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Blockchain Technology in Supply Chain Traceability Systems

Developing a Framework for Evaluating the Applicability

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PREFACE

This thesis project concludes the authors' M.Sc. degree in Industrial Engineering and Management at Lund University. The authors would like to express their gratitude towards ÅF Industry for instigating the idea behind the project, and for providing helpful guidance in their areas of expertise. Another acknowledgement goes out to everyone who participated in the interview studies and contributed with valuable insights from their respective fields, which effectively made the study possible. Finally, the authors would like to thank Sebastian Pashaei at the Department of Engineering Logistics at Lund University, who supervised this project and provided important feedback throughout the entire project.

Abstract

Title Blockchain Technology in Supply Chain Traceability Systems
Developing a Framework for Evaluating the Applicability

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Background The intersection between blockchain technology and supply chain traceability is regarded limitedly in academic research. Nevertheless, the retail industry sees potential in using the technology to improve traceability, and wishes to understand the benefits and limitations of the technology in their context. This study will develop a framework to guide businesses in this assessment.

Purpose The purpose with this thesis is to develop a framework for evaluating the applicability of blockchain technology in supply chain management to improve traceability.

Methodology To fulfil the purpose, a sequential method was designed with three phases: 1) a literature review on existing theory which condenses into a conceptual model, 2) an interview study with experts in the relevant fields to improve and adjust the model, and 3) an interview study with business representatives to validate the model.

Conclusions A framework for evaluating the applicability of blockchain technology to improve supply chain traceability was developed. In the evaluation, businesses first identify the drivers for traceability and how they can be addressed in a gap-analysis. Secondly, key properties of blockchain technology are assessed, and a draft for an application is designed. Lastly, the drafted application is evaluated based on goal fulfilment, data requirements, degree of novelty and complexity of the application, and the inherent technical limitations of blockchains. While the developed framework fulfils its purpose effectively, it is still difficult to see how blockchain technology should be used to effectively improve traceability.

Keywords Blockchain technology, Supply Chain Management, Traceability, Evaluation Framework

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1. INTRODUCTION

This study aims to develop a framework for evaluating the applicability of blockchain technology in supply chain traceability systems. In this chapter, a background to supply chain traceability and blockchain technology is presented, the purpose and focus of the study is specified, and the structure of the report is described.

1.1. BACKGROUND

Ever since the launch of the Bitcoin currency in 2009, *blockchain technology* has been a topic of great interest. In the first few years, many remained skeptical towards this new currency, and Bitcoins struggled to get any significant traction. During 2013 however, the Bitcoin quote rose from 13.96 USD/BTC (Jan 7, 2013) to an astonishing peak of 979.45 USD/BTC (Nov 25, 2013). This adds up to roughly 6900% return for those who held the currency during that year. Since then, the quotation has been highly volatile and it currently stands at near 3000 USD/BTC (Jun 6, 2017), showing no signs of slowing down. So, what is it that makes this currency so special, and how can we harness the technology behind it?

The underlying technology is commonly called blockchain technology (BCT). Proving its usefulness in the Bitcoin application, companies and industries are eager to find other areas of application using BCT. One particular industry showing interest in this is the retail industry, which sees potential in using the technology for improving traceability in supply chains. The following section will provide an introduction to supply chain traceability and blockchain technology.

1.1.1. Supply Chain Traceability

The modern retail market is increasingly globalised, and supply chains from producers to end-consumers are getting longer and more complex. It is not uncommon for a product to be produced in China, packaged in USA and sold in Sweden. This creates many new challenges, for example when products fail to meet regulatory or quality demands. In these instances, it is important not only to find the cause for the product failure, but also to find everyone who were affected by the failure. There are some regulations and legislations to ensure that the traceability reaches an adequate level in these situations. However, these legislations often only require companies to track products one step backwards and one step forwards in the supply chain, leading to cumbersome work to reveal the entire supply chain.

There is also a growing trend of consumers demanding information about the provenance of products. The consumers want to be confident with the authenticity of goods, and seek to be ensured that products are produced with concern to environmental impact and ethical working conditions (Loop, 2016; New, 2010). Consumers and other stakeholders also hold companies accountable for wrongdoings that may occur outside the company's organisation, such as within their suppliers or end-consumers (Parmigiani et al., 2011). This means that companies must oversee the entire supply chain involved in a product, to ensure no misconducts and communicate this transparently to their customers.

These aspects together pressure companies to improve their ability to trace products, all the way from producers to end-consumers. Sophisticated traceability systems become an advantage, as it enables for instance efficient responses to product failures and trustworthy information to all relevant parties.

1.1.2. Blockchain Technology

Blockchain technology is a database structure that was first deployed for handling transactions in the Bitcoin currency. The Bitcoin blockchain works as a public, distributed and decentralised ledger for keeping a permanent record over all historical transactions in the currency (Iansiti and Lakhani, 2017; Loop, 2016). Here follows a simplified description of the original implementation, derived from an analogy made by Nikolai Hampton (Hampton, 2016):

The Bitcoin blockchain can be thought of as a physical book, where each page contains approximately ten minutes of transactions in the Bitcoin currency. Once a page is filled up with new transactions it is time stamped, signed with a unique serial number, and glued into the book. In this analogy, the pages represent blocks and the serial numbers represent the link between the blocks. The serial number is a product of the transactions in that page, and the serial numbers of adjacent pages are locked together through a mathematical function, forming a robust chain of pages. This makes it impossible to alter one of the transactions without altering the serial number of that page and hence ruining the link between that page and the following page.

To alter one transaction in the book, one would need to rip out the page with the transaction and all subsequent pages, fill up these pages with new transactions, create new serial numbers, and glue all the pages back into the book. The users of this book will always consider the book with the most pages to be the true book and since the book keeps growing, with a new page being added every ten minutes, one would need to work faster than the rest of the community combined to successfully rewrite history. The amount of effort needed to complete this task is simply too large for any person to accomplish and therefore the structure is secure.

The result is a system where transactions can be made between individuals without the need of a trusted third party. Everyone can see the complete transaction history which ensures that everyone agrees about all historical events. The completeness of the transaction history also enables the validation of each coin; all coins can be traced back to the moment they were created.

1.2. PROBLEM DEFINITION

Blockchain technology itself has been subject to extensive research lately, but the intersection between blockchain technology and supply chain traceability is still rather unexplored. There are companies who say that they have launched pilot projects of using BCT in supply chain management (Kharif, 2016; Tian, 2016). However, the presented pilot projects are blockchain *based*, and there is a lack of detailed information on the technical implementation in these projects.

Nevertheless, the retail industry sees potential in using this technology for improved traceability. In a recent study on the application of 'Bitcoin data-structures' in supply chain management (English & Nezhadian, 2017) it is stated that "the final determination of the degree to which the data management techniques described […] are practically useful is empirical.". The researchers further claim that while some properties of the Bitcoin implementation might be useful in a SCM context, there are still few existing implementations to back this up. With little research conducted on the subject, it is difficult for the actors in the industry to understand exactly *how* the technology could be used in their specific business situation. To better understand the technology and possibly generate new implementations, the actors in the industry would benefit from an evaluation model, but no such model exists.

The aim of this study will be to determine what inputs and evaluation tools are needed to evaluate the applicability of BCT in supply chain management. The output of the evaluation process should be conclusions on the effectiveness of BCT as a means for improved traceability in a specific business situation. Figure 1 on the next page shows the framework that will be developed in this study.

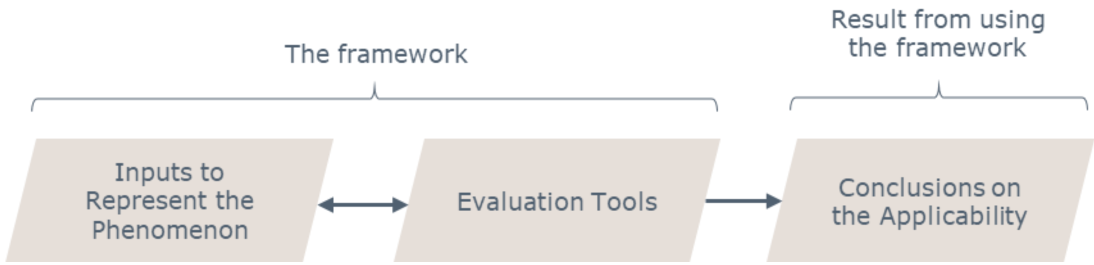

Figure 1. The framework this study aims to develop.

1.3. PURPOSE

The purpose with this thesis is to develop a framework for evaluating the applicability of blockchain technology in supply chain management to improve traceability.

1.4. RESEARCH QUESTIONS

RQ1. What inputs are necessary to evaluate blockchain technology as a means for improved traceability?

RQ2. How can blockchain be used to improve traceability?

1.5. FOCUS AND DELIMITATIONS

- The framework will focus on traceability in the *retail* industry
- The framework will focus on creating *new* blockchain applications rather than using existing applications
- Smart contracts will not be in the focus of this study

1.6. STRUCTURE OF THE REPORT

The report begins with a description of the methodology for this project. A literature review on relevant theory is then presented, which condenses into a conceptual evaluation model in the next chapter. The following chapters describe the results and analysis of the empirical data, gathered from two separate interview studies. The analysis of the empirical data together with the conceptual evaluation model results in the final evaluation framework, which is presented in the next chapter. Conclusions, discussion, and suggestions for further research are presented in the final chapter, followed by references and appendices.

2. METHODOLOGY

This chapter presents the authors' choice of methodology for this project. First, the high-level plan is presented in the research design. Second, the methodology in each phase of the study is presented. The chapter concludes with a discussion on the quality of the study.

2.1. RESEARCH DESIGN

The research design should provide a logical sequence on how the research questions will be answered through empirical data and conclusions (Yin, 2003). This project used a sequential research phase design, shown in Figure 2.

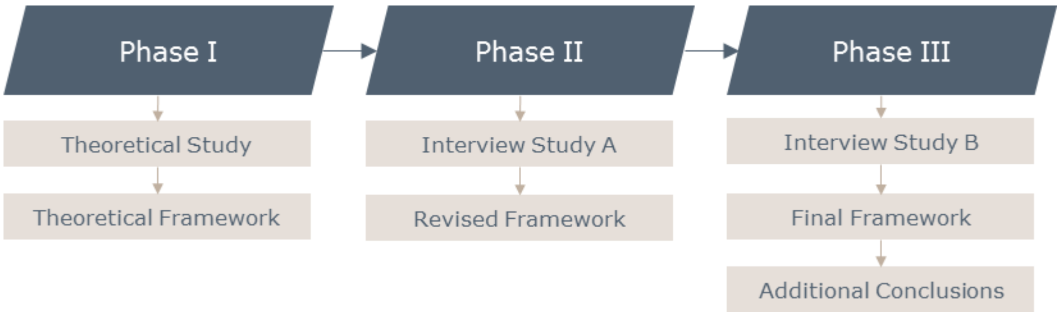

Figure 2. The three sequential phases in the research design of this project

The first phase consisted of building the theoretical frame of reference through a thorough literature review. A condensation of the literature review resulted in a *theoretical framework*. Second, queries regarding the theoretical framework and its effectiveness were formed based on the authors' analysis. These queries were addressed in an interview study with experts in relevant fields, and the results from these interviews formed the foundation for a *revised framework*. The first- and second phase primarily aimed to answer the first research question: *Which inputs are necessary for evaluating blockchain technology as a means for improved traceability?* The third phase tested the revised framework in an interview study with relevant business representatives. As the framework was applied to specific business contexts, the third phase assisted in answering the second research question: *How can blockchain be used to improve traceability?* This phase also tested the framework's effectiveness and enabled minor adjustments in the development of the *final framework*.

2.1.1. Phase I

The first phase aimed to build the theoretical foundation for the study.

Literature Review

A literature review summarises current research on the topic (Rowley and Slack, 2004), and creates an important knowledge base at an initial stage of the project (Höst et al., 2006). A key question when conducting a literature review is how to find relevant literature (Höst et al., 2006). Rowley and Slack (2004) propose four main search strategies for finding literature, shown in Table 1.

Table 1. Four main search strategies (Rowley and Slack, 2004).

Research Strategy	Description
Citation Pearl Growing	Phrases or words within retrieved sources are used to retrieve other sources in new searches
Briefsearch	Sources are retrieved quickly and crudely
Building Blocks	Search terms are combined with synonyms and similar concepts.
Successive Fraction	Searches are made within a large set of sources to eliminate non-relevant sources

Searches in this project were initially made on EBSCOHost for the strings "*blockchain technology*" and "*supply chain traceability*". The two searches resulted in near 800 and 200 hits respectively, but only one hit included both strings. To find relevant sources of information, the citation pearl growing approach was used to develop new strings in the building blocks strategy. Table 2 shows the strings used from this approach, that were used to conduct searches on EBSCOHost and Web of Science.

Table 2. Synonyms or related words used in the building blocks search strategy.

Search term	Synonyms or related words
Blockchain	(Distributed OR decentralised) AND (ledger OR record)
Traceability	Transparency OR ((tracking OR tracing OR provenance) AND (goods OR items))
Evaluation	Assessment OR ((innovation OR adoption) AND (framework OR model))
Definition	Concept OR categorisation OR description

The screening of articles was directed by four principles, based on the recommendation from Rowley and Slack (2004). The sources should preferably: *1) be relevant to the research subject, 2) be up-to-date, 3) hold extensive source referencing,* and *4) be written by an authoritative author*. When searches generated many search hits, the results were ordered based on number of citations of the article, and the first 20 articles were pre-screened based on the abstract. This technique was not used for articles regarding blockchain technology, as the research subject is new and the most relevant articles could be published recently and not yet have been cited. Relevant articles were screened on citations to find other articles that could be useful in the literature review, as a version of the citation pearl growing approach.

With the approach explained above, five sources relevant for blockchain technology and eight sources relevant for supply chain traceability passed screening and were read thoroughly. Table 3 shows an example of three sources in the literature review.

Table 3. Examples of sources in the literature review of this project.

Author(s)	Year	Title	Journal
Iansiti and Lakhani	2017	*The truth about blockchain*	Harvard Business Review
Loop	2016	*Blockchain: the next evolution of supply chains*	Material Handling & Logistics
Lemieux	2016	*Trusting records: Is blockchain technology the new answer?*	Records Management Journal

Theoretical Framework

The second step of the first phase was to condense the literature review to a theoretical framework. Rival framework designs were addressed by the authors, in accordance with what Yin (2003) suggests, to improve the validity of the analysis. The result was a justified, yet unrefined framework for evaluating the applicability of blockchain technology.

2.1.2. Phase II

With phase one being purely theoretical, phase two collected empirical data from an interview study to adjust and improve the theoretical model.

Developing Queries for the Interview Guide

The second phase began with deconstructing the theoretical framework and analysing each part of the framework. The analysis of the framework condensed to several queries on the precision and effectiveness of the framework. The queries formed the foundation for the interview guides, and were then addressed through an interview study with experts in the relevant fields.

Interview Study A

Interviews should be conducted in four phases: Context, initial questions, main questions, and summary (Höst et al., 2006). The first phase should present the interviewee with the context of the interview, which could consist of the purpose and why the interviewee has been selected. Second, some initial, neutral questions should be asked: the interviewees' age, education or assignments. After the initial questions, the main questions should be addressed in an order logical to the interviewee. After the main questions, some quick, neutral questions could be asked to keep interview momentum and politeness. Last, the interview should be summarised to the interviewee, to enable the interviewee appending additional information or clarifying misinterpreted information.

Interview Study Strategy

Interviews can be categorised as: Open-ended, semi-structured, and structured (Höst et al., 2006). *Open-ended interviews* typically discuss themes rather than specific questions (Höst et al., 2006). Such interviews might give valuable insights and lead researchers to information outside the preconception of the scope of the interview. However, there is a risk of the interviewee avoiding subjects that he or she is uncomfortable in discussing (Höst et al., 2006). *Structured interviews* use completely predetermined questions with bound answers. This method is similar to a survey study. A benefit of interviewing instead of using surveys is that the interviewee does not need to fill in answers, and unclear questions can be explained. *Semi-structured interviews* use both predetermined questions with bound answers and open-ended questions with unbound answers. When conducting multiple semi-structured interviews sequentially it is important to ask the questions in the same order to prevent the interviewee being affected by previous answers (Höst et. al, 2006).

The interviews in the second phase of this study aimed to test queries regarding the framework. Completely open-ended interview guides are thus not possible, as addressing the queries require clear questions with bound answers. The interviews with experts still need to be of explorative nature, as the framework will be improved not only by addressing queries, but also by the opinions of the interviewees. A completely structured interview guide risk to forego other information held by the experts, that could help to improve the framework. The authors used semi-structured interviews in the second phase. Specifically, the semi-structured nature of the interviews consisted of an initial set of structured questions addressing queries, followed by broader, open-ended questions regarding the framework and their area of expertise. The interview guides differed slightly between the two expert fields, but both guides included questions such as:

- Open ended questions to allow for suggestions from the experts
- Bounded questions for addressing queries
- Point-based questions where the experts can evaluate the framework, as a form of bounded questions

The point based questions were statements, which the interviewees scored according to:

1. Completely disagree with the statement
2. Partly disagree with the statement
3. Partly agree with the statement
4. Completely agree with the statement

The interviewees were also asked to motivate each scoring.

Selection of Interviewees
Interviewees were selected based on their expertise in either traceability or blockchain technology. The authors networked and connected with professionals in these two business areas, to find persons that both have the knowledge and the time to serve as ‘experts’ in these fields.

The interviewees were professionals working in the industry of traceability system or blockchain technology, which produces a risk of biased expert opinions. An example of this could be if the blockchain-professional has investment in the blockchain industry, and could have personal and professional gain by portraying the applicability of blockchains unrealistically. This risk was mitigated by the semi-structured nature of the interviews. By asking clearly defined questions with bound answers, interviewees were not given the opportunity to avoid inconvenient subjects. In addition, the researchers enquired information about the interviewees background and assignments in the initial phase of the interviewees, enabling the assessment of bias from the experts.

The interview guides for interviewing traceability- and BCT experts are presented in appendices 10.1 and 10.2 on page 81 and 82, respectively.

Analysis and Developing the Revised Framework

In analyses of empirical data, Yin (2003) suggests that a chain of evidence should be presented accompanied with the addressing of rival syntheses, to ensure the validity of the analysis. The analysis was predominantly qualitative, based on the empirical findings from the interviews. The interviewees' score on the point-based questions provided quantitative support for the qualitative analysis. The analysis sought similarities in the interviewees' statements, and consistent criticism led to actionable conclusions. Diverse inputs from the interviewees resulted in actionable conclusions only when the analysis could motivate that they were not in conflict with existing theory or other criticism.

To ensure that the second phase's analysis was performed correctly, the authors sent the interviewees the results and analysis, enabling them to review that no concerns or suggestions have been misinterpreted by the authors.

2.1.3. Phase III

The third and final phase of the research design consisted of an interview study with representatives from the industry. The purpose was to test that the framework is understandable, relevant, and effective as a means of evaluating the applicability of blockchain technology for supply chain transparency. To do this, the revised framework was used as a case study protocol with the interviewees business situation as the unit of analysis. When the framework was used to analyse the business situation, the usability of the framework was assessed by the interviewees.

After the evaluation of the revised framework, the framework was developed to its final form. Lastly in this phase, the practical usability and precision of the final framework was discussed by the researchers, based on the two interview studies in the thesis project.

Interview Study B

The framework was assessed regarding business case usability. Structured questions are needed to use the revised framework as intended to study the business situation. The evaluation of the usability of the framework had predefined questions that were replicated for the different interviewees. The interviews also included open-ended questions, where the interviewees shared their views and opinions on the framework openly. Like interview study A, interview study B held semi-structured interviews, containing both questions with bounded- and open-ended answers. The interviews contained statements, that the interviewees scored and motivated as presented in the previous interview study. The interview guide for this interview study is presented in appendix 10.4 on page 85.

Selecting Interviewees
The interviewees in this interview study were found by using customers to, and the network of ÅF Industry. The interviewees represent a company or organisation with a business situation related to the scope of the framework, i.e. a business in the retail industry. To provide a good basis of evaluation of the framework, the researchers looked for interviewees that hold extensive knowledge in the business' supply chain and traceability system.

Analysis and Developing the Final Framework
With the help of the interview study, the researchers analysed the practical usability of the revised framework. This analysis used the same methodology as the analysis in the second phase of this study, presented on page 10. Like the second phase's analysis, the interviewees of the second interview study were given the chance to review the presentation of the results and analysis, enabling them to identify any misinterpretations by the authors.

2.2. QUALITY OF THE STUDY

Höst et al. (2006) state that quality is a multifaceted concept, and the approach to quality can differ between studies. As a result, mutually exclusive yet collectively exhaustive attributes of quality are difficult to determine. The authors will use three factors proposed by Höst et al. (2006) to assess the quality of this study:

- *Reliability* – i.e. if the study could be conducted again with the same result
- *Validity* – i.e. if the study measures what it aims to measure
- *Generalisability* – i.e. if the results from the study could be used in or be relevant to other research

Reliability
The research area of this study is young, and research is scarce on BCT and its connection with supply chain traceability. An issue that arose was the difficulty in finding a coherent view in academic research on definitions and central concepts of the research subject, particularly regarding BCT. As an example, the authors struggled to find one "true" definition of what the technology is. The definition of BCT is central in a framework to evaluate its applicability. If academic research would come to agree on another definition of BCT, the result of this study could turn out differently. To mitigate the risk of low reliability of this study, the authors

introduced the reader to several definitions of BCT, and presented the reader with an explanation to why *one* definition was selected. The same procedure was made with other concepts and definitions in the report where the authors found inconsistencies in academic research.

