demand, or, as in this case, take into consideration customers with different demand than the investigated activated carbon producer, to allow for a broad expansion. Since the identified supply uncertainty is independent of the demand, it is assumed to remain constant. Therefore it is reasonable to test other types of demand uncertainty and discuss how these scenarios should be handled by the supply chain configuration to allow for a broad expansion of the biochar.

In our assessment, we divided the uncertainty into three levels, meaning that we could test two other types of demand uncertainty than the one experienced from The AC Producer. A high demand uncertainty would be that the customer is highly unpredictable regarding order characteristics, demand patterns and demanded service level. This could be expressed as unpredictable order sizes, lead times, emergency orders as well as having a dependable order pattern that cannot be predicted by the biochar producer. This would generate a high uncertainty for the biochar producer, who would not be able to plan the production for longer periods of time, and would be forced to deploy a constant excess capacity to meet the unpredictable order sizes and potentially urgent deliveries. According to Lee (2002), this would imply the need of a *responsive* supply chain, as illustrated in Figure 4.9.

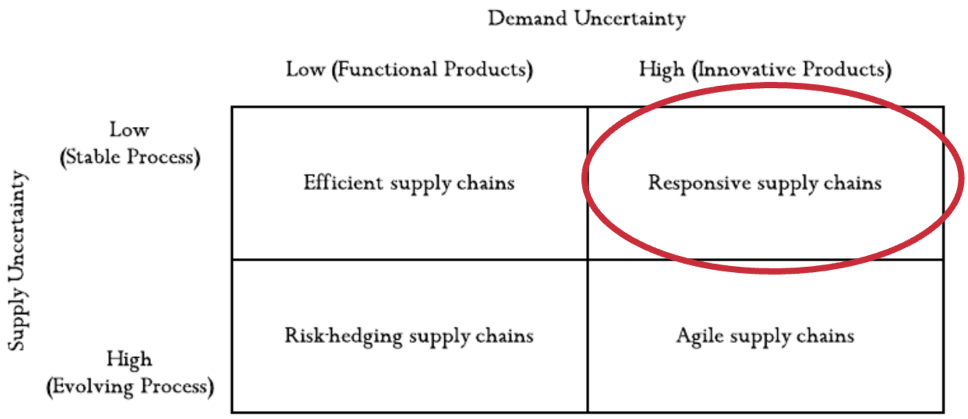

Figure 4.9 - Chosen supply chain strategy during high demand uncertainty.

To meet this, the supply chain would have to be very responsive regarding facilities, inventory and transport. The facilities would benefit from being decentralized in order to get closer to the market (Graungaard Pedersen et al., 2012), and in combination with the need of having excess buffer capacity in the production, it would mean having several production facilities. Each facility would also require to have a safety stock of foremost finished products in order to be able to always deliver directly from stock. Contracts with transporters that could deliver both full truck loads as well as smaller loads within a short time frame would also be necessary. The decentralized structure would also require a new type of coordination in order to get the husk packed from either the farmers or coffee processors to the different facilities that presumably would be spread out across the country close to bigger customers. It quickly becomes clear that this is a highly costly solution that is especially less suited for the actors with already established and fixed assets.

Though, the high demand uncertainty scenario is deemed unrealistic for this functional product. This is because we assume that the price premium that high demand uncertainty would imply is unlikely that the market would be willing to pay for. It is thus not realistic to assume that such costly demands from customers would arise. In addition, with the PPV300, it could already be more economical not to produce, and instead save the coffee husk, than not going on full capacity. This relatively expensive production, in combination with the assumption that the price premium would not be accepted by the market, does not go well with the responsive strategy that assumes that a lost sale is more costly than buffer capacity. It is therefore regarded as more realistic that a medium uncertainty arises from the customers. Such an uncertainty would need a combination of the strategies needed during low and high demand uncertainty to achieve a higher responsiveness but to a more realistic price. This could be done by utilizing the centralized approach by being located by a coffee processor, but holding larger safety stocks of finished products. Also contracting of transporters that are able to act on shorter notice could be desired, as well as sending smaller batches than full truck loads. Another approach could be to buy storage space for the finished biochar in warehouses closer to customers to achieve a higher responsiveness, but keep the more efficient strategy both in terms of inventory and transports at the centralized production facility.

However, even this more pragmatic approach is still deemed as unrealistic. We have not found anything that indicates that coffee husk-biochar could be sold for a higher price than, for example, biochar made from coconuts. Instead, we have found that the current price for coffee husk-biochar is too high to attract customers - both farmers as well as bigger companies such as The AC Producer. This leads to the conclusion that, in order to succeed, regardless of the market that the biochar is aiming at, the primary goal should be to always reduce costs. Additionally, since the biochar resembles a functional product, with low product variety and long product life cycle, it will according to Fisher (1997) most likely also over time experience a stable and predictable demand. Therefore, by taking the need of cost focus in combination with the likelihood of meeting stable demand due to the product characteristics, the most reasonable is to focus solely on the suggestions originating from stable demand and supply. And, as discussed, the most efficient solution available in the current context will still possess responsiveness in the shape of excess raw material inventory, meaning that a strict cost focus still will allow the supply chain to meet an occasionally uncertain demand.

An efficient supply chain strategy does also go well with the suggestions from Randall et al. (2003). The biochar market enjoys high growth rates, has low variety to its products but will also face competition from established actors and need to compete on price with presumably low contribution margins. The demand uncertainty is also found to be low, and assumed to remain low across other market applications due to the product characteristics. All these findings are in line with what Randell et al. (2003) recommend as prerequisites when one should enter the market with an efficient supply chain, which further strengthens the recommendation.

Lastly, it is important to note that the findings are not static. Even if the analysis shows that an efficient supply chain is the best option and that the demand most likely will not be uncertain due to the market and product characteristics, illogical situations might appear. For example, The AC Producer was shown not to place emergency orders, which might not be the case with perhaps less well-run companies. Situations like that cannot be foreseen, and in the current context, there is no room to speculate about other uncertainties that may arise when the biochar is sold to new markets. There is nothing that suggests that the risk for unforeseen changes is big enough to motivate any other supply chain. Therefore, the recommendation is to follow the analysis with an efficient supply chain, but remain open to changes if the situation would require it.

5. Discussion

Chapter 5 will present discussions about the producers of biochar and the recommended supply chain strategy, as well as discussions regarding the framework from Chopra and Meindl (2013) which was used for the analysis.

5.1 Relationships in the coffee husk-biochar supply chain

The analysis concluded that either an intermediary, a processor or a large-scale coffee farmer, which possess several attributes from both farmers and processors, are the most suitable actors to produce coffee husk-biochar in an efficient way. While the relationships in the coffee supply chain have been covered, they have also been concluded to be difficult to fully understand.

A question highly related to the cultural aspects that will affect the supply chain is the role of the supply chain leader, and how much effect that might have on the choice of configuration. In conventional supply chain literature, the supply chain leader will coordinate the supply chain and decide on its direction. However, in the case of an operation that requires a supply chain that to a large extent is built on trust, relationships and financial obligations, the supply chain leader's role might be more important than strictly coordinating actions across the chain. In this case, the leader may be the enabler of the whole business. Without an actor who both understands the difficulties as well as has the trust among the farmers, it is deemed as highly unlikely that an efficient flow of goods will be possible. In other words, the processor, with its contacts and trust with both buying agents and farmers, might be the enabler of the business and thus the only natural supply chain leader. A configuration where they participate is therefore deemed as necessary.

However, do the processors actually want to engage in biochar production? The processors who handle coffee husk do already in many cases have a stable market for their coffee husk, either sold as fertilizers or as material to burn, or they use them their self for the same purpose. This already brings them economical benefits, even if they may be small. When engaging in biochar, they will have to make rather large investments in machinery and possibly storage space, as well as changing much of their current way of working to adapt to the requirements of the new business. Presumably, they would only consider this risk if they believed in a higher income than what their current use of the husk generates. Unless the processors have a very long investment horizon, which we deem as unlikely, the increased income must also be rather high to, within a few years, compensate for the risk and investment.

Though, since the findings have indicated that the coffee husk-biochar has problems competing with biochar from other biomasses, and that lowering the cost from the PPV300 biochar production is needed, the margins will most likely be very small. In addition, it is in the very premise for this thesis that the first mover companies will face economic challenges, since the thesis is built on the assumption that in order to get the product viable, there need to be economies of scale. This implies that the first users of the PPV300 will have to pay a higher cost. In other words, there is a catch twenty-two. To get the product viable, actors need to invest, but they will only invest if there is a high chance of significantly increasing their income.

Perhaps a newly founded company would be more willing to take this risk as they have no previous business at stake, like the case with Husk Ventures in Cambodia. It is however clear that overcoming the issue with the relatively high risk, in relation to the possible reward during the establishment of the market, is the perhaps main problem with the continued business development.