Much like the literature review, the interview study also suffered from the novelty of the research subject. With time, more professionals and researchers will be knowledgeable in this research subject. With more knowledgeable interviewees accessible, the interview study could have yielded more rigorous results and possibly come to further conclusions. To address the risk of low reliability in the interview studies, the authors contacted several experts and professionals to screen their knowledge and availability. Multiple interviews were conducted in each interview study to mitigate risk of interviewee bias.

Validity

The study began by examining current research on the research area thoroughly in form of a broad but extensive literature review on the two subjects separately (traceability and BCT). The subjects were studied separately as there was little research conducted on the intersection between the two subjects or the specific topic of this thesis. In the second phase, an interview study with experts were conducted to ensure or improve the precision of the framework that had been condensed from theory. In the third and final phase, the framework was assessed on practical applicability by an interview study with businesses. By reviewing the framework in the second and third phase, the validity of the study is tested during the study process. It is in the authors' opinion that the validity of this study is ensured by the rigorous chain of evidence in the iterative development of the theoretical framework into the final framework.

Generalisability

The result of this study was a framework for businesses to evaluate the applicability of blockchain technology to improve supply chain traceability with a focus on retail supply chains. The study is generalizable by its generic setting and broad focus: 1) It does not focus on a specific business situation, but a generic business situation of the retail industry, 2) the contribution to research is a framework that could be used by any actor in the retail industry, or be the inspiration to further research with another focus. Large parts of the framework concerns BCT generally, enabling researchers to replace other components of the framework to suit further research on the technology in other contexts.

3. Frame of Reference

This chapter outlines the theoretical frame of reference of this thesis project. As the academic research on the phenomenon of BCT and supply chain traceability in combination is scarce, the subjects will be studied and presented separately. In the following chapter, theory on the two subjects will be combined and condensed into a theoretical framework.

3.1. Supply Chain Traceability

A supply chain is a network of manufacturers and service providers that work together to create products or services needed by end users (Bozarth & Handfield, 2006). The actors in a retail supply chain are linked together through the physical flow of products from producers to end consumers.

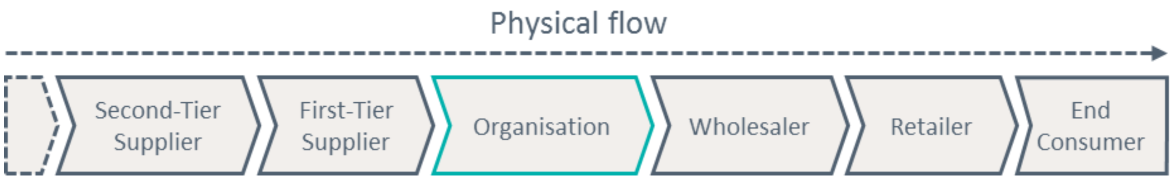

Figure 3: A typical supply chain in the retail industry (adapted from Bozarth & Handfield, 2006).

While the representation in Figure 3 looks simple enough, the true relationships between actors are often complex. Suppliers can be divided into several tiers, where a first-tier supplier provide the organisation *directly* with for example metal cans, and a second-tier supplier in this scenario would be the provider of raw material to produce the metal can (Bozarth & Handfield, 2006). The organisations typically have many suppliers in different tiers involved in a specific product, and the suppliers are commonly non-exclusive to the organisation under consideration. The result is a complex web of interrelated actors, shown in Figure 4.

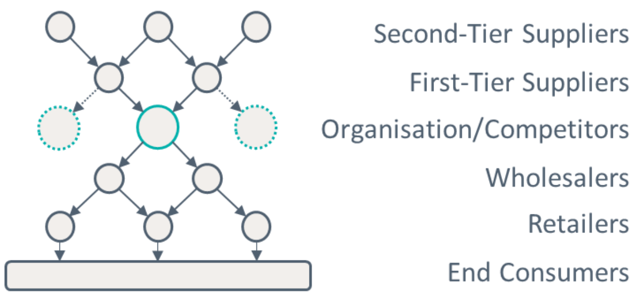

Figure 4: A complex supply chain with many actors.

In trade globalisation, supply chains are becoming increasingly complex, and tracing objects through these complex webs are hard. This section provides theory on supply chain traceability. First, traceability is defined, and central concepts and categorisations of traceability is outlined. Then, the technology of supply chain traceability is described by four defining aspects. Lastly, drivers for supply chain traceability and issues in achieving traceability are presented.

3.1.1. Definition of Supply Chain Traceability

Depending on context, different definitions of traceability exist from organisations, legislations or researchers (Aung and Chang, 2014). In a study on different traceability definitions, Olsen and Borit (2013) conclude that "even in scientific papers there is a lot of confusion and inconsistency" regarding the definition of traceability (p. 149). The researchers' study shows that scientific papers often use the ISO definition of traceability, and the most commonly cited definition from academic sources is the definition from Moe (1998) (Olsen and Borit, 2013). Table 4 shows four different examples of traceability definitions.

Table 4. Definitions of traceability from different sources.

Source	Definition
ISO 9000:2000	"The ability to trace the history, application or location of that which is under consideration"
European Commission (2002, chapter 1, article 3, no. 15)	"The ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution"
GS1 (2012, p. 13)	"Traceability is the ability to track forward the movement through specified stage(s) of the extended supply chain and trace backward the history, application or location of that which is under consideration"
Moe (1998, p. 211)	"Traceability is the ability to track a product batch and its history through the whole, or part, of a production chain from harvest through transport, storage, processing, distribution and sales or internally in one of the steps in the chain for example the production step"

The ISO definition of traceability is generic and inherently broad (Aung and Chang, 2014). This is necessary as it is a tool for achieving different objectives in different cases (Golan et al., 2004). However, traceability theory differs depending on what viewpoint on traceability is selected. In this study, the 2012 GS1 Traceability Standard definition of traceability is chosen as baseline. The primary reasons for this are:

1. It is based on the ISO definition of traceability, set in a supply chain context
2. It mentions not only the ability to *trace*, but also the ability to *track* (see Tracking and Tracing on page 16)
3. The definition is generic within the supply chain realm, while other definitions focus on specific supply chains
4. The GS1 standards are widely used in the industry

The documentation of the 2012 GS1 standard not only defines traceability, but also presents a comprehensive categorisation of important attributes and concepts of traceability. The use of this documentation as a blueprint for the following section is seen by the authors as a possibility to reach a mutually exclusive yet collectively exhaustive presentation of attributes and concepts of traceability. The 2012 GS1 standard will be supported with academic references to improve validity. Furthermore, other attributes and concepts of traceability from academic sources will be used as complements to give a more detailed description of what traceability is.

3.1.2. Central Traceability Concepts

This section outlines central concepts of traceability that the authors see relevant for the theoretical foundation in this report. These concepts are important for the reader to know of, to understand the reasoning and terminology in the following sections. Table 5 lists the concepts that will be presented in this section and their respective sources.

Table 5. Central concepts of traceability.

Concept	**Source(s)**
Tracking and Tracing	Aung and Chang, 2014; Bechini et al., 2008; GS1, 2012
Traceable Resource Unit	Aung and Chang, 2014; GS1, 2012; Moe, 1998
Internal, External and Chain Traceability	Bechini et al., 2008; Kalogianni et al., 2012; GS1, 2012; Moe, 1998
Breadth, Depth and Precision of Traceability	Golan et al., 2004; GS1, 2012
Master and Transactional Traceability Data	GS1, 2012
Private and Public Traceability Data	GS1, 2012
Centralised and Decentralised Data Model	Bechini et al., 2008

Tracking and tracing

Traceability can be split into the ability to *track* and the ability to *trace* (Aung and Chang, 2014; Bechini et al., 2008). Tracking, or *forward* traceability, is the procedure of revealing the whereabouts of an item from a given criteria. Tracing, or *backward* traceability, is the procedure of uncovering an items origin or characteristics from a given criteria (Aung and Chang, 2014; Bechini et al., 2008). The ability to track enables efficient recalling of non-compliant items, while tracing is necessary for finding the cause of non-compliance (Bechini et al., 2008). It is important for a traceability system to be able to both track and trace, as effective tracing does not imply effective tracking, and vice versa (Aung and Chang, 2014).

Traceable Resource Unit

The traceable resource unit (TRU) is a unit with a unique identifier that can be tracked or traced in a supply chain (Moe, 1998). What the TRU *is* differ depending on industry and product, and can have different attributes in different steps of the supply chain. At the highest level, the TRU could be a container ship. On a granular level, the TRU is the object that cross the Point-of-Sales (PoS) to the consumer. TRUs can be divided into the following types: (Aung and Chang, 2014; GS1, 2012)

- *Batch unit,* a set of items that has undergone the same processes
- *Trade unit*, the unit that is transacted between two parties in a supply chain
- *Logistics unit*, a logistic grouping of objects (e.g. a pallet or container)

Inherently, a batch unit could be a trade unit, a logistic unit could consist of other logistic units, et cetera. GS1 (2012) adds that any item other than the three types above can be a TRU if the traceability partners agree to consider it a traceable item. A traceable trade unit can either cross PoS to the consumer (e.g. a consumer unit), or not cross the PoS (e.g. a package of several consumer units).

Internal, External and Chain Traceability

Traceability can be categorised into two parts: *Internal* traceability (GS1, 2012; Moe, 1998), and e*xternal* traceability (GS1, 2012). A supply chain entity generates internal traceability when traceable input objects are processed to traceable output objects (GS1, 2012). External traceability is achieved when a transaction of a traceable object takes place between two entities. Full traceability, or *chain* traceability, is achieved when the entire supply chain of an object exchange information and provide internal and external traceability (Bechini et al., 2008; GS1, 2012; Kalogianni et al., 2012; Moe, 1998).

Breadth, Depth and Precision of a Traceability System

Traceability systems vary in breadth, depth, and precision (Golan et al., 2004). The *breadth* is the amount of information that is collected throughout the system. The information collected consists of anything measurable, such as weight, dimensions or colour of the TRU, or any information about the traceable event. The breadth of a system can vary in various parts of the chain, as an item can append new attributes or lose old attributes along the chain. System *depth* is a measure of how far back the system keeps track of an items attributes. System breadth often creates preconditions for system depth. For instance, the system depth of the attribute "decaffeinated" in coffee reaches only to the process of decaffeination; the attribute does not exist before this process. The *precision* of a system is the degree to which the system can identify a specific TRU (Golan et al., 2004). GS1 (2012) differentiates between precision, and *level in the logistical hierarchy*. GS1 defines precision as the ability to *uniquely* identify an object, while the level in the logistical hierarchy refers to the *granularity* of the object under consideration (i.e. single unit, batch unit, shipment unit etc.). With this distinction, a large shipment can have high precision and low granularity but not vice versa.

System breadth, depth, and precision are inherently linked. Surging any parameter increases the amount of information recorded in the system, and according to Golan et al. (2004) the extensiveness of the system must be evaluated based on efficiency. Keeping records of excessive breadth, depth, and precision is costly, and it should only be considered if it generates economic or performance yield. Instead, the system's extensiveness should be based on the objective of the traceability system (Golan et al., 2004).

Traceability Data

Traceability data can be categorised into *master* data and *transactional* data (GS1, 2012). Master data is consistent over time, and contains general information regarding the TRU. This includes practical information such as party names, addresses, contact information, and general attributes of the TRU such as dimensions, weight, model number, and product specification (GS1, 2012). Transactional data is generated by processes and events and include variable information such as process- or event information, shipment information, time stamps, and logistics unit information. (GS1, 2012)

Traceability data can also be either *private* or *public*. In this context, public data refers to the data that is shared among all parties in the traceability system. Private traceability data is stored only at one or some of the parties. Private data usually consist of more detailed information such as origin of raw materials, object quality, or results from object analysis. (GS1, 2012)

Centralised (Push) and Decentralised (Pull) Model
A centralised data model, or push model, requires all data in a traceability information system to be transferred (pushed) and stored at a single, central location (Bechini et al., 2008). In a decentralised data model, or pull model, data is stored with a distributed architecture. Typically, a decentralised model includes a trusted third party, that acts as an intermediary in the information system (Bechini et al., 2008). A decentralised model allows entities in the traceability system to hold data of different structures. Interoperability is only required in the event of interactions between decentralised data.

3.1.3. Key Principles of a Traceability System

Having central traceability concepts defined, this section outlines the key principles of a traceability *system* - a system of entities upholding or aiming for supply chain traceability. Olsen and Borit (2013) have found a general agreement on what properties a *food* traceability system should have. GS1 (2012) have similarly defined four key traceability principles in their standards document for *retail* supply chains. Table 6 presents the propositions from the two sources in comparison.

Table 6. Two views on the key properties of a traceability system.

Olsen and Borit (2013)	**GS1 (2012)**
A traceability system should be able to: 1. Group units as TRUs 2. Assign identities or keys to the TRUs 3. Record processes linked to identities or keys of TRUs 4. Hold a mechanism to access the records	"Key traceability principles are: 1. Uniquely identify traceable items 2. Capture and record traceability data 3. Share traceability data between traceability partners 4. Link inputs through changes or processing to outputs" (p. 37)

The two sources propose similar definitions of traceability or a traceability system. The authors find it useful to separate *capturing data* and *linking data*, hence, the GS1 standard will be used as the categorisation of this section. Here follows an elaboration on the four principles of traceability presented by GS1.

Unit Identifying
To successfully distinguish one TRU from another there must be some way to differentiate them. This can be done either by appending information to the TRU or by examining the existing attributes of the TRU. Three examples of identifying

technologies are serial number identification, DNA identifying, and detailed records.

Serial number identification is used to identify a wide range of TRUs. GS1 has created several standards for uniquely identifying objects of different precision and granularity, that Bechini et al. (2008) claim to be the world's most robust identification system. This system contains standards such as GTIN (Global Trade Item Number), SSCC (Serial Shipper Container Code), and GSIN (Global Shipment Identification Number). GTIN is used to give items, packages, and services identification numbers at a granular level. SSCC is a standard for identifying larger logistics units, often containing many smaller TRUs. GSIN is used to identify a group of logistics units which are part of the same shipment. The serial number can be attached to the physical object in numerous ways, such as a barcode (e.g. EAN), QR-code, or an RFID tag. (GS1, 2017)

Another means of unit identifying is *DNA identifying*. This technique identifies a unit uniquely from others with DNA-tests. The tests can be performed throughout the chain to capture and record data. DNA-testing is expensive (Aung and Chang, 2014) and although DNA is arguably persistent over time, processing of units with a unique DNA can sometimes damage the DNA (Aung and Chang, 2014). Thus, the technology has limitations regarding both linking data (see Linking Input- to Output Data on page 21) and the economic viability.

Detailed records are based on keeping a detailed description that uniquely identifies a unit. This requires that the unit has dimensions that can be documented with significant detail, that no other unit of this type have the same set of dimensions, and that the dimensions are persistent over time. For instance, the four quality factors of a diamond (i.e. colour, clarity, cut, and carat weight (GIA, 2017)) could be described in detail and kept in a record. As no other diamonds are likely to have the *exact* same dimensions, and as the dimensions are *practically* unalterable, one can claim with high degree of certainty that a specific diamond corresponds to a specific registry of a diamond in a ledger.

Data Capturing

When an object has undergone a process, there must be some way to link the process to the specified object, i.e. capture the relevant data. When the identity of a TRU is labelled with a visual code such as a barcode or QR-code it can be *scanned* by hand-held scanners or automated scanners at each traceable event in the supply chain (Aung and Chang, 2014). Using this technology, traceability data gets stored in the internal systems which creates a need for data sharing technologies, if the data is intended to be shared.

Instead of scanning an object and capturing the relevant data in a company's internal system, the data can instead be *appended* to the object. This is often done in the food industry, where processes are time stamped on the object, which makes it easy to determine the best-before date of a product. The appended information is not necessarily a time stamp but could be for example a delivery note or a sticker, signalling that the object has undergone a specific process.

Wireless Sensor Networks (WSN) can be used to capture information wirelessly. A WSN is typically used in combination with RFID-technology. This technology can improve efficiency in a supply chain by reducing manual labour. RFID-tags also introduce the possibility to not only scan data from, but also append new data to the TRU. Drawbacks with RFID-technology is that it is expensive, and that the readability of RFID-tags can be reduced by metals, glass, and liquids. (Aung and Chang, 2014)

Data Sharing

Once a TRU has been scanned and relevant information has been captured, the information must be stored somewhere. A data sharing technology could be any application or sets of applications that enables traceability data to be stored and shared between the system parties. In cases of multiple traceability applications, using global standards for interoperability is necessary to successfully achieve chain traceability (Aung and Chang, 2014). Some information might get stored on private servers while other information is shared among one or more parties in the traceability system. GS1 has developed several standards for traceability data sharing technology, two of them are GDSN and EPCIS.

The GS1 Global Data Synchronisation Network (GDSN) uses a network of interoperable data pools enabling collaborating users to securely synchronise master data based on the GS1 standards (GS1, 2017b). The technology is particularly useful for sharing the latest information about a TRU's master data across a supply chain, for example all the raw materials used in a product. This way, the latest information about a product can be delivered with confidence by a retailer to the consumer. It also helps all parties in the supply chain to anticipate and adapt to changes in the physical dimensions of a TRU.

Electronic Product Code Information Services (EPCIS) is a standard developed to enable parties to share information about the physical movement and status of products as they travel throughout the supply chain (GS1, 2017c). Using this standard, all transactional events in the supply chain should be recorded with information regarding *what*, *where*, *who* and *why* an event took place. This standard is aimed at creating a shared view of where a product has been and at which times. It can also be used to fetch real time data of a TRU's location, enabling the anticipation of arrival times.

Linking Input- to Output Data

When a product is processed by a company in the supply chain, the input TRU(s) might not be the same as the output TRU(s). The three previous aspects are generally related to *external* traceability while this aspect relates more to the *internal* traceability. To preserve the traceability of an object through such a process within a company, the details of the process must be described and recorded (GS1, 2012). A sample of internal processes are shown in Table 7. Examples of internal processes (GS1, 2012).Table 7.

Table 7. Examples of internal processes (GS1, 2012).

Internal Process	Example
Many to One	Raw materials are combined into a finished product
One to Many	A batch of a product stored in bulk is packed into cases
One to One	Raw material is transformed from fresh to frozen
One to None	Material is destroyed

By identifying and describing the internal processes, the companies can maintain their internal traceability and provide the rest of the supply chain with adequate information for the external- and chain traceability. Linking input- to output data is not *only* relevant in the internal traceability but can also involve connecting and aligning data between parties of a traceability system.

3.1.4. Drivers for Supply Chain Traceability

Aung and Chang (2014) and Golan (2004) present three main objectives for traceability: 1) better supply chain management, 2) product differentiation and quality assurance, and 3) better identification of non-compliant products. Besides these three objectives, an additional driver for developing traceability is to comply with regulatory and standards requirements.

Better Supply Chain Management

Supply chain management drivers for traceability are the possibilities of cost reductions or supply chain efficiency (Aung and Chang, 2014; Golan et al., 2004). A traceability system can be used to monitor and improve quality of raw materials to reduce costs. The system can support inventory management which, besides cost reduction, ultimately could lead to product differentiation through shorter lead times. According to Aung and Chang (2014), traceability capabilities may also provide efficiency or cost reduction of labour through targeted recall systems. The researchers also mention improved chain communication, improved supply chain transparency and interoperability, and improved supply chain safety as drivers for better supply chain management.

Product Quality Assurance
Traceability can be used to ensure product quality, especially when specific quality attributes of a product are subtle or hard to verify (Aung and Chang, 2014; Golan et al., 2004)). Such quality attributes might be that a product originates from a specific region (e.g. Parmesan cheese from Modena), or is produced by a special brand (e.g. a Rolex watch). In trade globalisation, when the product is not purchased directly from its provenance source, such features become an issue to verify (Golan et al., 2004). Traceability help to mitigate those issues, with detailed information about the product's path through the supply chain.

Better Identification and Traceability of Non-Compliant Products
A driver for traceability is the ability to trace and track goods at any stage of the supply chain when quality or safety standards are not met (Aung and Chang, 2014). Besides the prevention of providing customers with hazardous or defective products through effective recalls, the ability to trace non-compliant products in the supply chain also enables efficient identification of the underlying cause of the non-compliance.

Standards and Regulations Driving Traceability
Standards are norms or requirements that pose no legal sanctions in cases of non-compliance (Marucheck et al., 2011). Standards can be related to certifications issued by standards organisations as the International Organisation for Standardization (ISO). Other examples of standards organisations are the Swedish Standards Institute (SIS), Fairtrade International (issuer of Fairtrade certificates), and GS1. Regulations institute governmental agencies that overlook basic rules and responsibilities (Marucheck et al., 2011). Such agencies often have authority to issue sanctions or fines in cases of non-compliance (Marucheck et al., 2011). An example of a regulating agency is Livsmedelsverket in Sweden.