5.2 The production of coffee husk-biochar

The PPV300 has, throughout this thesis, been the assumed machine unit for production of coffee husk-biochar. It must however be considered if the PPV300 is the best alternative for the production of biochar, if considering our findings that the produced biochar is too costly compared to other types of biochar. The main issue that needs consideration is if a system that generates excess heat and re-supplies its own fuel is needed for this purpose, as this causes higher financial costs for the technology. These functionalities can however be utilized by for example a coffee processor if they would be the producers of biochar, as they could dry coffee cherries with the heat or potentially convert the heat to electricity needed for other purposes. A reduced need of energy for drying coffee cherries, or less electricity needed, gives the opportunity to allocate less costs to the produced biochar as it creates value that decreases costs in other areas. This is therefore aligned with the objective of reducing costs for the biochar, assuming the biochar producer can make full use of the excess heat.

To allocate the costs correctly is however not an easy task, and there is a risk that an actor would allocate the savings to another business area, meaning that the price would remain high and thus lowering margins or not reaching the market. This would bring back the situation with too low margins to be willing to continue with the operations. It is by that of high importance that the actor who engages in this not only is willing to take a risk, but also can allocate the costs correctly to reach the full potential.

Another benefit with the PPV300 that could be utilized is the smoke-free production process, as discussed by Flammini et al. (2019). This means production with the PPV300 reduces health costs related to emissions during combustion. Reducing smoke is of course beneficial to the individuals that are less exposed to the hazardous emissions, but the reduced costs related to this are primarily social costs rather than costs for the enterprise. It could therefore be difficult to argue for these cost reductions unless society, rather than the enterprises, compensates for the investments needed to achieve them. Another alternative is of course to use regulations as incentives, which rather force the enterprise to strive for such cost reductions. Although such incentives would not mitigate the found supply chain uncertainties, they would make the PPV300 more attractive and potentially support the expansion of coffee husk-biochar production in Vietnam. In other words, governmental regulations or incentives are required to activate the full benefits of the PPV300. That is however assumed to be outside the ability to affect from a producer perspective, and the producer should thus "hope for the best, but plan for status quo."

A strict financial perspective would instead promote searching for a cheaper technology that has similar capacity, and can fulfill the purpose of producing biochar from several types of biomass similar to the PPV300. It may be unlikely that the cheaper technology is cheaper in the long-term compared to a machine like the PPV300, as heat savings may be more significant over time than cost savings from investment in another technology. To find an alternative that requires a lower initial investment could however be beneficial from the aspect that it is easier to convince stakeholders that have a shorter time horizon. It could thereby support in lowering the threshold of producing the biochar, and open up for a market growth that later creates a bigger opening for a more advanced technology like the PPV300. A market growth would allow for increased proof of the viability of using biochar to improve soils for farmers, and bigger investments in production equipment could therefore easier be motivated when the assumed market already is convinced.

5.3 Strategy considerations

The biggest hindrance of the efficient strategy proved to be the inventory, as low raw material stocks and thereby low costs were found to be difficult to achieve. A coffee husk-biochar producer is also dependent on the Vietnamese coffee industry if limiting the biochar production to the raw material of coffee husk. It is this dependency that would force a producer to source a yearly production stock during the coffee harvest season to enable supply of biochar all year long. To direct the issue with the high stocks that are needed, the producer could also consider the usage of other raw materials than coffee husk if finding markets for it. For that purpose, it should include biomass that is harvested during other parts of the year than coffee. If using several types of raw materials, the production will have to be more flexible as the machine might need different types of settings and requirements on machine operators will therefore increase.

Lastly, with this new supply chain, it is of great importance that the goal of the supply chain is clearly communicated to all the actors and that there exists an understanding that they together form a supply chain that competes against other supply chains. Our analysis shows that price is the single most critical factor, and it requires a broad understanding and cooperation to be able to reduce the price. That means, all the actors must strive towards the same goals to be as cost-efficient as possible in order to be able to compete in the market. Communication between the actors to be able to act proactively to reduce disruptions, cooperation to reduce capital binding and shared resources should also be of high priority in order to optimize the whole supply chain rather than single companies. That will further reduce uncertainties at their source by hindering them from arising and mitigating friction that may arise between the actors. This also strengthens the argument to somehow include a coffee processor in the supply chain, since these already have an established relation and good communication channels with the farmers. The potentially difficult process with establishing a trustworthy relation is therefore already completed to a large extent, which further mitigates uncertainties.

5.4 Evaluation of the used framework

The strategic fit framework has a couple of flaws when adapting it to the current case. To fully utilize the framework, it is a prerequisite that there is an already existing business, or, that an already proven product should compete in an already functioning market, such as a new type of shampoo or juice. This is not fully stated in the work by Chopra and Meindl (2013), but has become obvious throughout this thesis, such as forcing us to assume a demand just to be able to use the framework. In other words, the problem does not lie in the framework itself, but rather in its underlying assumptions to use it for its original purpose. The framework is therefore first and foremost in need of a clarifying statement regarding the intended use of it.

In the case of coffee husk-biochar as raw material for activated carbon, it had not been proven viable, and would not be adjusted for in the framework. In fact, our findings indicated that it is unlikely there would be any demand for the mentioned purpose as the market is today. If then following the framework without having done the initial market and product assessment, time and money will be spent on assessing uncertainties that are not relevant for the business. In addition, when using the framework, a list of requirements and limitations to the supply chain would be beneficial. These requirements and limitations would be derived from the initial market assessment. In our case, that would for example be not to investigate small-scale farmers as extensively, since the context makes this option unrealistic for the investigated purpose.

Though, even if there is an existing business, the framework could be difficult to work with as it does not give any guidance on how to weigh the different uncertainties against each other. For example, some variables can show a great uncertainty in themselves, but would in the overall context be secondary to other uncertainties. Here, the framework offers little guidance and solely states that the uncertainties should be weighed together to get an overall uncertainty. This assumes an either already thorough understanding of the business, or extensive knowledge regarding supply chain management to be able to understand how the different uncertainties should be valued. While our three-leveled approach offered transparency and structure, it still relied heavily on the judgement of us to weigh the findings and give each variable a level of uncertainty. This criticism was already present in van der Vorst and Beulens (2002), meaning that there is still a need for improved frameworks that better addresses the actual operations.

Lastly, the framework is still deemed as a good tool in assessing the supply chain strategy for a product. The framework sets the overall supply chain strategy and aims at viewing the supply chain holistically, rather than just addressing single risks. If doing so, contradicting solutions might be implemented, while the framework better works with the context and at least in theory mitigate isolated solutions to a bigger problem. A confirmation of this could be that our findings aligned well with what the framework recommended as well as other used supply chain theories.

6. Conclusions

In Chapter 6, we will present the conclusions of our theis. We will answer the stated RQs and suggest how these answers contribute to practice and theory. As some research areas related to our thesis still are uncovered, we will also suggest areas for future research.

The purpose of this thesis was to increase the understanding of supply chain uncertainties that might hinder an expansion of coffee husk-biochar production in Vietnam, and recommend how the coffee husk-biochar supply chain could be configured to address these. We used a case study regarding the potential use of coffee husk-biochar as raw material for activated carbon, as a tool for understanding the supply chain uncertainties and needed responsiveness. This gave us a case specific demand uncertainty, although supply uncertainty was assumed to be constant in scenarios with other levels of demand uncertainty. Through that approach, we were allowed to understand how the supply chain could be adjusted depending on the characteristics of the desired market for the coffee husk-biochar.

6.1 RQ1: Understanding supply chain uncertainties

What are the supply chain uncertainties if activated carbon is made from coffee husk-biochar?

Demand uncertainties

The demand uncertainties we found were based on the interview with The AC Producer, as we were unable to get in contact with the only other competitor on the Vietnamese market. We found that it was irrelevant to understand uncertainties from different customer segments, as no distinct segments exist in this oligopoly market. Our conclusion was therefore that, despite the fact that only one activated carbon producer was interviewed, we got a fairly representative picture of the activated carbon industry in Vietnam.

We found that the biggest uncertainty from The AC Producer was that they hold great power towards their suppliers. The reason behind this power is that they only have one direct competitor along with the fact that they have a big supplier base with suppliers contracted over short periods of 2-4 weeks. However, they also showed understanding towards the capacity of their small scale suppliers and what could be demanded from them, which implied few strict requirements and low uncertainty. The overall demand uncertainty was in the end considered to be low as no other indications of uncertainties were found.

Supply uncertainties

Supply uncertainties were based on interviews with Binh Minh Cooperative, current intermediary biochar producers (Viet Hien and Husk Ventures), the PPV300 manufacturer (Viet Hien), independent experts as well as literature resources. We did also initially consider the opportunity of activated carbon producers to produce the biochar that they later could use as raw material for their activated carbon. This alternative was however excluded from the analysis due to the lack of data that would support a suggestion regarding its feasibility.