3.1.5. Issues with Achieving Supply Chain Traceability

Arguably, the main issue with improving traceability is that the perceived or economic benefits of traceability must outweigh the costs of the system. Golan et al. (2004) explains that organisations are only interested in improving traceability if it can add value to the customer or reduce costs for the organisation. Traceability efforts will *decrease* profits if the information gathered from the traceability system fails to reduce costs, or fails to communicate added value to the consumer. According to Saak (2016), an implication of this is that mandatory traceability might decrease social welfare, and explains: "This happens if the downstream firm can build a reputation for high quality in the no-traceability regime but not in the traceability regime, or if the downstream firm prefers to exit the market for high quality because of the negative effects of traceability on profits" (Saak, 2016, p. 157). Aung and Chang (2014) provide other examples of issues related to traceability:

- *Standardised formats* - there is a lack of standardised formats between entities in the supply chain, especially between countries with different regulations
- *Trustworthy information* – paper is still used as a cheaper alternative to digitalised and more trustworthy databases
- *Traceability of bulk produce* - challenging to trace through internal processes
- *Organisational hurdles* – transparency and confidentiality of information must be balanced between traceability parties
- *Technological hurdles* – not all traceability parties have the required soft- or hardware for internal traceability, and software integration and interoperability between parties is often limited

Aung and Chang (2014) state that the technological hurdle and the manual exchange of information between parties are two of the main challenges of traceability. In line with this, Berman (2010) explains: "China has more than 300 million farmers working 1-2 acre plots. These small farmers typically take their food products to wholesale markets, get paid in cash for their wares, and do not exchange documentation with buyers" (p. 46).

3.2. BLOCKCHAIN TECHNOLOGY

The concept of blockchain technology was introduced in October 2008 as part of the proposed Bitcoin currency by an unidentified programmer under the pseudonym Satoshi Nakamoto (Iansiti and Lakhani, 2017; Lemieux, 2016). Bitcoin is the first implementation of blockchain technology (Iansiti and Lakhani, 2017; Yli-Huumo et al., 2016), but the technology can be applied to many other uses (Yli-Huumo et al., 2017). This section will start by defining what blockchain technology is, then present two evaluation tools developed for evaluating the suitability and applicability of blockchain technology, and finally discuss issues and limitations of the technology.

3.2.1. Defining Blockchain Technology

The technical specification of the Bitcoin blockchain is arguably the original definition of blockchain technology. Researchers however provide broader definitions of the technology. Lemieux (2016) summarises blockchain technology as:

> *"… a distributed transaction database in which different computers – called nodes – cooperate as a system to store sequences of bits that are encrypted as a single unit or block and then chained together"* (p. 118).

Tian (2016, p. 3) states that "the essence of blockchain is a technical scheme of a reliable database which is collectively maintained by the way of decentralised and trustless methods". Yli-Huumo et al. (2016, p. 2) declare that "The goal of Blockchain technology is to create a decentralised environment where no third party is in control of the transactions and data". The definitions vary in detail and the authors struggle to find one "true" definition of what the technology is. Table 8 shows four categorisations and specifications of blockchain technology found during the literature review.

Table 8. Blockchain technology summarised by different sources.

Nakamoto (2008)	• Peer-to-peer network • Chronological order of transactions determined by proof-of-work[1] • Blocks contain transactions of coins, a timestamp, and a hash of the previous block • Private-public key pairs are used to digitally sign transactions while maintaining privacy
Iansiti and Lakhani (2017, p. 125)	• Distributed database • Peer-to-peer transmission • Transparency with pseudonymity • Irreversibility of records • Computational logic
(Loop, 2016)[2]	• Concatenated blocks of transactions • Shared digital ledger across a network of computers • Transactions without intermediaries • No single party has the power to tamper with the record
(Tian, 2016)	• Reliable database, collectively maintained by decentralised and trustless methods • Blocks are created with cryptography and contains data of all transactions in the system within a period of time • Blocks are linked together in chronological order, with every block containing a hash of the previous block

The definitions described in Table 8 are all similar but they differ in some respects. Nakamoto describes proof-of-work as a core mechanism in his proposed solution, while the other researchers are content with the fact that the consensus must be distributed in a P2P network in a BCT application. Tian (2016) and Loop (2016) claim that the blocks should contain *transactions* while Iansiti and Lakhani's definition allow for other types of information to be stored on the blockchain. Researchers clearly have different opinions on how strict the term blockchain technology is. Some believe that the structure of the database must resemble the Bitcoin implementation while others believe that only a few of the core concepts of the Bitcoin implementation need to be fulfilled for it to be considered a blockchain.

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[1] Proof-of-work is a technology used in the Bitcoin blockchain to enable majority decision-making. When a new block is appended to the chain, the system will always consider the chain with the most proof-of-work to be true (Nakamoto, 2008).

[2] Originally a citation by Hackett, Robert. *Fortune*. 2016-01-06, Vol. 173, Issue 7, p. 18

As BCT was originally described by Nakamoto in 2008, it could be argued that his whitepaper would provide the best definition for the technology. There are however two problems that arise with this choice. First, the unknown identity (or identities) of Nakamoto renders issues in determining the credibility of the contents of the original whitepaper. Second, if the original implementation was used as the definition of BCT in a strict sense, all other implementations of the technology would essentially be mere replications of the Bitcoin implementation. Other definitions, as the five basic principles of BCT proposed by Iansiti and Lakhani (2017), can define blockchain in a wider sense than the original implementation. The authors believe that different business problems call for different technological solutions in a BCT application. By using a broader definition, specific technologies or features in the Bitcoin blockchain can be altered to serve different purposes, resulting in diverse types of BCT applications.

In this study, the five basic principles of BCT suggested by Iansiti and Lakhani (2017, p. 125) will be used as the baseline for defining the key characteristics of BCT. Additional information and technological description will be provided from other peer-reviewed articles, as well as from the whitepaper of Nakamoto.

3.2.2. Defining Characteristics of Blockchain Technology

This section outlines five defining characteristics of blockchain technology, based on the five basic principles of BCT proposed by Iansiti and Lakhani (2017).

Principle 1: Distributed Database
BCT is a distributed database (Iansiti and Lakhani, 2017; Loop, 2016; Lemieux, 2016; Yli-Huumo et al., 2016). The database is distributed among nodes, that some researchers state to be computers (Lemieux, 2016), while other authors refer to them in more general terms, as *parties* of a system (Iansiti and Lakhani, 2017). The entire database is accessible for all nodes in the BCT system, although no single node has control of the data stored on the blockchain. New registry entries (e.g. transactions) on the blockchain are verified directly by the nodes in the system, with no need for any intermediaries (Iansiti and Lakhani, 2017; Yli-Huumo et al., 2016).

Principle 2: Peer-to-Peer Transmission
Instead of using a central platform for communicating between parties, individual nodes store and forward information directly to each other in a peer-to-peer network (Iansiti and Lakhani, 2017; Yli-Huumo et al., 2016; Nakamoto, 2008). The blockchain is stored by all nodes in the BTS, and all nodes forward information to all other nodes (Iansiti and Lakhani, 2017). Other authors claim that the entire blockchain is not necessarily stored by all nodes, but should be available for all

nodes (Yli-Huumo et al., 2016; Nakamoto, 2008). Nakamoto (2008, p. 4) also states that all new transactions do not need to reach *all* nodes, but rather “sufficiently many” nodes, which will be enough for the transaction to be incorporated into a block over time.

Principle 3: Transparency with Pseudonymity

Transparency in the blockchain technology system is achieved by all nodes being able to see every transaction in the system (Iansiti and Lakhani, 2017; Yli-Huumo et al., 2016). Yli-Huumo et al. (2016) state that the system is more transparent than a centralised system, where transactions are administered by a trusted third party.

Several sources declare that the BTS is anonymous (Yli-Huumo et al., 2016; Tian, 2016), as did Nakamoto in the whitepaper. Iansiti and Lakhani (2017) state that the system is pseudonymous. In contrast to cash, where transactions can be made *completely* anonymous, the transactions in Bitcoin are always tied to an account. Pseudonymity is achieved as each user has a unique address for their identification, and transactions occur between addresses (Iansiti and Lakhani, 2017). Users will remain anonymous through their pseudonymous address, and do not need to disclose their true identities in the BTS.

Principle 4: Irreversibility of Records

The BTS uses computational algorithms and approaches to provide irreversibility of the records stored on the blockchain (Iansiti and Lakhani, 2017). However, in the whitepaper from 2008, Nakamoto claims that records are “computationally impractical to reverse”, rather than impossible (p. 1). The term “chain” derives from all new records being linked to previous records in a chronological order on the chain (Iansiti and Lakhani, 2017). The entire chain of blocks stores all transactions ever recorded in the blockchain. It is impossible to alter the information in an old block without breaking the chain and thus it will become apparent for all nodes if the data has been tampered with.

Principle 5: Computational Logic

As a BTS is of digital nature, computational logic can be tied to transactions on the blockchain (Iansiti and Lakhani, 2017). Nodes can use programmed algorithms or rules for automatic triggering of transactions (Iansiti and Lakhani, 2017). The BTS can be programmed to handle any type of information, be it transactions, contracts, or any type of information that the business problem calls for.

3.2.3. BCT Adoption Tool

This section describes a tool for how the adoption of blockchain technology can be evaluated. BCT is a foundational technology as it has the potential to create new foundations for economic and social infrastructure (Iansiti and Lakhani, 2017). There will likely not be a blockchain revolution, but the adoption will rather be gradual and steady. To help companies understand what challenges blockchain innovations may present, Iansiti and Lakhani (2017) propose a tool for blockchain adoption. The researchers claim that the tool can be used in any industry.

The tool is based on how the adoption of technologies naturally depend on the degree of novelty in the technology, and the amount of complexity and coordination required for implementing it. Regarding this, technologies are typically adopted in four phases: Single use, localisation, substitution, transformation. Figure 5 shows an overview of the four phases, depending on the two dimensions.

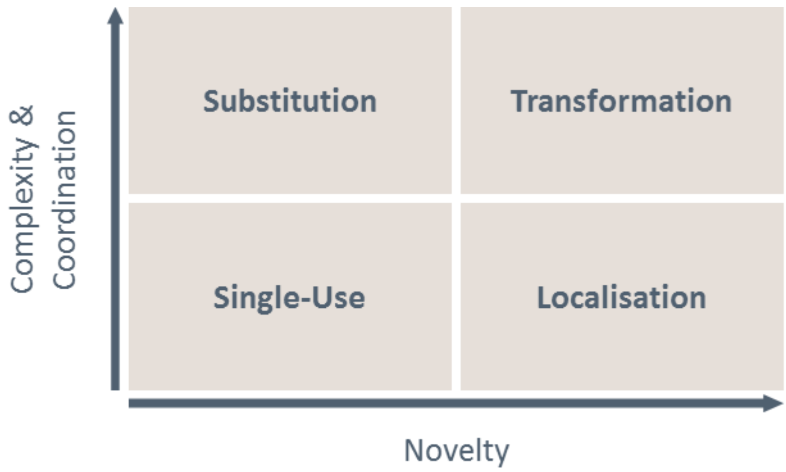


Figure 5. Four types of technology adoption (adapted from Iansiti and Lakhani, 2017, p. 123).

Single-Use

With low degree of novelty and lack of complexity, single-use technology applications should create applications "better, less costly, highly focused solutions" (Iansiti and Lakhani, 2017, p. 124).

Iansiti and Lakhani (2017) believe that single-use applications are most suitable for initial blockchain technology adoptions, with minimal risk exposure and low need of coordination with other parties. Organisations may approach blockchain technology in form of an internal database that keeps record of assets, transactions, or identities. Such implementation of the technology would be of interest for organisations struggling with multiple internal databases, according to the researchers (Iansiti and Lakhani, 2017).

Localisation

Localised technologies are novel without the need of coordination for immediate value. Iansiti and Lakhani (2017) state that localised applications are easy to promote because of this. Localised solutions would be the next step for organisations after single-use applications, according to Iansiti and Lakhani (2017). Localised blockchain solutions, involving a single or a few number of trusted counterparties, can be developed for simplifying transactions. Organisations might also solve specific transaction problems with localised applications, such as using blockchain to track items through complex supply chains (Iansiti and Lakhani, 2017). The researchers claim that such experimental applications of blockchain technology are already being used.

Substitution

Substitutive technology applications aim to replace ways of doing business, and typically face higher barriers of adoption (Iansiti and Lakhani, 2017). The applications often build upon single-use or localised technologies that are already implemented, but require higher level of coordination. Substitutive technology applications may replace current, deeply embedded processes or applications in an organisation.

Iansiti and Lakhani (2017) state that substituting existing applications require planning. Substitution might demand users to change behaviours, and substitutive technology adoptions that are easy for the users to understand and adopt will likely get more traction. The researchers elaborate that being unable to communicate similar or better functionality of the new application prevents substitutive technology adoption.

Transformation

Transformative technology applications have high degree of novelty while requiring high degree of coordination. Typically, technology transformation requires social, legal and political changes (Iansiti and Lakhani, 2017). If the technology adoption is successful, Iansiti and Lakhani (2017) state that it can change the very nature of economic, social, and political systems. The researchers mention smart contracts as a possible transformative technology enabled by BCT. Iansiti and Lakhani (2017) explain that "a tremendous degree of coordination and clarity on how smart contracts are designed, verified, implemented, and enforced will be required" (p. 126).

Iansiti and Lakhani (2017) believe that transformative applications of blockchain technology are still far away (p. 126). However, evaluating the technology now is reasonable, as investments can be made in developing the foundational technology that enables future transformation.

3.2.4. BCT's Technical Limitations

This chapter presents some technical limitations that might spring from blockchain technology. Yli-Huumo et al. (2016) state that BCT face technical challenges within: throughput; latency; size and bandwidth; security; wasted resources; usability; versioning, hard forks, and multiple chains; and privacy. The technical challenges pose limitations to blockchain technology, although specific implementations and applications of the technology might overcome some limitations. The technical challenges listed by Yli-Huumo et al. are heavily based on the Bitcoin implementation, although the authors claim that they concern the adoption of Blockchain technology generally. Here, the challenges are presented in more detail:

- *Throughput* – the current Bitcoin network has only a capacity of seven transactions per second, while in comparison, VISA can provide 2000 transactions per second.
- *Latency* – a Bitcoin transaction takes roughly 10 minutes to complete, as this is the time it takes for a block to be created.
- *Size and bandwidth* – the size of the entire Bitcoin blockchain is over 100 GB (February 2017). Each block is approximately 1 MB of size, and the creation of a new block every 10 minutes imposes a limitation of transaction capacity with the current bandwidth.
- *Security* – the Bitcoin blockchain can be subject to a 51 % attack, malleability problems and authenticity or cryptography issues.
- *Wasted resources* – proof-of-work mining "wastes" huge amounts of energy each day, with the sole purpose of maintaining consensus in the database.
- *Usability* – the Bitcoin application programming interface is not developer-friendly, and difficult to use.
- *Versioning, hard forks and multiple chains* – Different nodes might run on different versions of the source code which might cause problems. A hard fork occurs when the community decides to revert the transaction history to some date in the past, for example to suppress a fraudulent transaction.
- *Privacy* – the anonymous nature of the Blockchain could be undermined. Experimental evidence shows the possibility of linking Bitcoin Blockchain addresses to IP-addresses through analysing transactions and meta-data.

Security is one of the major research topics of the limitations mentioned above (Yli-Huumo et al., 2016). Not much research is conducted on the challenges of latency; size and bandwidth; throughput; versioning, hard forks and multiple chains (Yli-Huumo et al., 2016).

3.2.5. BCT's Data Requirements

Apart from the technical limitations presented in the previous section, blockchain technology has practical issues that are presented in this section. Lemieux (2016) relate discussions about trusting records to two interlinking concepts: reliability and authenticity. Reliability of records, sometimes referred to as *historical truth*, is the trustworthiness of a record based on its trustworthiness as a fact at the time of creating the record. Authenticity, or *documentary truth*, is the preservation of the identity and integrity of the record, from its point of creation.

Regarding the concepts of trusting records, Lemieux (2016) provides a heuristic for determining the suitability of Blockchain technology as a digital ledger for recordkeeping. The heuristic polarises blockchain applications with regard to the record's *retention*- and *evidential* requirements. Figure 6 shows the heuristic and the researcher's examples of Blockchain technology solutions. The heuristic shows Lemieux's own analysis of the most and least suitable application of blockchain technology.

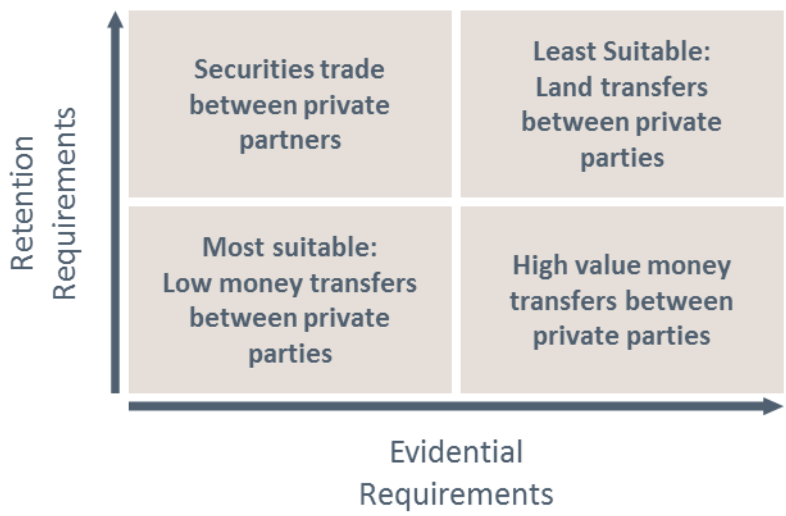


Figure 6. Suitability of BCT based on data requirements (adapted from Lemieux, 2016)

According to Lemieux (2016), the most suitable application of Blockchain technology is where evidential and retention requirements are low. In relation to the three concepts of trustful records, this would correspond to low requirements of historical and documentary truth. When data requirements are high, companies will rather use well tested applications instead of new technology. Lemieux adds that future designs of the technology might mitigate risks and issues, rendering less suitable applications to become more viable.

4. THEORETICAL FRAMEWORK

This chapter begins by compiling presented theory into a theoretical framework. Next, the authors perform their analysis as to whether the components of the framework are relevant and accurate in the context of this project. The analysis leads to several queries regarding the framework that the authors wish to settle in the following interview studies.

4.1. COMPILING THEORY INTO A CONCEPTUAL FRAMEWORK

With the theory presented on supply chain traceability and BCT, it is possible to develop the evaluation model presented in Figure 1 on page 4. Theory that should be appended to the evaluation model consists of inputs that represent traceability and BCT, and relevant evaluation tools. The theory presented in the frame of reference is summarised in Table 9.

Table 9. Presented theory on supply chain traceability and BCT.

Presented traceability theory	Presented BCT theory
• Definition of traceability • Central traceability concepts • Key principles of a traceability system • Traceability drivers • Traceability issues	• Five basic principles of BCT • BCT adoption evaluation tool • BCT's technical limitations • BCT's data requirements

The definition of supply chain traceability and the central traceability concepts are fundamental for the theoretical foundation in the study, and for aligning the view on traceability for readers of this report. However, the authors believe that these aspects are not fundamental for the evaluation and are hence excluded from the framework figure.

The authors suggest that the evaluation process begins by identifying the objective for the contingent changes. The objectives for improved traceability are well described by the *traceability drivers.* The user should then identify *how* the drivers could be met by improved traceability, this relates closely to the *key principles of a traceability system* and how they can be improved. The authors further believe that *traceability issues* relate closely to the key principles of traceability systems and hence does not need its own place in the figure. Only when the necessary improvement measures have been identified, the user should proceed to look at BCT, to see how it can address the areas of improvement for the specific business problem at hand. An application is drafted using the *five basic principles of BCT* to address the areas of improvement. When the application is drafted, the user should evaluate the draft using the *blockchain adoption evaluation tool, data requirements evaluation tool,* and asses the *technical limitations.*

It could be argued that the steps should follow a different order, for instance to begin by examining BCT to see how it can be useful in the context of traceability, or to begin with the evaluation tools to assess if the technology is relevant. If the user were to begin by examining BCT, the user runs a bigger risk of forcing a BCT solution to a non-existing problem, or to a problem which already has an apparent solution. The authors further believe that the draft should be done prior to the evaluation, since the evaluation heavily depends on the specific application under consideration. These arguments together support the authors belief that the natural order is to first explore the business problem, then create a drafted application, and lastly evaluate the application. The theoretical framework is presented in Figure 7 below.