Our finding was that supply uncertainties mainly concerns external risks, risk of disruptions in production as well as the lacking safety procedures regarding operating the PPV300. Biochar production, if based on coffee husk, is dependent on the coffee industry and for example low yields from harvest would strongly affect the supply of coffee husk-biochar. The supply uncertainties were mainly the same independent of if the biochar producer is a farmer or an intermediary, but external risks were found to be bigger if farmers would produce the biochar. This is explained by the conclusion that it is more natural for an intermediary to use a bigger supplier base, with bigger geographical spread to protect the supply towards for example unfavorable weather. Altogether, an intermediary as producer of coffee-husk biochar was concluded to imply lower supply uncertainty than coffee farmers although the overall supply uncertainty was fairly low for both types of actors.

6.2 RQ2: Suggesting supply chain configurations for further expansion

How could the supply chain be configured to address the found uncertainties and fit into the current context?

Needed supply chain responsiveness

The needed responsiveness among both farmers and intermediaries if either one of these would produce biochar were found to be low, due to the low level of supply chain uncertainty that was found in these configurations. This finding implied an efficient strategy regarding facilities, inventory and transports no matter which of the two types of actors that would produce the biochar.

As decentralization indicates a higher responsiveness whereas centralization is appropriate to achieve efficiency, i.e. low responsiveness, it was concluded that centralization would be needed for the production facilities. We found that farmers would not be hindered from this approach, but rather forced to it, due to their challenges in utilizing machine capacity as well as to afford the machine costs. There were neither any hinders for an intermediary to centralize as they rather would benefit from the economies of scale this solution would enable. Inventory was however found to be difficult to run efficiently in this context due to continuous demand of biochar, the need of utilized machine capacity to reduce biochar cost as well as the fact that coffee harvest only lasts a couple of months. These aspects make it inevitable to store excess amounts of raw material, and thus have a responsive inventory, unless also other biomass than coffee husk, that is harvested during other periods of the year, is used as raw material for the biochar. Transports should however be able to run efficiently for both farmers and intermediaries as no indications of strikingly high costs were found related to this activity in Dak Lak. These transports should be outsourced to reduce costs and shipped in full truck loads when possible.

Supply Chain Configurations

It was found that small-scale farmers, due to their difficulties in financing and utilizing the PPV300, are inappropriate producers of coffee husk-biochar. These suggestions were supported by findings which indicated that around 80 average farmers would be needed to invest in the PPV300, whereas the yields of average farms indicated that around 125 average farmers would be needed to fully utilize the PPV300. This can be compared with the Binh Minh Cooperative, which was one of the subunits, that included 30 farmers.

Intermediaries, on the contrary, were found to be appropriate producers of coffee husk-biochar. One reason is that they, as mentioned, imply lower supply uncertainty than the small-scale farmers. They could also take advantage of the fact that around half of the coffee husk arises at coffee processors as some of these, just like around half of the farmers, dehusk the coffee cherries. This opens up for a solution where an intermediary is located in the facility, or close by the facility, of one or more coffee processors and produce biochar from the coffee husk these processors generate. Overall transports needed in the supply chain could thereby be kept to a minimum as the intermediary could piggyback on the logistics operations of the coffee processor, and flows of materials that already are in place.

Considering this, the processor themselves could also be an appropriate producer of biochar. As this solution would exclude an additional intermediary, the uncertainties related to having too many actors in the supply chain could be reduced. Such uncertainties could be for example additionally fluctuating demand upstreams the supply chain from the increased information asymmetry. The coffee processor could also use its already established distribution channels to sell biochar back to farmers, and would not, like the external intermediary, have to establish new relationships and build trust in the complicated Vietnamese coffee supply chain. Even so, it is uncertain whether it lies in the interest of coffee processors to invest in this side business as the potential incomes might be relatively low and also distract the processor from its core business. Also large-scale farmers, which are similar to coffee processors as they also process the coffee, could be viable as coffee husk-biochar producers. Although they would have similar benefits as the coffee processor, they would likely have to source from many other farmers and therefore need bigger changes to their current operations than the coffee processors.

6.3 Concluding discussion

Our research has only touched on very basic concepts regarding logistics theory, such as transportation, inventory and facilities. Even so, we found that the research was complicated and challenging to conduct, which can be explained by the difficult context that was the subject for our research. That decreased our need for more advanced theory regarding logistics and supply chain management, as further research and understanding of the biochar, coffee industry and activated carbon is needed before this is deemed relevant.