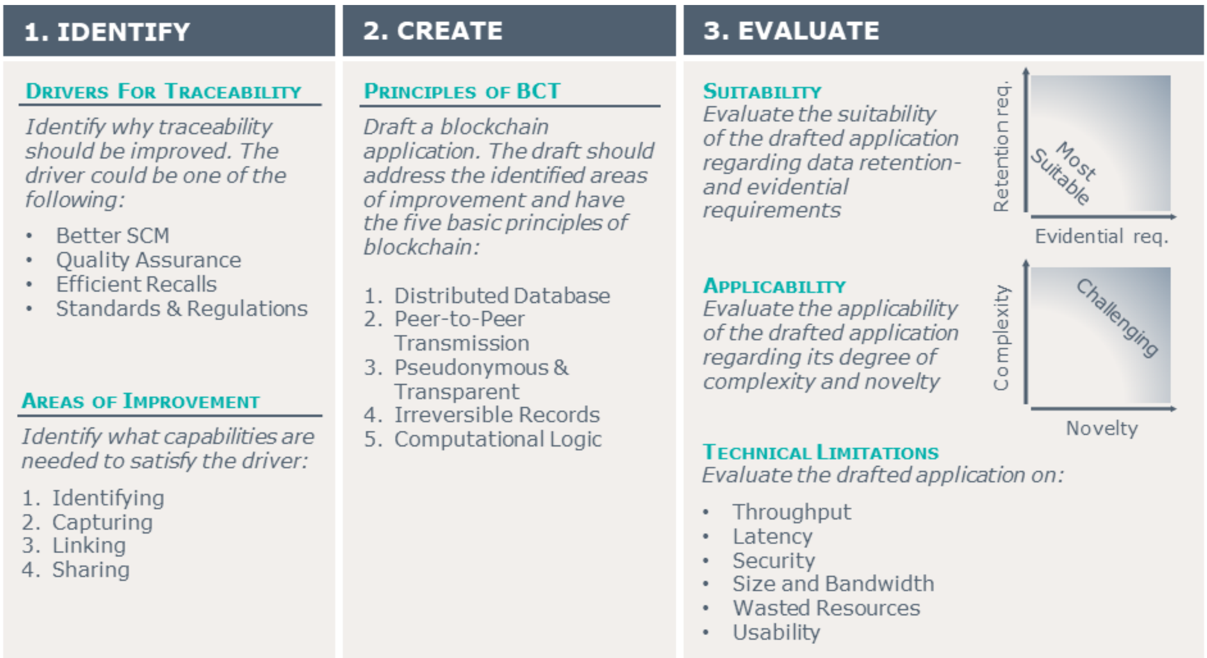


Figure 7. The theoretical framework.

4.2. DEVELOPING QUERIES FOR THE INTERVIEW GUIDES

This section analyses the theoretical framework and identifies which areas of the framework need to be questioned in the interview studies.

The theoretical framework is a condensation of theory from two separate fields, whose intersection is regarded limitedly by scientific research. Two questions that arise are: 1) whether the theory on the two phenomena have been combined correctly in the condensation or not, and 2) if the condensation of theory covers all relevant aspects to be considered for the framework. In combination, the two issues form the first query:

Query 1. Is the theory condensed accurately into the framework, while retaining sufficient information for the framework's purpose?

The framework is a condensation of theory from different fields, and it is appropriate to challenge the connections between the components of the condensation. Terminologically, how easy it is to proceed between the framework's steps will be described by whether the connection is *distinct* or *vague*. In the design of the theoretical framework, step one is a condensation of traceability theory, while step two and step three are condensations of BCT theory. The authors assume this is related to the clarity of the sequential connections:

- The connection between the components in step one is **distinct**; the components are both related to traceability theory.
- The connection between step one and step two is **vague**; the steps are condensations of theory from two different fields.
- The connection between step two and step three is **distinct**; both steps are condensed from BCT theory.

These assumptions should be tested in the interview study, leading to the second query:

Query 2. Are the connections between framework steps clear?

The third step of the framework evaluates the drafted application using existing tools from BCT theory, linking step two and step three together. The authors argue that step three should also contain evaluation tools linking with step one, i.e. evaluating the fulfilment of drivers for traceability or improvement of traceability areas. Similarly, there might be further aspects that should be regarded in the framework. The third query addresses this concern:

Query 3. *Are there any missing components of the framework?*

In interview study A, experts in the fields of traceability and BCT will be interviewed to settle queries one to three. The interview study will result in a 'revised framework'. To test if the revised framework fulfils its purpose effectively, the following queries are formed:

Query 4. *Is the framework easy to understand?*
Query 5. *Are the framework's steps and components relevant?*
Query 6. *Is the framework effective?*

These queries will be tested in interview study B with business representatives, in development of the 'final framework'. Table 10 summarises the formulated queries and in which interview study they will be addressed.

Table 10. The queries addressed in the different interview studies.

	Interview Study A	**Interview Study B**
Query 1	✓	
Query 2	✓	
Query 3	✓	
Query 4		✓
Query 5		✓
Query 6		✓

The queries are the foundation for the interview guides developed for the interview studies A and B. The interview guides are presented in the appendices of this report: The interview guides in study A for traceability- and BCT-experts are presented in section 10.1 on page 81 and 10.2 on page 82, respectively. The interview guide for study B is presented in appendices section 10.4 on page 85.

5. INTERVIEW STUDY A

This chapter presents the results of the interview study with traceability and blockchain experts. This interview study aims to increase the accuracy of the theoretical framework, which currently is a pure condensation of existing theory. The results are analysed and in the end of the chapter, the revised framework is synthesised from the analysis.

5.1. PRESENTATION OF INTERVIEWEES

This section presents the interviewees of the interview study with experts. Table 11 presents the interviewees briefly.

Table 11. Interview study A's interviewees and their area of expertise.

Interviewee	Working for	Area of Expertise
Blomborn, E.	Coca Cola Company	Traceability
Catela, K.	GS1	Traceability
Dobrovolskis, D.	GS1	Traceability
Unnervik, N.	Netlight Consulting	Blockchain technology
Öberg, L.	Chromaway	Blockchain technology

E. Blomborn is a civil engineer in chemical engineering. Blomborn has worked in the food industry for 10 years with project management and business development. Blomborn has worked with traceability in general for many years, often focusing on traceability strategy and regulatory compliance. Blomborn has little to no experience in BCT.

Both K. Catela and D. Dobrovolskis work at GS1. Catela is responsible for traceability and works as a traceability expert at GS1, both with a global and Swedish scope. Catela is participating in international groups within different industries as health care, food, etc. Catela has worked with traceability focus for 4-5 years, but has little or limited knowledge in BCT. Dobrovolskis works at the GS1 standards-department, being responsible for the technical development of GS1 Directory. Dobrovolskis has also worked with traceability in the military, but has only some rudimentary knowledge in BCT.

N. Unnervik is a civil engineer in data science. Unnervik works as an IT-consultant at Netlight Consulting AB. Unnervik has worked specifically with BCT for four months, but has been interested in crypto-security for a longer time. Currently, Unnervik helps a client with evaluating how BCT can be used in their business, both with a technical and business perspective on blockchains. Unnervik's background in traceability is limited to only the concept of traceability in an IT-context.

L. Öberg works as a Business Developer at Chromaway. Öberg has been familiar with BCT since 2011, and has been working with BCT during the last three years. Öberg has looked at some use-cases of BCT regarding traceability, but is only familiar with the basics of traceability.

5.2. RESULTS

This section presents the results of the interview study. First, a summary of the point-based questions results is presented. Then, the empirical results other from the open-ended questions are presented.

5.2.1. Results from Point-Based Questions

In this interview study, the interviewees were given point-based questions where statements were scored according to:

1. Completely disagree with the statement
2. Partly disagree with the statement
3. Partly agree with the statement
4. Completely agree with the statement

A summary of the point-based questions result is shown in Table 12 on the next page. The full result is presented in appendices' section 10.3 (Table 14 on page 83 shows the traceability experts' scores, and Table 15 on page 84 shows the blockchain experts' scores). The experts verified the framework's contents related to their area of expertise. In general, the experts found the framework easy to understand and fairly effective. In aggregation, the experts found the connection between the first and second step to be the only vague framework connection, although the link between the first and third framework step also scored low on clarity.

Table 12. The interviewees' scoring on the point based questions in interview study A.

Statement	Traceability Experts' Average Score	BCT Experts' Average Score
The drivers for change are accurate	4	n/a
The areas of improvement are suitable	4	n/a
The identifying step is easy to understand	4	3.5
The creating step is accurate	n/a	2.5
The creating step is easy to understand	1.33	4
The evaluation tools are relevant	n/a	3.67
The evaluation tools are easy to understand	3	3.5
It is easy to proceed from the identifying step to the creating step	1.33	1.5
It is easy to proceed from the creating step to the evaluating step	n/a	4
It is easy to see the connection between the identifying- and evaluating step	2	2.5
The framework is easy to understand	3.67	3.5
The framework is effective	2.67	3

5.2.2. Results from Open-Ended Questions

The results presented here are emerged from the open-ended questions of the interview study, or when the experts have made specific comments when answering the point-based questions. The opinions from the interviewees has been grouped by discussion topic or framework step in this section. On each topic, the traceability experts' review is presented first, followed by the review from the blockchain experts.

The section begins by presenting the empirical result on general aspects of the framework. Then, each step is presented sequentially. Lastly, the experts' views on the connections between the framework steps are presented.

General Framework Aspects

The traceability experts consider the framework being easier to understand than the blockchain experts. Dobrovolskis (2017) states that the framework is easy to understand as step one can be considered as a problem description, step two as problem solving, and step three as follow-up on the problem solution. Unnervik (2017) only partially agrees that the framework is easy to understand, while adding that a more clear and detailed description would make the understanding easier. The figure of the framework is hard to understand in isolation, Unnervik (2017) clarifies.

Both the traceability and blockchain experts consider the effectiveness of the framework questionable. Blomborn (2017) states that the effectiveness of the framework depends heavily on the users' familiarity and knowledge in BCT. It ought to be clarified who should use this framework, specifying *who* should answer each question, and so on (Blomborn, 2017). Dobrovolskis (2017) requests more follow-up on the solution, perhaps using quantitative evaluation methods. Both blockchain experts request two improvements to achieve better effectiveness: 1) Reviewing if step one has been addressed in step three, and 2) a clearer connection between step one and two (Unnervik, 2017; Öberg, 2017b).

Identifying Step

The traceability experts uniformly declare this step accurate while still being open for more development. Blomborn (2017) states that each driver could be developed with more detailed sub-drivers or related areas. One related area is mentioned by Catela (2017) and Dobrovolskis (2017), who mention CSR as a relevant driver for traceability. Catela (2017) states that quality assurance is a wide concept, including not only the customer perspective, but many business perspectives as well. More detailed descriptions or descriptive examples of the drivers would help the understanding of the first step. Between different industries drivers of traceability could differ so it is important to be able to find what you look for in the framework, Catela (2017) elaborates. On this note, Blomborn (2017) believes that the specification and development of both the traceability drivers and the areas of improvement could be made in infinity, and repeats that the condensation is adequate as it is presented right now.

Discussing areas of improvement, Catela (2017) believes that upstream suppliers generally are not as developed in the traceability technology as downstream suppliers. On another note, Dobrovolskis (2017) emphasises that traceability applications often are developed in isolation, disregarding potential conflicts with other applications. On this topic, Catela (2017) requests the framework clarifying how the areas of improvement have a global perspective. Isolated or localised applications are "dangerous" according to Catela (2017), and the framework should raise this concern.

The blockchain experts find the first step easy to understand, although it being outside of their area of expertise. Unnervik (2017) motivates that the first step is closely related to a generic change-management approach, making it easy to understand also for a developer.

Creating Step

The traceability experts found the second step of the framework easy to understand. Dobrovolskis (2017) wishes for a better description of *how* the problem is aimed to be solved (how the BCT application will solve the area of improvement), to make the step even more understandable. On another note, Dobrovolskis (2017) states that irreversibility of records can be a problem in the context of traceability, as human errors often occur in supply chain activities. An application needs to have a mechanism for handling incorrect entries, if it is to be useful in the context of traceability (Dobrovolskis, 2017).

The blockchain experts consider the second step being both accurate in describing BCT, and comprehensively presented. Regarding its accuracy, Öberg (2017b) states that the five principles of BCT is an “OK definition”. Applications of BCT today meet the five basic principles “more or less”, but at the same time the five basic principles can be met by applications that are not BCT-based (Öberg, 2017b). There is no *true* definition of blockchains, according to Öberg (2017b). While the five basic principles are accurate, some principles are vague or ambiguous. For instance, *irreversibility of records* depends on how “irreversibility” is defined; even the Bitcoin blockchain is not completely irreversible, although arguably being *practically* irreversible, Öberg (2017b) explains.

Both Unnervik (2017) and Öberg (2017b) state that the five basic principles of BCT are not binary, but should rather be viewed as concepts. The five basic principles can be met to various degrees by a BCT application, and Unnervik (2017) expresses that a clarification of this would improve the accuracy of the second step. Öberg (2017b) exemplifies that the five basic principles can be seen as attributes of BCT rather than a defining specification. A more detailed specification of the application would help a developer to know how to create these attributes, Öberg (2017b) claims. Such a specification could contain a description of what Öberg (2017b) would say a blockchain is characterised by: 1) Transactions are grouped in blocks, timestamped and connected to previous blocks, creating a timeline; 2) a historic transaction cannot be changed without changing the whole chain, 3) there is a consensus algorithm, 4) there is a means of identification, e.g. with private/public keys. Öberg (2017b) further claims that BCT requires three distinct roles: readers, writers and validators. Readers have permission to read the entries on the blockchain, writers have permission to create new entries, validators have the power to determine which entries are valid and which are not. Öberg (2017b) claims that these roles should be defined in the technical specification.

Both blockchain experts find the second step easy to understand. However, both Unnervik (2017) and Öberg (2017b) raise concern to whether it is easy for the user to understand what is meant with *pseudonymity*. Öberg (2017b) raise the same concern regarding the user's understanding of the meaning of *peer-to-peer transmission*.

Evaluating Step

The traceability experts easily understand the third step of the framework. Dobrovolskis (2017) wishes for more descriptive examples in the evaluation tools to further improve understanding. Dobrovolskis (2017) declare that demands and regulations differ depending on product, and pharmaceuticals are a good example of a type of product where retention requirements can be very high. Another point made by Dobrovolskis (2017), is that financial aspects are missed in the evaluating step of the framework. If large financial benefits from the drafted application can be shown, other limitations might not be as relevant to assess, Dobrovolskis (2017) claims.

The blockchain experts can easily understand the third step of the framework, although Öberg (2017b) expresses that the evaluation tools can be considered a bit vague and subjective.

On the topic of whether there are other relevant aspects, Dobrovolskis (2017) states that it is important to show that blockchain is only *one* way of solving problems; rival solutions may exist. On the same topic, Öberg (2017b) wishes that the third step of the framework considers the potential benefits of the drafted application, to enable assessing how the drafted BCT application outperform rival solutions. This will also assist the discussion of how the application will be financed, according to Öberg (2017b).

Unnervik (2017) and Öberg (2017b) both express the need of reviewing step one in the evaluating step, both examining the degree of driver fulfilment and the degree to which the area of improvement has been addressed. In extension, Unnervik (2017) believes that also the five basic principles of BCT should be reviewed, to assess which attributes the drafted application reached.

Here follows a presentation of the blockchain experts' review on the specific evaluation tools.

Suitability Evaluation Tool

Öberg (2017b) like the general idea of the suitability tool but does not agree with its conclusions. Öberg (2017b) questions whether it will be relevant to have coffee-purchases on the blockchain; it is not reasonable to store such data (low evidential- and retention requirements) on such a secure database. With higher maturity of BCT, the place in the tool's figure of most or least suitable applications might switch places, Öberg (2017b) claims. On the same note, Öberg (2017b) discusses that the suitability tool fails to separate what one could "dare" to develop now, vs. what is rational or interesting to develop in the long-term. Öberg (2017b) believes that the most interesting applications of BCT is in the upper right corner of the figure, despite that the maturity of the technology might not enable such applications today.

Adoption Evaluation Tool

Öberg (2017b) stresses that while the adoptability tool is relevant for evaluating the implementation of the application, it does not consider the benefits the application brings. Generally, if an application is assessed as transformative with the tool, it will both be difficult to implement quickly but could *also* bring larger benefits, Öberg (2017b) explains.

On another note, Öberg (2017b) discusses that this evaluation tool is "moving away" from proof of concepts and beginning to look at the implementation instead. It inevitably brings questions related to economy and business models: *Is it viable? Does it fit with our business model? How will we finance this? How will value be created?* (Öberg, 2017b).

Technical Limitations Evaluation Tool

The technical limitations tool is considered highly relevant and easily understandable by both blockchain experts. Unnervik (2017) clarifies that not all technical limitations are relevant in all applications. At the same time, if a technological limitation is not relevant for an application, it simply is not a limitation to that application (Unnervik, 2017).

Connection Between the Identifying and Innovating Step

Both the traceability experts and blockchain experts find it difficult to see the connection between step one and step two. All traceability experts vaguely express the need of a more communicative layer of step two. Dobrovolskis (2017) specifies that the connection is static. One should ask questions as: *What is the problem? What do we want to do?* This would improve the communication and understanding between step one and two, Dobrovolskis (2017) claims. Dobrovolskis (2017) also wishes for examples of solutions (applications) in the connection between step one and two.

Blomborn (2017) believes that step two should begin with a feasibility check, to evaluate if this is the right direction of development. One cannot put too much work into an application simply hoping for it to turn out useful in the end, Blomborn claims (2017). Such feasibility check could help executives to determine the scale of the project, and answer important questions as: *Can we work with a distributed database? Can we communicate peer-to-peer within the supply chain?*

Such questions need answering before an application can be given more time and resources to be developed (Blomborn, 2017). The need of feasibility check increases with the level of detail in the BCT draft. Blomborn (2017) ends this discussion by suggesting that step two as it is now *is* the feasibility check, and then another component the innovating step should be to develop a technical specification of the application.

Unnervik (2017) find it unclear what is the input and what is the output of step two. This could be made clearer by specifying what is being *ordered*, both from the developer's perspective and the traceability perspective, Unnervik (2017) claims. To enable specifying what is being ordered, Unnervik (2017) suggests a structured dialogue in the framework, communicating well with both step one and two. On the same note, Öberg (2017b) sees the need of specifying the infrastructure of the application to improve the connection between step one and two. It is difficult to develop a new BCT application simply from the current output of step one and the current components of step two, Öberg (2017b) explains.

Unnervik (2017) suggests that applicability and suitability assessment could be done prior to step two. "*What if you draft an application and realise it scores poorly in the evaluation?*", Unnervik (2017) asks rhetorically. The evaluation tools could be used both prior to step two *and* in step three. In some sense, these evaluation aspects set the frame of the blockchain application as a part of the identifying step, Unnervik (2017) elaborates. By setting the frame of the application, the chances of developing a useful and implementable application increases.

Connection Between the Innovating and Evaluating Step

None of the experts found it difficult to connect step two and three in the framework. Unnervik (2017) described that it was straight forward, especially proceeding from the drafted BCT application to assessing its technical limitations.

Connection Between the Identifying and Evaluating Step

Generally, the connection between step one and three were considered quite vague by all experts. Blomborn (2017) misses important questions as: "*How is value created?*", "*Have drivers from step one been fulfilled?*", "*Why is the drafted BCT application the best means of fulfilling the traceability drivers?*", in the connection between the steps. On a similar note, Dobrovolskis (2017) wishes for a quantitative evaluation to how step one A and step one B were fulfilled.

"The connection between step one and three is very distinct, so distinct that I gaze at step three just after stage one", Unnervik (2017) declares. "But there should be a connection with the objective (i.e. driver for change or area of improvement) as well" (Unnervik, 2017). Öberg (2017b) expresses that there is an indirect, relevant connection between step one and three, but not a *direct* connection. A direct connection would at least include the reviewing of how the driver for change have been fulfilled, according to Öberg (2017b). Another two-dimensional graph could be developed to help the evaluation of if the drafted application was what the BCT was intended to be used for, Öberg (2017b) suggests.

5.3. Analysis of the Interview Study with Experts

This section analyses the results of the interview study with experts. The analysis begins on a high-level, discussing general aspects of the framework. The high-level analysis is followed by a step-by-step analysis of the framework's three steps, including an analysis of the connection between steps. A summary of this section is found in section 5.3.3 on page 53, where the analysis' key points are presented. That section also presents the revised framework.

5.3.1. High-Level Analysis

Both traceability experts and blockchain experts have trouble in understanding the details of the framework by simply looking at the picture. This critique is focused on the need of more exemplifying in the framework steps, as well as more thorough explanation of what each step means. By the experts' undivided criticism, it is evident that all parts of the framework need better exemplifying and a better description. The overall effectiveness of the framework is not evident for all experts. The experts argue that the effectiveness of the framework would be improved with better understanding of the framework, although specific concerns are mentioned by the experts. One mentioned concern is that the effectiveness would be improved by better explanation of *who* should discuss various aspects, as well as a clarification on how extensive the user's knowledge in BCT need to be to use the framework effectively. To increase high-level understanding *and* effectiveness, the framework should address this concern. One way of clarifying what technical knowledge the user needs to have in various steps of the framework is to separate *strategic* areas from *technical* areas, where strategic areas should not need technical knowledge to hold discussions and support decision-making.

Adding technical- and strategic dimensions in the framework requires determining which framework steps needs technical expertise to be appropriately addressed. In the current framework, identifying drivers for change require no technical level of detail as opposed to identifying areas of improvement, which require defining current technical capabilities and issues. In the creating step, basic principles of

BCT should be discussable on a strategic level. In the evaluating step, the suitability- and adoptability tool enable evaluating the application and implementation on a conceptual level so they can be discussed on a strategic level. The technical limitations are closely connected to specific technical attributes of the application, and without technical knowledge the limitations are difficult to assess. Without changing the steps or components of the framework, the strategic- and technical areas of the framework will be delineated as shown in Figure 8.

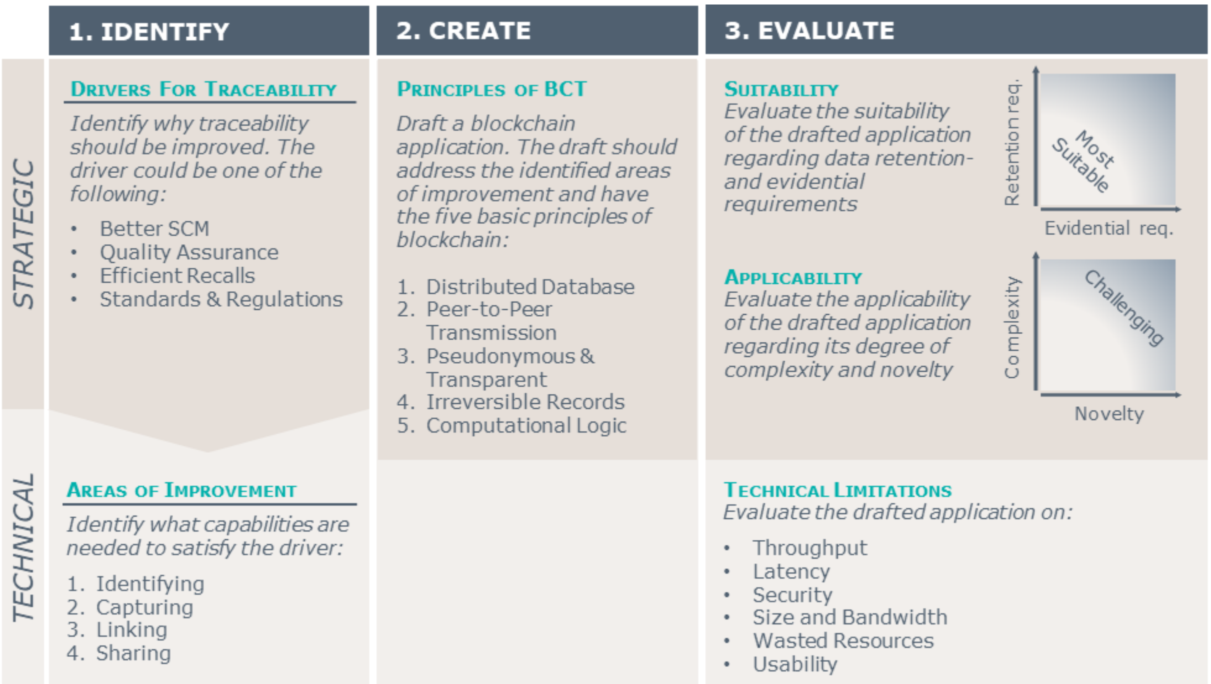


Figure 8. The new illustrative framework-design with a strategic- and technical dimension.

To summarise, the high-level criticism of the framework concern descriptions and exemplifications mostly. The overall logic of the framework, e.g. the order of the steps or the contents of the steps, is supported by the experts, while the framework's effectiveness is questioned on different notes. With a high-level perspective, this section has added a technical- and strategic dimension to the framework figure, and motivated the general need of more descriptive information and exemplification in the framework.

5.3.2. Step-by-Step Analysis

This section will analyse each framework step, followed by an analysis of the connections and links between framework steps. Each sub-section will conclude with a summary of suggested changes to the framework.

Identifying Step
The identifying step scored perfectly in all aspects by the traceability experts. This unanimously answers the first query: the identifying step is accurate. Despite being accurate, the traceability experts raise concern to whether the drivers are described well enough. The experts also discuss that drivers should only be specified to a reasonable degree. This vague discussion renders the empirical data being ambiguous in the suggestions on *how* traceability drivers could be better presented, while being unambiguous in that the drivers *should* be better presented. The experts do however make two concrete suggestions: 1) Add CSR aspects to the driver set, and 2) add information to show that the drivers are not an exhaustive list.

The experts discuss the AoIs, suggesting them to be complemented with more detailed information. The theoretical frame of reference of this report holds complementary information about the four improving measures, that can be appended to the framework to help the user's understanding.

Before summarising improving measures to the first step of the framework, two additional concerns raised by the traceability experts will be addressed. The experts discussed that upstream parties generally are not as technologically developed as downstream parties in a supply chain. This was stressed as an important aspect in the identification of areas of improvement. This fact can undermine the credibility of traceability systems, when the historical truth of records is uncertain. Taking the experts' discussion in mind, the framework should stress this concern, mitigating the risk of the user overlooking important improving measures that might lie outside of their businesses scope. Another discussion was the experts' emphasis on the danger of isolated application development. The experts stress that one must have global perspective when developing applications for traceability systems. With the previous reasoning, this concern could be appended to the creating step, helping the user of the framework to avoid potential pitfalls.

In summary, the experts critique on the first step has four major points: 1) The first step is easy to understand and accurately condensed from theory, 2) the drivers could include more information generally, mention "CSR", and a clarification that more drivers exist, 3) more information could accompany the areas of improvement in the framework, and 4) help the user better define AoIs by remarking on typical traceability-issues.

Creating Step
While the traceability experts have trouble in understanding the creating step of the framework, blockchain experts find it fully comprehendible. The traceability

experts wish for better explaining of *how* the problem is aimed to be solved, thus it seems not that the five basic principles are the underlying issue for the traceability experts' lack of understanding, but rather the lack of technical detail. On a similar note but regarding the blockchain experts' critique, the experts unanimously require a technical specification for the developers to be able to create any BCT application. It seems that adding a technical-level component in the creating step increases the traceability experts' understanding of the step, while making the step more effective according to the blockchain experts.

Regarding accuracy, the blockchain experts gave some criticism towards the 5BPs of BCT, scoring the accuracy on a neutral average of '2.5'. The blockchain experts both have approved the relevance and precision of the principles while disapproving of how the principles are presented and used in the framework. The experts disagree on the 5PBs functioning as a *definition* for BCT in the framework, but agree on that there exist no true definition. A major point made by both experts is that the 5BPs are rather *properties* of BCT that are non-binary, that applications can acquire to various degrees. The 5BPs currently are placed in the strategic level of the framework, which provide an important baseline of this discussion. On a strategic level, a component in the framework must be understandable and discussable without technical expertise. If the 5BPs are properties of BCT, it is logical to discuss whether these five properties are desirable or useful for an application to address the traceability objectives from step one. Would no property or concept of BCT be desirable, the user should consider if it is even relevant to continue to the technical level of creating the application. In some sense, the strategic level of the creating step is a *feasibility check*, if it is clarified that the 5BPs aim to start a discussion on the desirability and usability of BCT-properties and concepts.

On the same note combined with the previous discussion on a technical-level component in the second step, the blockchain experts have suggested that a technical specification could include additional help in defining the BCT application. Examples were given both on defining characteristics of BCT as well as technical aspects that need to be considered on the technical level of drafting a BCT application. Adding the provided examples to a technical specification, the criticism towards the 5BPs (ambiguousness, binarity, non-defining), are addressed not by changing the 5BPs, but complementing them with a technical-level component that *is* precise.

On another note, the traceability experts raised concern about irreversibility being an issue in the context of traceability. The possibility of human error requires records to hold a mechanism for correcting the errors. However, as the previous discussion suggested the 5BPs being used as a *feasibility* check of BCT, the user of the framework will inevitably reach a discussion of this issue.

Specific criticism from the blockchain experts was aimed at the terminology of the 5BPs. The experts questioned whether *pseudonymity* and *irreversibility of record* have an unambiguous meaning. Obscurity and ambiguousness of the 5BPs can have negative impact on the users understanding and the strategic-level discussion in the second step. Again, on a strategic level the terminology should not be obscure for a user without technical expertise. A simple solution to this problem is to describe the meaning of these words better in the framework.

To summarise, the framework will be changed to state "Basic Properties of BCT" as headline of the 5BPs. The framework will also be appended with a technical component in step two: Technical specification. The framework will present four aspects suggested by blockchain experts in the technical specification. The framework will also be appended with more information on the technical specification-component, as well as descriptive information on the basic properties of BCT, aiding the users' understanding of the strategic level in the second step.

Evaluating Step

The evaluating step is the only step that scores positively (above '3') on all aspects by all experts. Although this could suggest no significant improving measures need to be made, all experts request better description and exemplifications in the evaluation tools. It was also stated that the evaluation tools are subjective, criticising some of the tools' conclusions. Two improvements can be derived from this criticism. Firstly, the framework should include descriptive information and exemplifications accompanying the evaluation tools. Some examples have been given by the experts; pharmaceuticals are mentioned as a typical product category with high data retention requirements. Secondly, the evaluation tools' conclusions should be challenged in the framework. Some of the opposing conclusions by the blockchain experts are completely opposite to the conclusions presented in theory, but the experts provide an explanation to why they believe so. As an example, theory states that the upper right corner is least suitable and bottom left corner most suitable in the suitability evaluation tool, considering the current maturity and trust in BCT. Opposed to theory, a blockchain experts state that the upper right corner is most suitable and bottom left corner least suitable, considering attributes of BCT.

The conflict of opposing conclusions can be solved by presenting both the conclusions found in theory *and* the conclusions suggested by the blockchain experts, if it is clarified what reasons either party consider generating their conclusions, e.g.: *"Theory states that 'X' is the conclusions because '…' while experts state that 'Y' is the conclusions because '…'"*.

Another note discussed by some experts is the lack of financial aspects in the framework. For instance, it was stated that financial aspects could make the reviewing of technical limitations less relevant, with the argument that businesses are interested in financial benefits primarily. Whether the argument is generally true or not, the purpose of the framework must be reviewed when addressing this remark. The framework is conceptual, require the user to only *draft* a blockchain application, and evaluate the drafted application of BCT on important aspects *prior* to further investment and development. Financial aspects and quantitative evaluation tools will have little precision in a framework limited to a conceptual level. If the drafted BCT application is evaluated to have potential on a conceptual level, the next step could be to investigate how the application could be developed and implemented, relating to financial aspects.

An important remark on the topic of financial aspects is how large benefits could make issues originated from evaluation tools' discussions less important. Relatedly, a reoccurring topic discussed by the experts was how the evaluation tools generally does not consider potential benefits of the drafted BCT application. To conclude the discussion in the previous paragraph then: It should be emphasised that potential benefits should be investigated together with potential issues in each evaluation tool. This emphasis can be made in the framework.

The experts requested reviewing step one, perhaps also step two, in the evaluating step of the framework. It was suggested that the user should review the fulfilment of drivers and AoIs, and review to what degree the drafted application holds the 5BP-attributes. In other words, the user should review the fulfilment of goals set during preceding framework steps. In the discussions on evaluation tools' conclusions and their lack of financial aspects, the experts have argued that identified issues could be outweighed by estimated benefits. With the same argument on this topic, potential benefits can be suppressed by the inability to address original drivers for change, or the inability to fulfil original drivers. Moreover, if the framework aims to help the user come to conclusions on whether BCT is applicable for improving traceability or not, it is reasonable to not only evaluate the drafted application itself, but also if the application succeeds in improving traceability as specified. In terms of concrete improving measures for the evaluating step on this topic, the following suggestions have been given by the experts:

- Review fulfilment of drivers in a new evaluation tool
- Review the entire first step in a new evaluation tool
- Review the entire first step and the 5BPs in step two in a new evaluation tool
- Make a new evaluation tool with a 2-dimensional graph

Since all experts suggest a new evaluation tool for analysing fulfilment of previous steps in general, the first improving measure is to add this evaluation tool. All experts consider it relevant to review driver fulfilment, whereas their view differ on how relevant reviewing other fulfilments. It can thus be suggested to review the fulfilment of all preceding framework steps, while emphasis is put on reviewing the fulfilment of drivers. On the note of making the new evaluation tool a 2-dimensional graph, the authors believe that the new evaluation tools function simply: The user evaluates fulfilment by revisiting and assessing previous steps. On a general note, a 2-dimensional graph is motivated by two distinct aspects yielding conclusions or remarks in combination. Only one aspect is being evaluated in the new evaluation tool suggested in this discussion, namely the degree of fulfilment.

Concluding the analysis of the evaluating step, four improving measures have been presented. As with previous framework step, the evaluating step needs better descriptive information and exemplification for its components. Secondly, the evaluation tools' conclusions suggested by theory should be accompanied with opposing conclusions or remarks by experts. Thirdly, the evaluating step should clarify that potential benefits should be discussed together with potential issues that the evaluation tools discover. Lastly, the evaluating step should include a fulfilment analysis as an additional evaluation tool.

Connections and Links Between Steps

The connection between step one and two, and the link between step one and three were subject to substantial criticism from the experts. The connection between one and two were the only aspect scoring below 2.5 with a 1.5-score on average, while the link between step one and three averaged a 2.5-score. Many suggestions of changes have already been done to the framework steps in previous analysis-sections. This section will analyse whether the criticism towards the framework's connections and link have been addressed or if there are additional improving measures to discuss. Additionally, this section tests previously proposed improving measures by bringing additional criticism to the table.

It has previously been suggested to add a communicative layer between step one and two. On the connection between step one and two, the experts expressed the need of a dialogue with developers before an application can be developed.

Propositions were given by the experts to make the connection more dynamic and communicative with leading questions or by the framework giving examples of solutions. On the note of exemplifications, both theory and experts have explained that few clear BCT applications exist that have been fully implemented. Adding examples of how BCT-solutions can be designed would be difficult to present exhaustively. In extension, giving few, vague, or un-facilitating examples of solutions could result in additional criticism. On a wider note, previous discussions have suggested adding a technical level of the second step, using the 5BPs as properties of BCT on a strategic-level discussion. This proposition of design changes in the second step arguably addresses the concern with a static connection with the first step. With the new design, the static connection rather lies in the transitioning to the technical specification in the second step, where the user is required to draft the BCT application technically. The propositions of adding leading questions or exemplifications of solutions will not be addressed further in this analysis, mainly by the criticism possibly having become redundant. If the second interview study brings additional criticism on this topic, the propositions may be reconsidered in that subsequent analysis.

Another suggestion made by the experts was adding a feasibility check between step one and two, helping the user to evaluate if more work should be put into the application. On a strategic level, the 5BPs of BCT function as a feasibility check with the proposed redesign of the creating step. The authors consider this suggestion addressed.

Another remark from the experts were that the input and output of step two is unclear. This is the only remark made on the connection between step two and three, which scored a perfect '4' by the experts. While the connection between step one and two have been addressed, the connection between step two and three connects other components than before, with the technical specification added to the creating step. The authors consider the perfect scoring on the connection together with the redesign of the second step render this remark dismissed.

Similar to a feasibility check, the experts requested reviewing the suitability- and applicability evaluation tools prior to drafting the BCT application in step two. As this would frame or delimit the application, the experts believed that this would make the connection between step one and two better. Setting up the scope could be done in the strategic level of step two, either before or after discussing the properties of BCT. It is arguably most logical to begin by assessing if the properties of BCT is desirable on a general note, and setting the scope of the application to be drafted after that. However, the authors believe that the evaluation tools are hard to use before the draft exists.

Regarding the link between step one and three in the framework, the experts remarked that the drivers of traceability or AoIs are not reviewed in the evaluating step. On the same note, some experts requested quantitative evaluation tools of step one to make the link better. This discussion has been analysed previously, and although not using quantitative methods, the evaluating step has been proposed to be redesigned, analysing the fulfilment of previous framework steps in addition to existing evaluation tools. By that, it is assumed that the remarks on the link between step one and two have been addressed.

5.3.3. Concluding Analysis and Development of the Revised Framework

Reviewing the interviewees' inputs and score on statements, all queries tested in interview study A have been addressed:

- *Query 1*: Is the theory condensed accurately into the framework, while retaining sufficient information for the framework's purpose?
- *Query 2*: Are the connections between framework steps clear?
- *Query 3*: Are there any missing components of the framework?

To summarise the improving measures stated in the analysis, the following list presents the main conclusions and changes regarding the framework:

1. The framework should generally hold more descriptive information and examples in the framework components.
2. The framework will be divided into strategic and technical dimensions.
3. The 5BPs will be used as properties of a BCT application rather than a definition.
4. The creating step will be complemented with a technical specification of the application.
5. The creating step will be appended with a component setting up the scope of the application to be drafted on a strategic level.
6. The evaluating step will be complemented with an evaluation tool reviewing the fulfilment of previous framework steps.

With too much information appended to the framework figure, it becomes difficult to get an overview and understanding. Therefore, the framework will be presented in two figures: One condensed illustrative figure, and one descriptive figure with more detail. Figure 9 shows the illustrative figure of the revised framework. The descriptive figure of the revised framework is presented in Figure 13 in appendix 10.4.

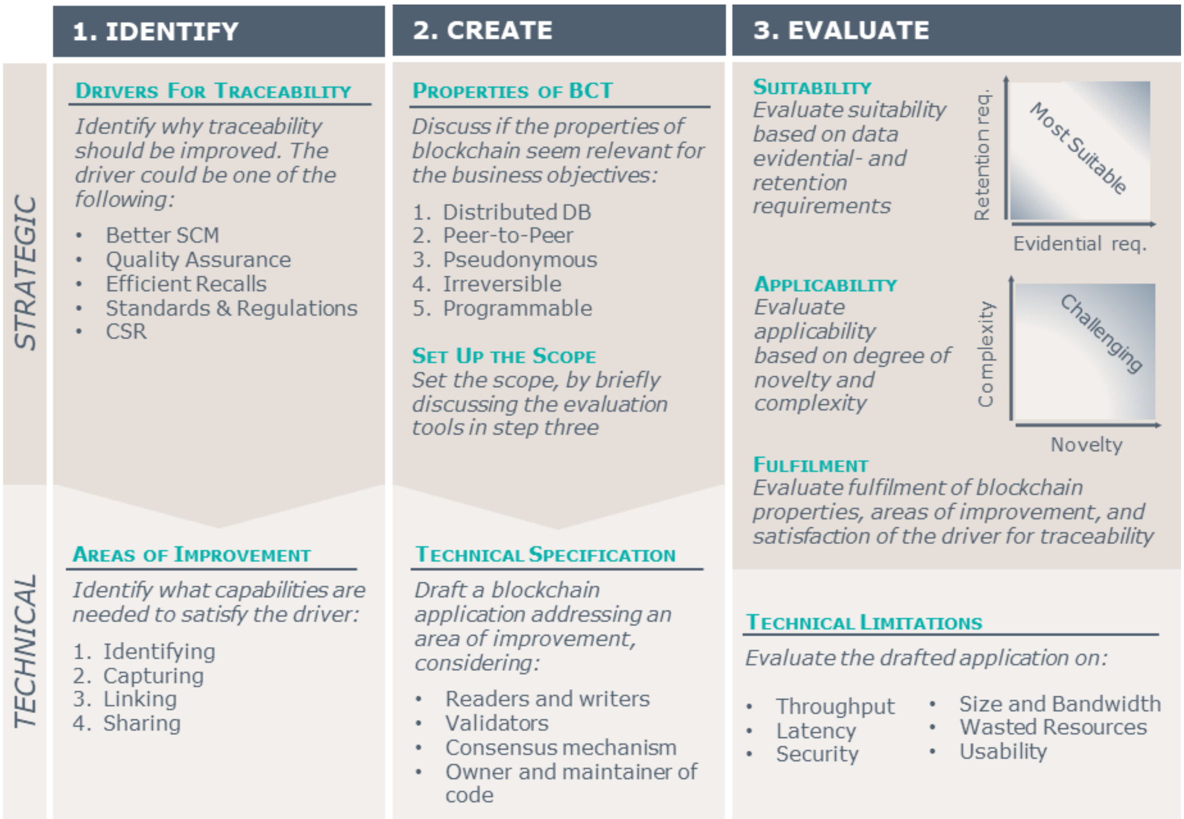


Figure 9. The revised framework.

6. INTERVIEW STUDY B

This chapter presents the results from the two interviews conducted with representatives from the industry. This interview study aims to validate the contents of the revised framework, and make minor final adjustments to it. The interview results are presented first, followed by an analysis of the results. In the next chapter, the final framework is presented.

6.1. INTERVIEW AT AXFOOD

This section begins with a short presentation of Axfood and the interviewees. Then, the interview's result on each framework step is presented. Lastly, the interview's discussion on general aspects of the framework is presented.

6.1.1. Presentation of Axfood and the Interviewees

Axfood is a Swedish food-retail corporation. The corporation holds the food-retail stores Hemköp and Willys. Dagab is a part of Axfood responsible for product development, purchasing, and logistics. (Axfood, 2017). The interviewees on Axfood subject to this interview were K. Billinger and J. Åstrand.

Billinger is responsible for quality assurance on Dagab purchasing and logistics. Quality assurance can involve setting targets for new products, working with quality on current products, and developing informative texts on consumer packaging, Billinger explains. Billinger is also involved in targeted recalls to stores. J. Åstrand is responsible for developing IT-systems in warehousing at Axfood, and has been in contact with GS1 regarding traceability. While Billinger holds expertise in the upstream supply chain, Åstrand has better insight in processes and IT-infrastructure downstream.

6.1.2. Result

In summary, both Billinger and Åstrand found all components and steps of the framework to be relevant and easy to understand. They both considered the framework being successful in achieving its purpose, and fully agreed that the framework is an *efficient* tool for achieving its purpose. In the following sections, the step-wise results will be presented. Discussions related to their subjective experiences or views with Axfood's business are also presented.