As we used a case study where we investigated the potential application area for coffee husk-biochar as raw material for activated carbon, we did also realize that the success of this application area is unlikely. Although it was outside of our purpose and RQs of this thesis to investigate required product properties and price, we stumbled upon information that these most likely were incompatible with the coffee husk-biochar. This discovery enables the project to focus on other application areas for the biochar instead, as these have greater chances of success. Even so, we recommend the project stakeholders to send a sample of the coffee husk-biochar to The AC Producer so more thorough testing can be done regarding the viability of its product properties.

Lastly, our strict supply chain focus in this thesis could be an issue. Our focus meant that the cultural aspects and other circumjacent factors were not taken into account. If the supply chain perspective, when it comes to the actual execution, remains as the most relevant is something yet to be discovered.

6.4 Limitations

The main limitation to the thesis has been the limited number of interviews. There are three main reasons for this. Firstly, both the scale of the UNIDO project, as well as the phase it is in, limited the number of people that were knowledgeable regarding our questions. Secondly, it became clear that the number of actors in some areas were much more limited than anticipated, and thirdly, it was more difficult than anticipated to find interviewees in the coffee industry. The difficulties with finding interviewees in the coffee industry could probably to a large extent be explained by language barriers. The limited number of interviews did neither allow us to examine different perspectives at each actor. We would also have liked to talk to coffee processors as they are mentioned in possible supply chain configurations to receive their viewpoint on such a supply chain, and thereby confirm or deny its viability.

Further, the limited data meant that the applicable theory was limited. It became clear that the majority of the investigated supply chain literature is written for a more developed context, either not taking the challenges in a developing country into consideration, or, assuming a different 'tool box' to solve the supply chain problems. This limited us from most of the conventional supply chain literature.

The research was also limited to a small area of the country, the Dak Lak region, which may mean that farmer preferences and methods could differ in other parts of the country. Though, since it is in the Dak Lak region that both a large part of the country's coffee production takes place, as well as housing the machine manufacturer, the limitations is considered to be motivated. Even so, more demand uncertainties from activated carbon could perhaps be found if increasing the research area to neighbouring countries.

Lastly, a limitation in the research was that we could not confirm the viability of the coffee husk biochar as input material to activated carbon. Reports have shown that it is possible, but it requires production equipment adjusted for this. Whether or not the production equipment needed was available at The AC Producer could not be confirmed, nor could it be confirmed if they would be interested in the coffee husk biochar due to the need of intense testing before any conclusion could be drawn. Our strong interpretation of the interview was that it is not a viable raw material, but it is still to be fully confirmed and thus a limitation.

6.5 Contribution to theory

Previous research has mostly focused on how both smoke issues and soil degradation can be solved by the production of coffee husk-biochar, as well as the technology needed to achieve this. Our research was rooted in the idea that finding more application areas to the biochar potentially could scale up production, and thereby reduce the costs of producing biochar through economies of scale. From this, we contributed with an understanding of what supply chain factors that are important in the Vietnamese biochar industry and what contextual factors that affect them. While previous research has had the farmer perspective on coffee industry difficulties, we added supply chain perspectives that incorporate more actors in the whole supply chain. Through this outset, we were able to find uncertainties in the supply chain that might hinder the desired expansion of biochar production. We did also point out appropriate supply chain configurations for production of coffee husk-biochar, in order to address the found uncertainties in the current context.

When we evaluated uncertainties and needed responsiveness, we used a theoretical framework by Chopra and Meindl (2013), which aims at finding the right supply chain strategy for a given level of uncertainty. We have not found previous examples of when this framework has been used for a context where a new application area is evaluated. Through this new application of the framework, we understood that it is important to first consider whether the application area is viable in terms of willingness from the involved parties. The viability will otherwise likely be comprehended during the evaluation, but it will not have a natural place in the framework. It got obvious from our unconventional use of the framework, that it assumes that the businesses that are involved in the evaluation already have a business relation even though no such statement is made in the article.

We did also experience that the framework by Chopra and Meindl (2013) gave little guidance in how to weigh the different uncertainties. Our solution to this was to give levels to different categories of demand uncertainties and supply uncertainties where each level had a specific significance. The purpose of this was to offer the reader the structure and transparency we otherwise felt would be lost.