Identifying Step

The drivers for traceability were easy to understand, according to both Billinger and Åstrand. For them, better SCM is heavily related to cost-reducing and non-compliance tracing and tracking, as this is an area where much resources could be saved. Regarding quality assurance, Billinger discusses that some efforts have been and are being made in improving transparency, where pictures of the farmer are presented on the package, etc. Axfood strive to print origin on all private-label products, Billinger states. However, it does not always matter if *they* want to do this on their product, as the entire supply chain must cooperate for it to be achievable, according to Billinger.

Non-compliance tracking and tracing is very important. Axfood wishes to have more sophisticated systems for targeted recalls, and does not know exactly at which store products are located at the moment, Billinger explains. Currently these efforts are manually performed, as the ERP-system does not hold sufficient capabilities. This leads to interfering with stores, taking up many parties' time and resources, Billinger elaborates. Moreover, inefficient recalls create significant return-flows and costs. Åstrand claims that Axfood has a way of working that sometimes undermines traceability. In warehousing, they are unable to say exactly which pallet is being picked from, as replenishment of picking locations can result in items from a nearly exhausted pallet being laid on top of the newly stocked pallet. As costs are involved, the traceability *could* be improved on selected products with extra high demands, by changing picking routines, Åstrand explains. Åstrand adds that as human error is involved, even with picking routines adjusted it is difficult to achieve perfect traceability.

Billinger states that standards and regulations is probably the most important driver for many businesses, as this driver can motivate the induced cost. On the note of CSR, Billinger explains that the driver is always important, but maybe not as relevant in Axfood's case.

Both Billinger and Åstrand wishes for a *customer perspective* to be added to the traceability drivers. The customer perspective would include the drive of being transparent, "PR" in some sense. Being transparent does not necessarily come from drivers of quality or CSR, they explain.

Regarding AoIs, both Billinger and Åstrand state that it is very easy to understand, and state that the AoIs provide an inclusive categorisation of traceability technology. Looking at the AoIs there are much that can be improved and much information we do not have, Billinger explains. Billinger clarify that Axfood is a relatively small player in the industry. Essentially, Axfood cannot receive more information than they already have, as other industry players do not create *or* share other information. To improve this situation, it is important to assess *what* information is needed, and try to make the industry capture that information, Billinger concludes.

Creating Step
Billinger states that the 5PBs are understandable, "on some level". With little technical knowledge, it is still difficult to grasp *exactly* what the 5BPs or BCT means, but this will always be an issue with scarce technical understanding as precondition, Billinger explains. Åstrand states that the 5BPs are understandable on a reasonable technical level. There is a large threshold in understanding BCT, but this step makes it easier, Åstrand explains. Åstrand think of BCT as a collectively maintained, safe database, that lies in the 'cloud'. If these would be the fundamental attributes of BCT, Åstrand wishes that they were to be lifted earlier in the framework.

For Axfood, the BCT-attribute of a distributed database is the 'only way' of working with traceability and is thus highly relevant, according to Åstrand. Pseudonymity is also useful and relevant, as data integrity is important when cooperating across a supply chain. If Axfood uses BCT for a product that competitors must not see what store-volumes on, pseudonymity becomes important, Åstrand exemplifies. Åstrand concludes this discussion by explaining that irreversible records are fundamentally necessary for any trustworthy traceability system.

Åstrand states that the technical specification is easy to understand, while only persons with technical expertise can fully comprehend this step. Axfood cannot develop a system in isolation, a BCT application must be applicable in the entire industry, Billinger adds. With this mindset, the technological aspects are on a strategic level, as the aspects mentioned must be agreed upon widely by all potential users of the system, Billinger discusses. Åstrand also stresses the impossibility to develop a BCT application in isolation. The framework help them and Axfood see the benefits of BCT, but as Axfood is a part of a larger industry it is difficult to develop these aspects disregarding other industry actors. Billinger concludes the discussion by stating that even for a person with much knowledge in the current traceability efforts, it is still difficult to see the difference between using BCT and *not* using it. With any data, an important aspect is how the data is *created* and how the data is *stored*. Much of the traceability data is very basal and simple, and maybe it does not need to be stored with extensive safety, Billinger adds, suggesting that it is hard to see how BCT would bring relevant benefits to current traceability systems.

Evaluating Step

The suitability assessment tool is easy to understand and highly relevant, according to both Billinger and Åstrand. Åstrand questions Lemieux's conclusion that the 'most suitable' data requirement for BCT is in the bottom left corner. At the same time, Åstrand agrees that the top right corner is not suitable, as people maybe are not as willing to use 'new' technology for such data requirements, but will rather stick with well-established technologies. For Axfood, the interesting quadrants are the top left (pharmaceuticals), and bottom right (consumer products that are expensive or heavily regulated, as fish and meat produce), where they have many products, Billinger explains.

Åstrand discusses that if a business or industry put effort in developing a BCT application, all types of products become relevant for the application. The suitability assessment tool is useful for evaluating "where to start". On another note, Billinger adds that consumers are not willing to pay for anything, and it is important to relate to what driver you had (essentially, either cost benefit or cost reduce).

The applicability assessment tool is also easy to understand, according to both Billinger and Åstrand. They both believe that 'transformation' is what is relevant for Axfood and the industry. They explain that a big idea of using BCT for traceability is coordinating the industry for using an application with standardised formats. Åstrand explains that it *will* take 5 years 'no matter what', for a BCT application to be developed and implemented for traceability efforts, as standardisation-processes always take time. It can almost be stated that the application *needs* to be transformative for it to be interesting, Åstrand concludes.

Regarding the fulfilment analysis, Åstrand asks if this is where the user will know if BCT is to be used or not. Åstrand raises concern that if the 5BPs *could* be met with technology other than BCT, the fulfilment analysis does not assure the user that it is a BCT-application that have been drafted. On the same note, Åstrand elaborates that *if* the draft passes all evaluation tools well and fulfil the 5BPs, it should be irrelevant if a BCT-expert would call the drafted application a blockchain or not. We are looking for the function, not the brand or label, Billinger adds. Maybe the framework is precise enough in defining BCT, Åstrand concludes.

As one part of the fulfilment analysis is to evaluate other solutions parallel to the drafted BCT application, Billinger discusses an issue: Comparing with rival solutions basically means that time must be spent on developing those solutions in parallel. Billinger acknowledges that this framework and thesis project cannot consider the evaluation of other technologies. To conclude this discussion, Billinger states that 'comparing with alternatives' are a bit vaguely presented in the framework, and proposes to emphasise that the comparison can be done in various levels of detail.

Billinger and Åstrand state that the technical limitations analysis is very interesting. Åstrand explains that the technical limitations come as a surprise, having only heard of BCT as a solution to issues rather than a technology subject to its own issues. Throughput is a *very* big issue if the BCT application should be able to be used in every store and check-out, Billinger states. Billinger and Åstrand wishes to see the technical limitations earlier in the framework, as they are highly relevant.

General Aspects of the Framework

On a general note, both Billinger and Åstrand completely agree that the framework is understandable. Åstrand explain that it is easy to comprehend despite lacking knowledge on the subject beforehand. Billinger agrees on this note, while still expressing a slight trouble in understanding the concept of BCT fully, as it is a technical and difficult subject. There could be an introductory 'start up-guide' in the beginning of the framework, providing basic knowledge of BCT for the user that enable an effective use of the framework, Billinger suggests.

On another note, Åstrand discusses that the framework has an issue in that you can spend much time in step one and two, then come to step three and quickly realise that the application is not suitable. It comes back to how strict boundaries you wish to set, and it is a trade-off between drafting a good application and an easily implemented application, Åstrand discusses. Åstrand suggests that this issue is addressed by the user not strictly following a 1-2-3-chronological order, but iterating though the framework more than one time. On that note, Billinger discusses that it is difficult to gather all necessary competences long enough to complete the framework. When iterating through the framework several times, competences can be gathered in diverse groups at separate times, focusing on various aspects in the framework. Using the framework iteratively would address issues regarding the order of the framework's components and steps, Billinger concludes.

Billinger and Åstrand unitedly state that the framework achieves its purpose. The framework evaluates a technology that *supposedly* is BCT, although not *clearly* defining if it *is* BCT or not, according to Åstrand. As previously discussed, if there is no true definition if BCT, it is impossible to address this issue, Åstrand explains.

Billinger and Åstrand completely agree that the framework is an *effective* way of achieving its purpose. Today, the framework has been very useful for us, Åstrand explains. Besides fulfilling its purpose, it has also made us realise that we need to wait for the others in the industry. This type of understanding is very important for any business, Åstrand and Billinger discusses.

On the note of relevance, Billinger and Åstrand consider all components and steps being relevant. However, Åstrand clarify that you can get stuck on the first framework step if you realise that you need to 'wait for others' in the industry. Billinger explains that Axfood's business case is not large enough for them to develop a BCT application on their own. Axfood has power within their private label, being able to demand information being delivered in specific ways to some extents, but Åstrand believes that the driver for the development of BCT applications will come from standards and regulations firstly. In a sense, Axfood and the rest of the industry are waiting for GS1. What the industry needs is baby-steps in the right direction, and such baby-steps often come in collaboration with GS1, Åstrand clarifies. Everything is global, and the only possible solution is a global solution, Billinger concludes.

6.2. INTERVIEW AT SRS

This section begins with a short presentation of SRS and the interviewee, followed by the presentation of the interview's result on each framework step. The interview's discussion on general aspects of the framework is presented lastly.

6.2.1. Presentation of SRS and the Interviewee

Svenska Retursystem (SRS) administrates, manages, and develops the Swedish food industry's return systems of cases and pallets. The Swedish food industry was first with the idea of developing a system with reusable packaging instead of disposable packaging (e.g. cartons in corrugated board). Figure 10 shows an illustration of the reusable packaging's flow in the Swedish food industry.

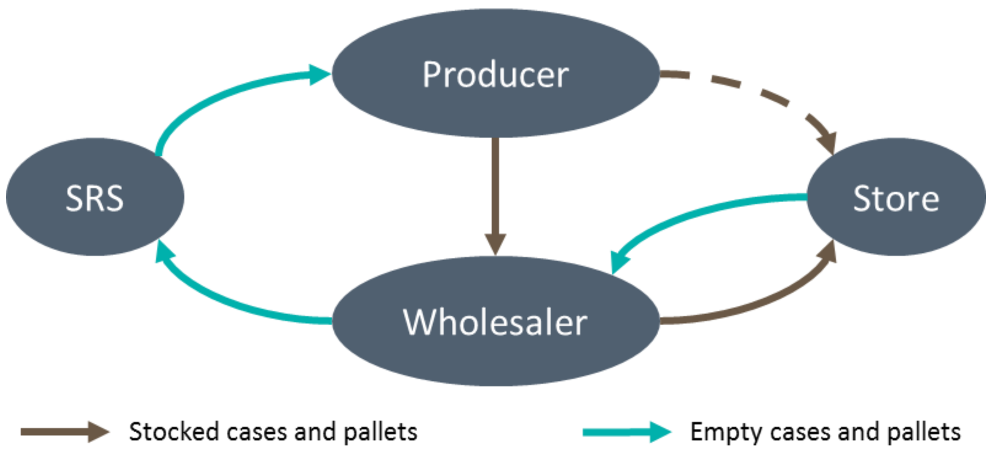


Figure 10. An illustration of the flow of SRS's products in the retail industry.

As Figure 10 shows, SRS administrates a cyclic flow of the reusable packaging. SRS have four locations in Sweden, providing producers with SRS's products. Producers load the reusable cases or pallets with produce. The producers ship mostly to wholesalers, but in some cases directly to stores as well when perishing-dates are short (e.g. dairy products). The wholesalers ship to retail stores, while receiving return flows of SRS's products from the stores. The wholesalers ship the reusable packaging back to one of SRS's locations. An entire cycle typically takes around 6 weeks, according to Engel. Engel is the CIO of SRS.

6.2.2. Result

In summary, Engel found all steps of the framework being easy to understand and relevant. Engel believes the framework achieves its purpose well, and completely agrees that the framework is *effective* in achieving its purpose. The following sections will present Engel's discussion on each framework step and lastly, Engels assessment of general aspects of the framework.

Identifying Step
The drivers for change are easy to understand and inclusive, Engel states. Engel suggests that another "box" that the framework could hold in the beginning of the evaluation process could address the business model. Improving traceability, a business could change the business model, e.g. by new value contribution or new services, Engel explains. SRS is currently developing new technology, resulting in them changing their business model by providing a new service and value to their customers. For SRS, the *driver* was not to change our business model, that is rather an effect of what we are doing, Engel explains. The driver was better control of flows, better quality and visibility, and working proactively with regulatory demands. The *effect* was a new service, that in turn resulted in the changing of the

business model. Engel discusses if this could be captured in "drivers for traceability", as the changing of the business model itself maybe is not the driver but rather a result of other drivers for change.

On another note, Engel wonder what the output of the framework is. At SRS, a plan-do-check-act cycle is used. Looking at the framework, Engel see how the plan-do-check aspects are mostly covered by the framework steps, but do not see any actionable outputs. "What you do when you have done the evaluation, where does it feed to, and do you iterate over the framework again?", Engel asks.

Engel states that the areas of improvement are easy to understand. Understanding only the figure is easy, especially with explanation, Engel elaborates. However, Engel raise concern that when you dig deeply in the AoIs and begin to outline these aspects with detail, the aspects become difficult to discuss on a strategic level. What areas of traceability can be improved should be assessed both technically and strategically, Engel stresses.

Engel explains that SRS work with sprints in change initiatives. First, a "wanted position", or to-be position is determined. Then, the to-be position is compared with the current capabilities, or as-is analysis, to pinpoint what capabilities are needed, what must be changed, and determining in what time-span different improving measures should be addressed. Based on this analysis, objectives are set up in sprints to reach the to-be position, Engel explains. Engel wishes that this this "road-map"-thinking could be adopted in the framework, claiming that this is how businesses typically work with change initiatives. By setting up objectives in sprints, it becomes easier to assess cost, time, and other resources needed, according to Engel.

Another point made by Engel on this framework step was that "tactical" should be used instead of "technical". Engel also argued that the AoIs could be placed in creating step, as a "to-be" position is outlined. On another note, Engel expressed that in the assessment of AoIs, it feels like the business should already have decided to put effort in developing a BCT application-draft, as it is time consuming to perform this assessment detailly.

Creating Step

Engel states that the 5BPs of BCT are easy to understand. They help to understand the basics of BCT well and provide a good insight in what benefits the technology might bring, Engel elaborates. It is relevant to set up delimitations and scope, and the technical specification is comprehensive, Engel states. Engel sees no need for changes in the creating step of the framework.

On a side note, Engel claims that they already have irreversible records. In SRS's system, an approved record cannot be changed but only "corrected" with a new entry.

Evaluating Step

Engel states that all evaluation tools are easy to understand and relevant. Regarding the suitability assessment tool, Engel agrees with the combined conclusions of Lemieux and experts: In the bottom-left corner of the figure BCT is too expensive, and in the very top-right corner of the figure, Engel questions if the technology is "trustworthy enough". The suitability tool does not evaluate the technical solution, which can be slightly unclear for the user, according to Engel. In the creating step, a technical solution is developed, and in the beginning of the evaluation step it is not the technical solution that is directly evaluated, but rather if it can be implemented, Engel elaborates. Engel proposes that the evaluation step should begin with the fulfilment analysis, and that the suitability tool could be used earlier in the framework.

General Aspects of the Framework

On a general note, Engel partly agrees on the idea that the framework is understandable. It is complex and have many dimensions, and it requires the user to put its head to work, Engel explains. Engel expresses that it is a good framework, and the complexity is derived from the technology it evaluates.

Engel repeats that the suitability tool could be used earlier in the framework. It differs from the other evaluation tools in *what* and *how* it evaluates. The other tools assess the implementation, the fulfilment, and impose only minor changes and adjustments in the drafted application. The suitability tool is more definitive and rules out some applications of BCT crudely regarding data requirements, Engel explains.

Engel states that the framework achieves its purpose, but suggests that the user might need to iterate through the framework several times. For instance, when the user gets to technical limitations, this should relate to technical specification, Engel exemplifies. Engel points out that if the framework is iterated through several times starting with a strategic discussion-level, the order of the framework steps becomes less important. The user gets a better grasp of the framework with a brief strategic iteration first. In every iteration, the user can go deeper into details, outlining up- and downsides, limitations, and risks, Engel concludes.

Engel considers the contents of the framework to be relevant, both for evaluating the applicability, *and* for learning about BCT. Engel stresses that learning about the technology and how it *could* be used in one's business is just as important as evaluating its applicability for a specific case of traceability driver. The framework raises interest in the technology, which is important as being up-to-date have become more and more important; a business can never “rest” on current capabilities, Engel discusses.

Regarding the framework figure, Engel suggests the strategic level components being united illustratively, and the technical level correspondingly. The strategic components and technical components are heavily connected, Engel explains. Technical limitations could be a part of the technical specification, Engel exemplifies. Engel considers that illustrating the horisontal connections or flows in the figure would improve the framework figure.

6.3. RESULT FROM POINT-BASED QUESTIONS

In this interview study like the previous, the interviewees were given point-based questions where a statement should be scored regarding the following directions:

1. Completely disagree with the statement
2. Partly disagree with the statement
3. Partly agree with the statement
4. Completely agree with the statement

Table 13 shows a summary of the interviewees’ scoring on the point-based questions in this interview study.

Table 13. The interviewees’ scores on each statement in interview study B.

Statement	**Åstrand**	**Billinger**	**Engel**	**Average**
The framework is easy to understand	4	4	3	**3.67**
The framework’s steps and components are relevant	4	4	4	**4**
The framework is effective	4	4	4	**4**

The table shows that the interviewees completely agreed with the statements of the framework having relevant steps and being effective. All interviewees except Engel fully agreed that the framework is easy to understand. Engel elaborated that the framework’s comprehensiveness is affected by the complexity of the phenomenon it evaluates. It is difficult to make BCT easy to understand, Engel explained, while acknowledging that the framework successfully simplifies the complexity of the phenomenon.

6.4. ANALYSIS

This section begins by analysing the interviews' results on each framework component and step, chronologically. Secondly, the interviewees' discussions on general aspects of the framework are analysed. Lastly, the analysis is concluded with the presentation of what changes are made to the framework.

6.4.1. Review of the Framework's Components and Steps

This section presents the framework's components and steps chronologically, beginning with the identifying step followed by the creating- and evaluating step.

Identifying Step

The interviewees suggested a customer perspective to be added to traceability drivers, regarding transparency and PR. The interviewees argued that the current drivers did not consider these aspects. While this perspective could be related to CSR or quality assurance (where PR and transparency can facilitate showcasing these concepts to customers), general improvement of PR and transparency capabilities can be the predominant driver for traceability.

Another point made regarding the drivers for traceability was the suggestion to add a business-model perspective in the beginning of the framework. The suggestion was motivated with a specific business case of SRS that changed their business model. The business case had original drivers related to cost-saving and value-add, motivating 'traceability drivers' still being the first component of the framework. The proposal would thus mean adding a business-model following the driver-component. The authors argue that assessing business-model aspects could be done when assessing AoIs as well, as new value propositions could be illuminated in that component too. Essentially, the business-model permeates the entire framework. Despite this, whether the business model is changed or not does not influence the conclusions made from the framework, the authors argue.

Regarding AoIs, the interviewees suggested that a road-map thinking could be adopted. The suggestion was well motivated with discussing how businesses typically work with change initiatives in this way, and that a detailed gap-analysis (between an as-is and to-be situation) enables setting up objectives in sprints with easily assessable resource needs. The authors argue that the suggestion does not conflict other remarks on the framework, and that the suggestion should be applied the framework's description of the AoI-component. On the note of AoI, the interviewees discussed that it is difficult for the user to put much effort in outlining the AoIs detailly. The effort would be easier to motivate if a decision already would have been made on putting effort in assessing BCT. The authors note that this is the first suggestion that the framework should be iterated through more than one time in this analysis.

Regarding the AoIs, the interviewees discussed that there is a strategic *and* technical level of this component. The authors will argue that the strategic level is intended to be understandable for decision-makers without technical expertise, while the technical level facilitate a discussion and delineating with more technical detail. The distinction between strategic and technical is based on this intention, and does not prevent the technical level being discussed strategically. Another suggestion was changing the word *technical* to *tactical*, as the words strategical and tactical are often used in combination: A strategical perspective focuses the *what*, while a tactical perspective focuses on *how*. This corresponds well with the components in the framework, the authors argue:

- The driver for traceability is the *what*, the AoIs *how* to achieve it.
- 5BPs of BCT is the *what*, and the technical specification defines *how* the BCT will achieve these properties.
- The strategical-level evaluation tools define the conclusion of the framework and assesses its implementation (*what*). The 'technical limitations' assess *how* the drafted application are subject to limitations, and connecting with 'technical specification' it helps analysing *how* these limitations can be addressed.

Another point made on the AoIs was that this component could be in the creating step of the framework, as a 'to-be'-assessment is of creative nature. The authors will argue that a major distinction between the first and second step of the framework, is whether the user of the framework identify *traceability* drivers and improving measures or create a *BCT* application draft. The distinction between traceability and BCT between step one and two is evidentially relevant as no other remarks have been made on this being difficult to comprehend by other interviewees.