Our research also helped strengthen the theories by Randall et al. (2003), Fisher (1997), Lee (2002) and Chopra and Meindl (2013) by using their supply chain theories in a new setting, and linking them together. It was shown that by following the theories of Chopra and Meindl, Fisher and Lee, our conclusions aligned well with the theories from Randall et al. on how to enter a market with a new supply chain.

6.6 Contribution to practice

The findings we made regarding supply chain uncertainties will increase opportunities of reaching a larger scale of production and thereby reducing the price of coffee husk-biochar, which from our findings seems crucial for its competitiveness. Our conclusions help UNIDO and other stakeholders to decide what type of actors that are most suitable as biochar producers, and how these can be supported in the best way.

The idea for the UNIDO project has been to enable the coffee farmers to use biochar that helps their soils, but, as we investigated another application area, we contributed with ideas of how coffee husk-biochar production needs adaptation for other purposes. Through this investigation, we were able to highlight the need of annual production, and therefore sufficient storing, if supplying biochar to other industries. We were also able to conclude the economical difficulties in having average farmers as producers of biochar as the proposed technology is a heavy investment unless many farmers invest together, along with our suggestion that about 125 average farmers would be needed to utilize its capacity. Higher utilization decreases costs, and since the price of biochar in comparison with chemical fertilizers is one the highlighted hinders of acceptance among farmers, we think this is important.

Finally, since the situation, according to our observations, is similar for other types of farmers, we believe our suggestions can be applicable to some extent also elsewhere in the Vietnamese farming context. This will mainly concern the possibilities of having centralized or decentralized facilities, effectively managing inventory and arranging efficient transports.

6.7 Suggestions for future research

Our study was as stated limited by both the number of interviewees. Future research should therefore firstly focus on addressing these issues by interviewing more farmers about their preferences for this specific purpose, as well as conducting interviews and research among coffee processors. The coffee processors need to be further involved in future research, as they were found to be relevant actors to involve in the biochar supply chain. Such research among the processors should mostly focus on their financial capabilities, how they could make use of the machine and their potential of having an efficient supply chain. Among the farmers, the cultural aspects and their relation to processors is of high interest as the cultural aspects have shown to be an important factor to establish the most efficient supply chain. Additionally, the second activated carbon manufacturer should be contacted and interviewed, as they might have other preferences for the supply chain. The additional interviews and perspectives could either further strengthen our conclusions, or add new perspectives of how the supply chain should be configured during different types of demand and supply.

It is also deemed interesting to further examine uncertainties in the coffee industry from a supply chain perspective. A recommendation would be to look into other variables that also affects the supply chain management, such as information flows and pricing, as these were left out in this thesis. Especially the pricing mechanisms is an area that is recommended to do a thorough analysis of. This study has indirectly made the assumption that the price of the coffee husk will remain constant even if they are opened up to a larger market. This is not necessarily true, since it is possible that the prices both go up and down depending on how the suppliers react to the increased demand. It is for example a possibility that the price increases to that extent that the efficient supply chain savings are eroded by the increased price of the husk, meaning that it cannot sustain a long-term business around it. For this reason, it is highly interesting to firstly conclude more of the price mechanism of coffee husk before making any industrial investments. It would also be of interest to see how other markets would react to the fact that coffee husk is removed from its current use. Since they are currently often used as fuel for drying activities, they would have to be replaced. This could for example increase the price of wood, and in combination with the extra work that would be required, selling coffee husk might not be a sustainable option for the farmers or other actors who actively are using it. We therefore recommend looking further into this research area.

Lastly, a great advantage of the PPV300 has shown to be its abilities to reduce smoke that mitigates health problems. This saves the society costs, both in terms of healthcare but also in terms of higher labour efficiency due to improved health. These are savings that are not yet covered by the society, and since they are savings in the long term and difficult to allocate to the buyer of the PPV300, we have assumed that the buyer will not allocate these savings to the biochar price. To conduct further research of how the societal savings could improve the viability of the biochar is therefore of high interest. If this is possible, it would open up for a more competitive price for the biochar, which in turn would open up for different kinds of supply chains to arise.

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Appendix

Appendix A - Interview guide

The interview guide was built around the subunits and the possible supply chain configurations presented in section 4.1.