Creating Step

The interviewees described the 5BPs of BCT as very important and very helping in the understanding of what BCT is. Concerning the previous interview study's analysis and the second query, the connection between step one and two in the framework is evidentially no longer vague but distinct and easy to comprehend. The interviewees discussed that it would be interesting for the user of the framework to see general attributes of BCT earlier. The authors understand that even though the empirical data unanimously show that the framework should be gone through in the order presented understanding BCT briefly in step one could be benefitted from. The authors note that this could be a second remark supporting the suggestion that the framework should be iterated through more than one time, as the general attributes of BCT would be reached quickly if the framework is first iterated through briefly on a strategic-level.

One remark on the technical specification was that this need to be discussed on a strategical level as well, especially if several businesses together discuss the development of a BCT application. The authors consider this being a sound point, and as previously have been argued the framework does not prevent the technical level being discussed strategically.

Evaluating Step

While the interviewees considered the evaluation tools of the evaluating step being relevant and easy to understand, some remarks were made on the order in which the evaluation tools were presented. One suggestion was that the suitability tool should be presented earlier in the framework. Similarly, it was suggested that the technical limitations should be presented earlier due to their relevance for the application's drafting. Evaluating the suitability-tool earlier in the framework has been proposed by experts in the first interview study as well. That proposal partly lead to the appending of a new component in the creating step, 'setting up the scope', where it was suggested that the user should review the suitability- and applicability assessment tool to set potential delimitations. It seems that interviewees in both interview studies wish to evaluate earlier in the framework, cutting to the chase, in a sense. The authors argue that it is difficult for the user to thoroughly assess these frameworks without having made a technical specification. There is a trade-off between evaluation-efficiency and understanding the underlying phenomenon, which can be complex and incomprehensible. The authors note that iterating through the framework on a brief level first followed by a more detailly iteration could address the issue: The user would be able to briefly understand BCT and consider important evaluation aspects, setting boundaries or adding resources for the case.

Engel made a remark claiming that the suitability tool is more definitive than the other evaluation tools, and that it has the power to rule out some applications early on if they have the wrong data requirements. This made the authors realise that the suitability tool must be tied directly to the drafted application and not only to the underlying data requirements. If the data requirements are high, the drafted application must be secure and reliable. Likewise, if the data requirements are low (e.g. registering every coffee purchase), the drafted application might need high throughput and demand low bandwidth. These attributes of the application are directly dependant on the technical specification, and hence they can't be evaluated before the application has been drafted. These new insights will be provided in the framework.

Another suggestion was performing the fulfilment analysis firstly in the third step, as it is the evaluation tool most directly connected with the application created in the previous step. The authors consider the order of the evaluation tools being of little relevance as all evaluation tools should be considered, but as the concern have been lifted by interviewees the fulfilment analysis will be placed first in the evaluation step.

The interviewees remarked that the comparison with rival solutions in the fulfilment analysis could be very time consuming. With the remark, the interviewee acknowledged that the framework cannot guide the user in assessing rivalling technologies as well, but suggests that the framework recognises this issue. The authors consider this suggestion being modest; the framework can clarify this issue.

Another remark made by the interviewees were that the fulfilment analysis does not accurately show that it is a *BCT* application that has been drafted. On this remark, the interviewees disputed themselves, acknowledging that whether the drafted application is *truly* BCT is irrelevant. The authors still claim that the 'technical specification'-component specifies one definition of BCT, so the drafted application should undeniably be a blockchain application according to this definition. While the fulfilment analysis does not review if these definitions have been fulfilled, the authors argue that if that the drafted application is *not* BCT, the tactical component of step two has been performed incorrectly.

6.4.2. Analysis of General Aspects of the Framework

On a general note, all framework steps and components were easy to understand, representative, and relevant according to all interviewees. Considering the scoring on the point-based questions, Table 13 on page 64 shows full support from the interviewees in settling query four through six: The framework is easy to understand, consists of relevant steps and components, and is effective in achieving its purpose.

A reoccurring topic in the interview study was the need to iterate through the framework more than one time. In the review on framework steps and components, the analysis suggested this on several notes. Discussing the framework's general aspects, the interviewees further added to this argumentation. One point was made that that a start-up guide of BCT would be presented early in the beginning of the framework, granting the user with basic understanding of BCT in the first step of the framework. The interviewees unanimously expressed that the second and third step of the framework gave such understanding; a first brief iteration of the framework could function as a start-up guide. Another argument for iterating the framework was that much time can be spent on step one and two, coming to critical conclusions first in step three. With brief understanding of step three, such interruptive evaluation conclusions could be prohibited. Moreover, it was pointed out by interviewees that there is a difficulty in getting together all competences necessary to reach the framework's conclusion, motivating the framework being iterated through several times with diverse groups and competences.

To conclude the discussion on iterating through the framework more than one time, the authors will suggest the user in the framework to iterate through the framework two times. The framework aims at providing an answer to whether BCT is applicable for improving traceability or not; if the framework were to be endlessly iterated through cyclically it would fail to conclude and fail in achieving its purpose. The authors recommend a brief iteration of the framework, mostly focusing on strategic-level discussions, followed by a second iteration with sufficient level of detail on tactical levels to decide on BCT's applicability.

A remark made by interviewees were that the framework is unclear what is acted upon. Relating to a "plan-do-check-act"-cycle, the framework captures all aspects but 'act', it was discussed. The authors repeat that the framework's purpose is to reach conclusions on the applicability of BCT to improve traceability; the framework disregards how the conclusions are acted upon.

Regarding the framework figure, it was suggested that the strategic- and technical levels of the framework should be connected graphically. Motivating this suggestion, the interviewees argued that the framework components are heavily interrelated. Especially, it was noted that the technical specification and assessment of technical limitations are interrelated to such extent that the user should keep the limitations in mind when outlining the technical specification, and that the technical specification should be directly assessed and revised regarding found technical limitations. Regarding this, the authors will argue that the picture already illustrates two flows in the picture: The numbering of steps shows a '1-2-3'-order and the strategic level 'feeds' into the technical level with an arrow-shape. Essentially, the technical level-components are detailed outlining representing *how* to reach the strategic *what* (as previously discussed). If the strategic components are related, the technical components are related by extension. In the technical specification, the identified areas of improvement must be addressed. In assessing the technical limitations, the technical specification is evaluated and potential revisions can be suggested. The framework could point out this connection.

Considering the suggested improving measures in this analysis, the authors revisit the previous discussion that led to the appending of the 'Setting up the Scope'-component in the framework. This component was appended to the framework in the previous interview study, with the motivation that the user could benefit from setting up delimitations for the BCT-draft. To enable setting up delimitations without out-scoping finding the 'best' solution, the user was suggested to look at the evaluation tools briefly. The authors will argue that with the newly suggested changes, this component has become redundant. First, it has been suggested to iterate through the framework on a strategic and brief level which essentially *is* what this component suggested. Second, with an emphasis on the connections between the technical components, the pinpointed AoIs effectively delimit the BCT draft; the goal of the technical specification is besides meeting the 5BPs of BCT, to assure that the AoIs are addressed.

6.4.3. Concluding Analysis and Development of the Final Framework

Reviewing the interviewees' inputs and score on statements, all queries in interview study B are settled:

- *Query 4*: Is the framework easy to understand?
- *Query 5*: Are the framework's steps and components relevant?
- *Query 6*: Is the framework effective?

The following list presents conclusions that will result in minor changes of the framework:

1. In 'Drivers for Traceability', a customer perspective is added regarding PR and transparency
2. The word 'technical' is changed to 'tactical'
3. The tactical level components are connected illustratively, to emphasise that they are heavily interrelated
4. Discussions regarding the usage and conclusions from the evaluation tools are added to the framework
5. The framework should be iterated through twice, with a brief, strategic-level iteration first.
6. Iterating through the framework twice and emphasising the close connection between the tactical components, the 'set up the scope'-component becomes redundant.

In the following chapter, the final framework is presented, both in an illustrative- and descriptive version.

7. Final Framework

Figure 11 shows the illustrative figure of the final framework, and Figure 12 on the next page shows the descriptive figure.

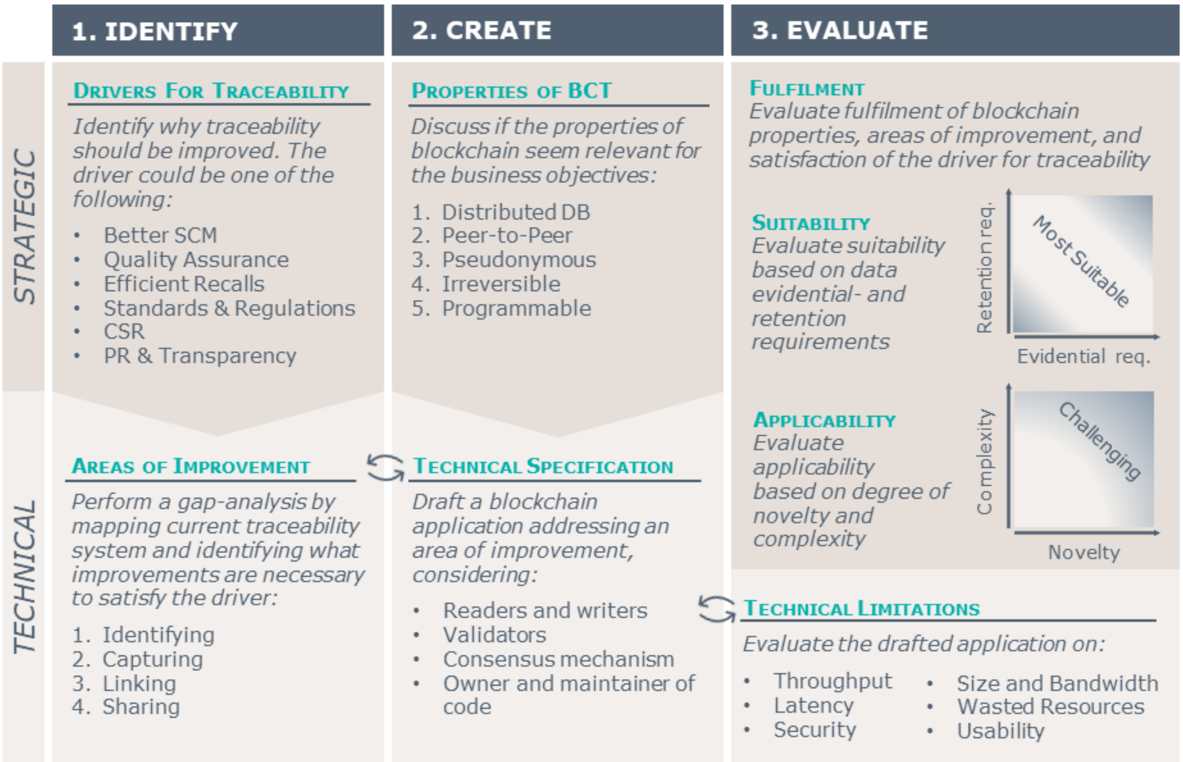


Figure 11. The final framework: Illustrative Figure.

EVALUATION FRAMEWORK: USING BLOCKCHAIN TO IMPROVE TRACEABILITY

The framework consists of three steps that should be addressed sequentially. The framework should be iterated through briefly first, assessing overall feasbility and resources needed to complete a second, full iteration of the framework.

The framework is divided into <u>strategic</u> and <u>tactical</u> components. The strategic components should be relatively easy to comprehend and are primarily aimed for open discussions, while the tactical components require some technical expertise. The strategic components feed into the tactical components, which in turn are connected closely: The technical specification should address the areas of improvement, and the technical limitations are closely related to what application have been drafted in the technical specification.

1. IDENTIFY

A. Driver for Change [Strategic]

Identify *why* traceability should be improved. The driver could be one of the following:

- <u>*Better SCM*</u>: Efficiency and cost reduction
- <u>*Quality Assurance*</u>: Assuring intangible quality attributes
- <u>*Efficient Recalls*</u>: *Trace* to find the cause of the non-compliance, and *track* to find affected customers.
- <u>*Standards & Regulations*</u>: Following standards to attain benefits (e.g. certifications), or complying with regulations to avoid sanctions (e.g. EU-regulations)
- <u>*CSR*</u>: Taking social responsibility and making sure that the products are produced with concern to ethical working conditions and environmental impact
- <u>*PR & Transparency*</u>: Broadcasting CSR or quality, or gaining benefits from general improvement of PR and transparency capabilities

B. Areas of Improvement [Tactical]

Map current state (as-is) and define what capabilities are needed to address the driver (to-be) in a gap-analysis. The following four traceability capabilities should be regarded:

1. <u>*Identifying*</u>: The capability to identify traceable resource units (TRUs).
   - How are TRUs identified in the supply chain?
   - What is the precision and granularity of TRUs?
2. <u>*Capturing*</u>: The capability to capture relevant information of TRUs and events.
   - How is relevant data at traceable events captured in the supply chain?
   - What is the breadth and depth of the traceability system?
3. <u>*Linking*</u>: The capability to link inputs to outputs in processing of TRUs.
   - Are there any troubles in achieving internal traceability and linking inputs to outputs?
4. <u>*Sharing*</u>: The capability to share traecability data.
   - How is master- and transactional data shared between traceability parties?
   - Is a pull- or push system used?
   - Are there any issues in achieving external traceability?
   - Are there any conflicting interests for sharing data?

Keep in mind that:

- The most urgent areas of improvement could be with upstream suppliers or other traceability parties.
- Traceability systems that work well in isolation does not guarantee traceability on a global scale

2. CREATE

A. Properties of Blockchain [Strategic]

Discuss the five key properties of blockchain technology, and assess if they seem useful:

1. <u>*Distributed Database*</u>: Data is stored on several places. There is no central point of attack, and the system can be more stable as there will likely always be at least one active node.
2. <u>*Peer-to-Peer Transmission*</u>: New entries in the database is communicated directly between nodes. No central authority controls the communication, but the system can be less agile.
3. <u>*Pseudonymity and Transparency*</u>: Virtual identities can hide true identities, allowing for transparency with integrity.
4. <u>*Irreversible Records*</u>: Records are very hard to alter or remove, making them reliable regarding documentary truth.
5. <u>*Programmable*</u>: Rules can be set for how the system should work, allowing for e.g. smart contracts where transactions can automatically trigger further events.

B. Technical Specification [Tactical]

Draft a blockchain solution where data is stored in blocks and linked to previous blocks mathematically in a chronological order. The draft should address the following questions:

- Who can become a node with permission to read the entries?
- Who can become a node with permission to write new entries?
- Who can become a node with permission to validate/discard entries made by other users?
- How are transactions validated?
- Who owns and maintains the source code?
- How does the network reach consensus regarding the transaction history?

Draft the application considering the gap-analysis in step 1:B, ensuring that the it addresses the area(s) of improvement.

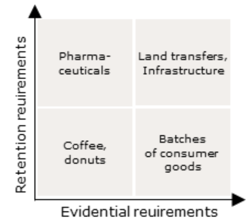
3. EVALUATE

A. Fulfilment [Strategic]

- Does the application reach the properties desired? Could these properties be reached using other solutions?
- Does the application improve the area(s) of improvement regarding traceability? Could these areas have been improved by other means?
- Does the application satisfy the identified driver? Could the driver be satisfied by more efficient means?

B. Suitability [Strategic]

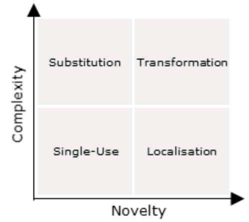
Consider the data's evidential- (related to the value of the transaction) and retention requirements. Data requirements that are either too high or too low are less suitable initially. With too low data requirements the security of the database structure is not needed, and with too high data requirements better tested applications are preferred. The suitability conclusion depend heavily on the technical specification in step 2:B.



C. Applicability [Strategic]

How many parties need to be involved in the application (complexity) and what is the novelty of the solution? The following could aid conclusions:

- <u>*Single-use*</u>: Could be implemented immediately
- <u>*Localisation*</u>: Could be tested if it seems promising
- <u>*Substitution*</u>: Better functionality must be communicated to enable substitution.
- <u>*Transformation*</u>: Research and develop - Could require social, legal, and political changes before they can be implemented.



D. Technical Limitations [Tactical]

Assess the following possible limitations, found in the Bitcoin blockchain:

- <u>*Throughput*</u>: The current Bitcoin network has only a capacity of seven transactions/second. In comparison, VISA provide 2000 transactions/second.
- <u>*Latency*</u>: A Bitcoin transaction takes roughly 10 minutes to complete, as this is the time it takes for a Bitcoin block to be created.
- <u>*Size and bandwidth*</u>: The entire Bitcoin blockchain is over 100 GB (Feb. 2017). Each block is around 1 MB, and the creation of a new block every 10 minutes imposes a limitation of transaction capacity with the current bandwidth.
- <u>*Security*</u>: The Bitcoin blockchain can be subject to a 51 % attack, malleability problems and authenticity or cryptography issues.
- <u>*Wasted resources*</u>: Proof-of-work mining "wastes" huge amounts of energy each day, with the sole purpose of maintaining consensus in the database.
- <u>*Usability*</u>: The Bitcoin application programming interface is not developer-friendly, and difficult to use.

Figure 12. The final framework: Descriptive Figure

8. CONCLUSIONS AND DISCUSSION

This chapter concludes this thesis project. First, the study's purpose and research questions are answered. Secondly, contributions to theory, limitations of the study and suggestions to future research are presented. Lastly, final conclusions from the study are discussed, concerning both the framework and BCT in general.

8.1. ADDRESSING PURPOSE AND RESEARCH QUESTIONS

The purpose of this thesis project was "to develop a framework for evaluating the applicability of blockchain technology in supply chain management to improve traceability". As the empirical results clarify that the framework can be used to effectively evaluate the applicability of BCT to improve supply chain traceability, the thesis project's purpose has been fulfilled by extension.

RQ1. Which inputs are necessary to evaluate blockchain as a means for improved traceability?

The final framework on page 71 is the answer to the first research question. To evaluate blockchain technology as a means for improved traceability, the objectives for the contingent changes are specified. The objectives can be split into the drivers for improved traceability and areas of improvement for the current traceability system. Then, the properties of BCT are discussed to assess how the technology could fit the business objectives. Next, a blockchain application is drafted with a technical specification to enable finally evaluating the application as a means for improved traceability.

RQ2. How can blockchain be used to improve traceability?

This study shows that determining how blockchain can be used to improve traceability is difficult. While the interviewees in phase three could easily discuss the strategic components of the framework and connect their business situation to the contents of the components to some extent, the discussions in the tactical components struggled to specify *how* blockchain technology should be used.

Some implementations of blockchain have been discussed by the interviewees in this study. One use-case discussed was to use BCT for digital certificates of products. As the product is transacted through the supply chain, the digital certificate also changes owner, with the blockchain ensuring that each product has only one corresponding certificate. However, the database structure can only preserve documentary truth, and a question that remains is how to ensure historical truth, i.e. how an actor in the supply chain can be prevented from sending a fake product together with a legitimate certificate, while selling the real product without a certificate. The inability to link historical truth with documentary truth presents another issue: If an event is falsely recorded, documentary truth might ensure the safekeeping of incorrect information. Yet another challenge is to determine who should issue the certificates. Öberg (2017a) discussed a conceptual model for digital certificates in the meat industry, where DNA tests can provide the link between historical truth and documentary truth. This implementation could support trustworthy certificates to relevant parties. At this point one must discuss the feasibility of the proposed solution, with questions as: Who should finance the implementation? Does the consumer care that the supply chain uses BCT-certificates or would they rather see a well-known certificate (e.g. Fairtrade) on the package? How is the implementation profitable? Certificates of this type only cover one small area of traceability, and does not correspond directly to the drivers concerning efficient recalls or standards and regulations, which were the most prominent drivers for the companies in this study and their traceability efforts.

Another use-case discussed was to store the same type of traceability data as today, only in a distributed fashion using a blockchain. The first question that needs answering is to determine the extent of said blockchain. It could either be one blockchain per supply chain, with localised solutions where technology seems relevant and promising. However, you can't expect large actors to have a separate system for each supply chain, and the development of localised solutions doesn’t necessarily improve traceability on a larger scale. It could also be one larger blockchain covering multiple supply chains, but such blockchains will likely blow up in size quickly if it should hold enough breadth and depth to be useful in a traceability context. It will also require substantial efforts in standardising master- and transactional data to be applicable. A significant benefit of a universal traceability-blockchain is that everyone is using the same platform, enabling easy access to the entire history of a product. However, this benefit is not a result from blockchains per se, but rather a benefit from integrated data-systems and cooperation between supply chain entities. Any type of integrated system would have similar benefits and it is hard to see what BCT provides that other implementations don't. Possibly, everyone owning the platform together instead of everyone giving their data to a trusted third party could be a benefit. This triggers further questions such as: Do the actors feel safer in sharing their information in a distributed network rather than sharing it with a trusted third party? Who owns and develops the source code? Do the companies trust the implementation? While many blockchain applications can provide high security, the security of a specific blockchain application is entirely dependent on its technical specification, how it is implemented, and how it is maintained.

8.2. Contributions, Limitations and Future Research

This study contributes to theory with a framework that could be used in further research in studies with the framework as protocol. The study further contributes with new conclusions regarding BCT in the context of traceability, where limited research has been conducted previously.