Viet Hien	
Facilities	Is a separate part of the facility needed for use of the machine? If so, why?
	What is your estimation on the area needed for usage of the machine?
	If you were to expand your business, would you prefer expanding it here or rather spread it out? How so?
Inventory	How long are you able to store the husk before they get bad?
	What challenges are there with the storing of husk?
	How long are you able to store the biochar before it gets bad?
	What challenges are there with the storing of biochar?
	How much biochar do you normally have in storage?
	What need do you see for a safety stock?
	What are the space requirements for storing husk?
	What are the space requirements for storing biochar?
Transport	What challenges do you see in distributing your biochar to your customers?
	How reliable is transport, and how does it affect your operations?
	Do you send biochar directly to your customers or do you use some kind of intermediary?
	Why do you use this type of configuration?
	Does the infrastructure in the area affect you, and if so, how?
Production uncertainty	How does your biochar output vary during the year?
	What issues have you had with the machine?
	What would you say is the root cause for these issues?
	Can the machine work with any type of coffee husk, or does it need to be fresh, dry or other specifications?
	Could different coffee husk give different biochar in terms

	of specification?
	What is your estimation on the area needed for usage of the machine?
Machine questions	What are your plans for design changes on the machine?
	Have there been any changes to the design the last year?
	Could other actors serve the machine?
	How are your service possibilities dependent on your customer's location?
Intermediary: Husk Ventures	
Facilities	Is a separate part of the facility needed for use of the machine? If so, why?
	What is your estimation on the area needed for usage of the machine?
	If you were to expand your business, would you prefer expanding it here or rather spread it out? How so?
Inventory	How long are you able to store the husk before they get bad?
	What challenges are there with the storing of husk?
	How long are you able to store the biochar before it gets bad?
	What challenges are there with the storing of biochar?
	How much biochar do you normally have in storage?
	What need do you see for a safety stock?
	What are the space requirements for storing husk?
	What are the space requirements for storing biochar?
Transport	What challenges do you see in distributing your biochar to your customers?
	How reliable is transport, and how does it affect your operations?
	Do you send biochar directly to your customers or do you use some kind of intermediary?
	Why do you use this type of configuration?
Production uncertainties	How does your biochar output vary during the year?
	What issues have you had with the machine?
	What would you say is the root cause for these issues?
	What additional service/maintenance would you wish for?
	Does the quality of the input material affect the output in any way?
	Can the machine vary the output amount, and if so, is it

	an economically/technologically viable option?
	Is 42,5 kg per hour for your output correct and how does this output vary?
Activated Carbon Producers - Demand uncertainty	
Introduction and about the company:	Can you tell us a bit about your company, number of employees, etc?
	What specific customer segment do you target?
	Do you sell your products directly to the final consumer or to another manufacturer (B2C or B2B)?
	Do you buy raw materials such as coconut shells, coffee husk or such, or rather biochar (processed waste)?
Order characteristics	Do you prefer the biochar to have a certain % of moisture when buying it?
	How often do you place emergency orders to your suppliers?
	How does your production vary during the year?
	How does your customer orders vary during the year?
	Have you chosen a more multiple or single sourcing strategy?
Demand patterns	How big are your order sizes to your suppliers?
	How does your supplier orders vary over the year?
	Does the infrastructure (such as roads) affect your operation in any way, and if so, how?
Service level	What are your expectations on delivery in terms of lead time from point of order?
	How is the biochar, or other type of raw material, delivered today?
	Do you have any other requirements on the products you buy (such as size, shape, porosity, carbon content, etc)?
	What are your requirements on the raw material quality, i.e. what are your acceptance levels of errors etc?
	How do you control that this is fulfilled?
	What are your expectations on suppliers in terms of available stock?
Additional questions	Do you have any other thoughts on uncertainties related to activated carbon/biochar?
Binh Minh cooperative	
Facilities	Is a separate part of the facility needed for use of the machine? If so, why?
	What is your estimation on the area needed for usage of

	the machine?
Inventory	How long will you be able to store coffee husk before they turn bad?
	Are you able to store the biochar or is it used immediately?
Transports	How reliable is the transport from you to the producers?
	How big portion of your total costs relates to transportation [of the coffee beans]?
Supply uncertainty	Does the quality of the coffee husk affect the quality of the biochar in any way?
	Do you use all the husk, or do you only use certain parts of it?
	Is the coffee husk always usable for the machine, or can it become unusable? If so, why or how?
	Can there be a moment when you are able to use the coffee bean but not the husk, or the other way around?
	During harvest, can there be times when no one can run the machine or will it always be up and running?
	Do you have the capacity to run the machine all year around if there was enough material?
	Do you use the machine for other materials than just coffee husk? If so, is this just during harvest season or other times of the year?