Current literature provides no *true* definition of BCT, and BCT-professionals confirm that no such definition exists. Consequently, different definitions of BCT could render different evaluation frameworks and conclusions. While businesses are not interested in what the coherent definition of BCT is, it is important to unambiguously define the phenomenon being studied for research purposes. The authors recognise that the framework developed in this study should be revised if a coherent definition of BCT are agreed upon in the future. The novelty of the research area makes it not only difficult to find a rigorous theoretical foundation, it also makes it difficult to find sources of empirical data. Would there exist more implementations of BCT in SCM, such cases could be studied to collect empirical data. Likewise, with more BCT-professionals and businesses knowledgeable in the research area, surveys or additional interviews could have been conducted to challenge existing theory or to reach further conclusions.

Future research might include using this framework in a broader study with many businesses involved in supply chain traceability, to reach conclusions on for example which types of products and supply chains are suitable for the technology. Furthermore, as the second and third step of the framework are not specific for SCT, the components of the first step of the framework could be replaced for it to function for evaluating BCT in another context. Finally, this framework focuses on creating a *new* BCT application, instead of utilising an existing BCT application and piggybacking on their infrastructure. This is a choice made by the authors, not necessarily because it is the right way to go for businesses, but rather limited time to investigate both paths. Further research could investigate the possibilities of using an existing application instead of creating a new application.

8.3. Discussion

In the world of Bitcoins, each coin can be traced to its origin and all transactions are transparent. These two properties are aligned with some of the core properties of a successful traceability system. This may lead companies to believe that the technology behind Bitcoin must be useful to reach the same properties in a traceability system. Even the linguistic similarities in *blockchain* and *supply chain* seem to lead people to believe that the two concepts have an inherent connection. In the framework developed in this study, the user is asked to specify the areas of improvement for the traceability system and try to address these areas directly with the technical specification of the blockchain application, and at this point it is no longer apparent that BCT is the most suitable solution in reaching the wanted position.

There are many popular reports on BCT, describing how the technology can be used to reach great benefits in diverse areas. This study dives deep into one specific area and focuses on how the technology can improve *traceability*. To serve this study's scientific purpose, the framework has a distinct focus which might not always align with the business perspective. Businesses are not interested in restricting their evaluation of the technology to only improve traceability, they are interested in any kind of benefits the technology might bring. Relatedly, businesses are not only interested in developing an application which has the "permission" to be considered a blockchain, they are interested in any type of application if it is valuable to their business. This conflict of interest is difficult to circumvent, as the framework can't always be scientific and practical at the same time.

BCT implies high levels of coordination and standardisation. This can easily result in evaluations on the effects of BCT essentially being an evaluation on the effects of coordination and standardisation. The same problems that are hindering supply chain integration and standardisation are also hindering the development of BCT implementations. Two prominent issues that have been identified in this study are confidentiality issues (i.e. companies being resilient to share private information to potential competitors), and the technological development (or lack thereof) in the upstream suppliers. An appropriate evaluation of blockchain technology should compare the proposed solution to solutions which demand the same degree of coordination, standardisation, transparency, and development, and not only compare it to the solutions of today which often require minimal efforts in comparison.

This study also shows that it can be difficult to grasp the idea of BCT without significant guidance. Perhaps this is partly the reason for BCT being hyped:

Businesses hear and read of BCT as a panacea, but don't understand the technology sufficiently to challenge how it is being promoted. Meanwhile, the endorsement of BCT as the perfect solution is made by businesses that can turn the hype into revenue, they don't benefit from criticising the technology. While the framework helps researchers and businesses understand BCT, this study also shows that BCT does not offer a turn-key solution. If there existed apparent applications of BCT without limitations or drawbacks, such applications would already have been implemented. Still, despite not offering any low-hanging fruit, the interviewees expressed that the technology has *properties* that are desirable for supply chain traceability on a *strategic* level. As the developed framework also functions as an educative tool for understanding BCT, it enables researchers and businesses to explore and find novel ideas on how to harness its capabilities.

9. References

Aung, M. M., Chang, Y. S., 2014. Traceability in a food supply chain: Safety and quality perspectives. *Food Control*, Vol. 39, pp. 172-184.

Axfood, 2017. About Axfood. Available at: http://axfood.se/en/About-Axfood/. Accessed 2017-05-05.

Bechini, A., Cimino, M., Marcelloni, F., Tomasi, A., 2008. Patterns and technologies for enabling supply chain traceability through collaborative e-business. *Information and Software Technology,* Vol. 50, Iss. 5, pp. 342-359.

Berman, B., Swani, K., 2010. Managing product safety of imported Chinese goods. Business Horizons, Vol. 53, Iss. 1, pp. 39-48.

Billinger, K., 2017. *Interview Study B: 1 – Axfood* [Interview] (2017-05-05).

Blomborn, E., 2017. *Interview Study A: 4 – Traceability* [Interview] (2017-04-24).

Bozarth, Cecil C., Handfield, Robert B., 2006. Introduction to Operations and Supply Chain Management, New Jersey, USA: Pearson Education.

Catela, K., 2017. *Interview Study A: 1 – Traceability* [Interview] (2017-04-11).

Dobrovolskis, D., 2017. *Interview Study A: 1 – Traceability* [Interview] (2017-04-11).

Engel, J., 2017. *Interview Study B: 2 – SRS* [Interview] (2017-05-08).

English, Matthew S., Nezhadian, Ehsan., 2017. Application of Bitcoin Data-Structures & Design Principles to Supply Chain Management. University of Bonn.

European Commission, 2002, chapter 1, article 3, no. 15. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1488202332570&uri=CELEX:32002R0178. Accessed at 2017-03-15.

Golan, E., Krissoff, B., Kuchler, F., Calvin, L., Nelson, K., Price, G., 2004. Traceability in the US food supply: economic theory and industry studies. Agricultural Economic Report, Iss. 830, No. 3, pp. 1-56.

GIA (Gemological Institute of America), 2017. Diamond Quality Factor. Available at: https://www.gia.edu/diamond-quality-factor. Accessed at 2017-03-15.

GS1, 2012. GS1 Standard Document: GS1 Global Traceability Standard. Available at: http://www.gs1.org/sites/default/files/docs/traceability/Global_Traceability_Standard.pdf. Accessed 2017-02-23.

GS1, 2017a. GS1 Identification Standards. Available at: http://www.gs1.se/en/our-standards/Identify. Accessed 2017-03-14.

GS1, 2017b. How GDSN Works. Available at: http://www.gs1.org/how-gdsn-works. Accessed 2017-03-21.

GS1, 2017c. EPCIS and Core Business Vocabulary. Available at: http://www.gs1.org/epcis. Accessed: 2017-03-21.

Hampton, N., 2016. Understanding the blockchain hype: Why much of it is nothing more than snake oil and spin. *Computerworld*. Available at: http://www.computerworld.com.au/article/606253/understanding-blockchain-hype-why-much-it-nothing-more-than-snake-oil-spin/. Accessed: 2017-02-20.

Höst, M., Regnell, B., Runeson, P., 2006. *Att genomföra ett examensarbete.* Lund, Sweden: Studentlitteratur.

Iansiti, M., Lakhani, K., 2017. The Truth About Blockchain. *Harvard Business Reveiw*, Vol. 95, No. 1, pp. 118-127.

Kalogianni, E. P., Tektonidis, D., Salampasis, M., 2012. TraceALL: a semantic web framework for food traceability systems. *Journal of Systems and Information Technology*, Vol. 14 Iss. 4, pp. 302-317.

Kharif, O., 2016. Blockchain May Help Walmart Stop Bad Food. *Bloomberg Businessweek*, Issue 4501, pp. 20-21.

Kotzab, H., Seuring, S., Müller, M., Reiner, G., 2005. *Research Methodologies in Supply Chain Management*. Heidelberg, Germany: Physica-Verlag.

Lemieux, V. L., 2016. Trusting records: is Blockchain technology the answer? *Records Management Journal*, Vol. 26, No. 2, pp. 110-139.

Loop, P., 2016. Blockchain: The Next Evolution of Supply Chains. *Material Handling & Logistics*, Vol. 71, No. 10, pp. 22-24.

Marucheck, A., Greis, N., Mena, C., Cai, L., 2011. Product safety and security in the global supply chain: Issues, challenges and research opportunities. *Journal of Operations Management*, Vol. 29, Iss. 7-8, pp. 707-720.

Moe, T. 1998. Perspectives on traceability in food manufacture. *Trends in Food Science & Technology*, Vol. 9, No. 1, pp. 211-214.

New, S., 2010. The Transparent Supply Chain. *Harvard Business Review*, Vol. 88, No. 10, pp. 76-82.

Nakamoto, S., 2008. Bitcoin: A Peer-to-Peer Electronic Cash System. Available at: https://Bitcoin.org/Bitcoin.pdf. Accessed: 2017-03-21.

Olsen, P., Borit, M., 2013. How to define traceability. *Trends in Food Science & Technology*, Vol. 23, pp. 142-150.

Parmigiani, A., Klassen, R., & Russo, M., 2011. Efficiency meets accountability: Performance implications of supply chain configuration, control, and capabilities. *Journal of Operations Management*, Vol. 29, No. 3, pp. 212-223.

Rowley, J., Slack, F., 2004. Conducting a literature review. *Management Research News*, Vol. 27, Iss. 6, pp. 31-39.

Saak, A. E., 2016. Traceability and reputation in supply chains. International Journal of Production economics, Vol. 177, pp. 149-162.

Tian, F., 2016. An agri-food supply chain traceability system for China based on RFID & blockchain technology. *Service Systems and Service Management* (ICSSSM), 2016 13th International Conference on. IEEE, 2016.

Unnervik, N., 2017. *Interview Study A: 2 - Blockchain technology* [Interview] (2017-04-18).

Yin, R. K., 2003. *Case study research: Design and methods*. 3rd edition. United States of America: Sage Publications.

Yli-Huumo, J., Ko, D., Choi, S., Park, S., Smolander K., 2016. Where Is Current Research on Blockchain Technology? - A Systematic Review. *PLoS ONE*, Vol. 11, No. 10, pp. 1-27.

Åstrand, J., 2017. *Interview Study B: 1 – Axfood* [Interview] (2017-05-05).

Öberg, L., 2017a. *Discussion on blockchain technology* [Interview] (2017-03-08).

Öberg, L., 2017b. *Interview Study A: 3 – Blockchain technology* [Interview] (2017-04-19).

10. APPENDICES

10.1. INTERVIEW STUDY A: TRACEABILITY

This is the interview guide for traceability experts in interview study A.

Instructions

This interview guide uses point-based questions. "*This is a statement*". Each statement should be rated and motivated:

1. I completely disagree with the statement
2. I partly disagree with the statement
3. I partly agree with the statement
4. I completely agree with the statement

Introduction

- What is your profession and role?
- How long have you worked with traceability?
- Do you have any experience in blockchain technology?

Framework Discussion

Step 1

- "*The drivers for change are accurate*"
- Are there other drivers for change?
- "*The areas of improvement are suitable*"
- Are there other areas of improvement?
- "*The first step is easy to understand*"
- *"It is easy to proceed from step one to step two"*

Step 2

- "*The five basic principles of blockchain technology are easy to understand*"

Step 3

- "*The evaluation tools are easy to understand*"
- "*It is easy to see the connection between step one and step three*"

General Aspects

- "*The framework is easy to understand*"
- "*The framework is effective*"

10.2. INTERVIEW STUDY A: BLOCKCHAIN

This is the interview guide for BCT experts in interview study B.

Instructions

This interview guide uses point-based questions. "*This is a statement*". Each statement should be rated and motivated:

1. I completely disagree with the statement
2. I partly disagree with the statement
3. I partly agree with the statement
4. I completely agree with the statement

Introduction

- What is your profession and role?
- What is your experience in blockchain technology?
- Do you have any experience in supply chain management or traceability?

Framework Discussion

Step 1

- "*The first step is easy to understand*"
- "*It is easy to proceed from step one to step two*"

Step 2

- "*The five basic principles of blockchain technology are accurate*"
- "*The five basic principles of blockchain technology are easy to understand*"
- "*It is easy to proceed from step two to step three*"

Step 3

- "*The suitability evaluation tool is relevant*"
- "*The adoption evaluation tool is relevant*"
- "*The technical limitations evaluation tool is relevant*"
- Are there other relevant evaluation tools or aspects?
- "*The suitability evaluation tool is easy to understand*"
- "*The adoption evaluation tool is easy to understand*"
- "*The technical limitations evaluation tool is easy to understand*"
- "*It is easy to see the connection between step one and step three*"

General Aspects

- "*The framework is easy to understand*"
- "*The framework is effective*"

10.3. POINT BASED QUESTION RESULTS IN INTERVIEW STUDY A

Table 14 presents the traceability expers' score on the statements, and Table 15 on the following page shows the BCT experts' score.

Table 14. The traceability experts' complete scoring on the statements.

Statement	Blomborn's Score	Catela's Score	Dobrovolskis' Score	Average Score
The drivers for change are accurate	4	4	4	**4**
The areas of improvement are suitable	4	4	4	**4**
The identifying step is easy to understand	4	4	4	**4**
The creating step is easy to understand	2	1	1	**1.33**
The evaluation tools are easy to understand	3	3	3	**3**
It is easy to proceed from the identifying step to the creating step	2	1	1	**1.33**
It is easy to see the connection between the identifying- and evaluating step	2	2	2	**2**
The framework is easy to understand	3	4	4	**3.67**
The framework is effective	3	2	2	**2.67**

Table 15. The BCT experts' complete scoring on the statements.

Statement	**Unnervik's Score**	**Öberg's Score**	**Average Score**
The identifying step is easy to understand	3	4	**3.5**
The creating step is accurate	2	3	**2.5**
The creating step is easy to understand	4	4	**4**
The suitability tool is relevant	4	3	3.5
The applicability tool is relevant	4	3	3.5
Technical limitations are relevant	4	4	4
The evaluation tools are relevant (average)	4	3.33	**3.67**
The suitability tool is easy to understand	3	4	3.5
The applicability tool is easy to understand	3	4	3.5
Technical limitations are easy to understand	3	4	3.5
The evaluation tools are easy to understand (average)	3	4	**3.5**
It is easy to proceed from the identifying step to the creating step	1	2	**1.5**
It is easy to proceed from the creating step to the evaluating step	4	4	**4**
It is easy to see the connection between the identifying- and evaluating step	3	2	**2.5**
The framework is easy to understand	4	3	**3.5**
The framework is effective	2	3	**3**

10.4. Revised Framework: Descriptive Figure

EVALUATION FRAMEWORK: USING BLOCKCHAIN TO IMPROVE TRACEABILITY

The framework consists of three steps that should be addressed sequentially. The framework should be iterated through briefly first, assessing overall feasbility and resources needed to complete a second, full iteration of the framework.

The framework is divided into strategic and technical components. The strategic components should be relatively easy to comprehend and are primarily aimed for open discussions, while the technical components require some technical expertise. The strategic components feed into the technical components, which in turn are connected closely: The technical specification should address the areas of improvement, and the technical limitations are closely related to what application have been drafted in the technical specification.

1. IDENTIFY

A. Driver for Change [Strategic]

Identify *why* traceability should be improved. The driver could be one of the following:

- *Better SCM*: Efficiency and cost reduction
- *Quality Assurance*: Assuring intangible quality attributes
- *Efficient Recalls*: *Trace* to find the cause of the non-compliance, and *track* to find affected customers.
- *Standards & Regulations*: Following standards to attain benefits (e.g. certifications), or complying with regulations to avoid sanctions (e.g. EU-regulations)
- *CSR*: Taking social responsibility and making sure that the products are produced with concern to ethical working conditions and environmental impact

B. Areas of Improvement [Technical]

Define what capabilities are needed to address the driver. The following four traceability capabilities should be regarded:

1. *Identifying*: The capability to identify traceable resource units (TRUs).
   - How are TRUs identified in the supply chain?
   - What is the precision and granularity of TRUs?
2. *Capturing*: The capability to capture relevant information of TRUs and events.
   - How is relevant data at traceable events captured in the supply chain?
   - What is the breadth and depth of the traceability system?
3. *Linking*: The capability to link inputs to outputs in processing of TRUs.
   - Are there any troubles in achieving internal traceability and linking inputs to outputs?
4. *Sharing*: The capability to share traecability data.
   - How is master- and transactional data shared between traceability parties?
   - Is a pull- or push system used?
   - Are there any issues in achieving external traceability?
   - Are there any conflicting interests for sharing data?

Keep in mind that:

- The most urgent areas of improvement could be with upstream suppliers or other traceability parties.
- Applications that work in isolation does not guarantee traceability on a global scale

2. CREATE

A. Properties of Blockchain [Strategic]

Discuss the five key properties of blockchain technology, and assess if they seem useful:

1. *Distributed Database*: Data is stored on several places. There is no central point of attack, and the system can be more stable as there will likely always be at least one active node.
2. *Peer-to-Peer Transmission*: New entries in the database is communicated directly between nodes. No central authority controls the communication, but the system can be less agile.
3. *Pseudonymity and Transparency*: Virtual identities can hide true identities, allowing for transparency with integrity.
4. *Irreversible Records*: Records are very hard to alter or remove, making them reliable regarding documentary truth.
5. *Programmable*: Rules can be set for how the system should work, allowing for smart contracts where transactions can automatically trigger further events.

B. Set Up the Scope[Strategic]

Set up the scope, by briefly discussing the evaluation tools in step three and assessing the feasibility of the application.

C. Technical Specification [Technical]

Draft a blockchain solution where data is stored in blocks and linked to previous blocks mathematically in a chronological order. The draft should address the following questions:

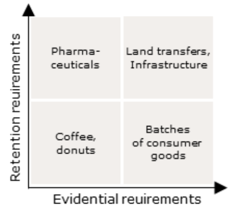
- Who can become a node with permission to read the entries?
- Who can become a node with permission to write new entries?
- Who can become a node with permission to validate/discard entries made by other users?
- How are transactions validated?
- Who owns and maintains the source code?
- How does the network reach consensus regarding the transaction history?

Draft the application considering step 1:B, ensuring that the it addresses the area(s) of improvement.

3. EVALUATE

A. Suitability [Strategic]

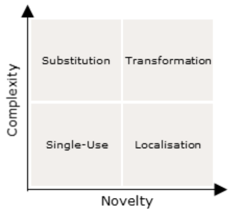
Consider the data's evidential- (related to the value of the transaction) and retention requirements. Data requirements that are either too high or too low are less suitable initially. With too low data requirements the security of the database structure is not needed, and with too high data requirements better tested applications are preferred. The suitability conclusion depend heavily on the technical specification in step 2:B.



B. Applicability [Strategic]

How many parties need to be involved in the application (complexity) and what is the novelty of the solution? The following could aid conclusions:

- *Single-use*: Could be implemented immediately
- *Localisation*: Could be tested if it seems promising
- *Substitution*: Better functionality must be communicated to enable substitution.
- *Transformation*: Research and develop - Could require social, legal, and political changes before they can be implemented.



C. Fulfilment [Strategic]

- Does the application reach the properties desired? Could these properties be reached using other solutions?
- Does the application improve the area(s) of improvement regarding traceability? Could these areas have been improved by other means?
- Does the application satisfy the identified driver? Could the driver be satisfied by more efficient means?

D. Technical Limitations [Technical]

Assess the following possible limitations, found in the Bitcoin blockchain:

- *Throughput*: The current Bitcoin network has only a capacity of seven transactions/second. In comparison, VISA provide 2000 transactions/second.
- *Latency*: A Bitcoin transaction takes roughly 10 minutes to complete, as this is the time it takes for a block to be created in that implementation.
- *Size and bandwidth*: The entire Bitcoin blockchain is over 100 GB (Feb. 2017). Each block is around 1 MB, and the creation of a new block every 10 minutes imposes a limitation of transaction capacity with the current bandwidth.
- *Security*: The Bitcoin blockchain can be subject to a 51 % attack, malleability problems and authenticity or cryptography issues.
- *Wasted resources*: Proof-of-work mining "wastes" huge amounts of energy each day, with the sole purpose of maintaining consensus in the database.
- *Usability*: The Bitcoin application programming interface is not developer-friendly, and difficult to use.

Figure 13. The descriptive figure of the revised framework.

10.5. INTERVIEW STUDY B

This is the interview guide for businesses in interview study B.

Instructions

This interview guide uses point-based questions. "*This is a statement*". Each statement should be rated and motivated:

1. I completely disagree with the statement
2. I partly disagree with the statement
3. I partly agree with the statement
4. I completely agree with the statement

Introduction

- What is your profession and role?
- How much do you know of BCT?
- How does your business work with traceability?

Framework Discussion

Step 1

- Are the drivers for traceability accurate in your business case? What is your driver for improved traceability?
- Are the areas of improvement suitable for your business? What is your areas of improvement?
- Is this step easy to understand?

Step 2

- Are the properties of BCT desirable and relevant in your business case?
- Is this step easy to understand?

Step 3

- What is your assessment on data requirements? How does this demonstrate in your business case?
- What is your assessment on applicability? How does this demonstrate in your business case?
- What is your assessment on the technical limitations of BCT? How does these demonstrate in your business case?
- Are the evaluation tools easy to understand and relevant?

General Aspects

- "*The framework is easy to understand*"
- "*The framework's steps and components are relevant*"
- Does the framework achieve its purpose?
- "*The framework is effective*?