

Creating a Framework for the Economic Impact of Multi-party Computations

Master thesis submitted to Delft University of Technology in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

in **Management of Technology**

Faculty of Technology, Policy and Management

by

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To be defended in public on May 28, 2021

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Preface

This thesis that lays before you is the final project of my masters degree ‘Management of Technology’ at the TU Delft. This thesis is written as part of the Safe Data-Enabled Economic Development project which is part of the European Union’s Horizon 2020 research and innovation program. I would like to show my gratitude and appreciation for all of those who have helped me in this project and those who have helped me throughout my Bachelor’s and Master’s degrees.

The first person I would like to thank is my first supervisor Mark de Reuver. I would like to thank him for all his advice, feedback, connections, and the discussions which helped during my thesis. Not only did he provide me with great guidance within the thesis, but he also helped me with the doubts that I had and he assured me that I was on the right track. I would also like to express my gratitude towards Hosea Ofe who has helped me so much on multiple occasions. He took it upon himself to connect multiple students who had a hard time during corona to find each other. He brought several students together so that we could have discussions about our topics and help each other. He also actively asked if I needed to discuss any problems. He also continuously provided me with feedback on my work and my problems, many thanks to you Hosea. Also many thanks to my second supervisor Zenlin Roosenboom-Kwee who shined a different light on the thesis and provided me with new feedback. Also, thanks to all the people from the Safe-DEED project from the bi-weekly meetings. Last but not least, thanks to all the people who participated in the interviews. All of the discussions provided me with new knowledge and insights which contributed significantly to the outcome of the thesis.

Then a big thanks to my family and friends. My parents, who have supported me all the way throughout my study and during tough times. Also, to my brothers and friends who helped me with keeping my mind off of study, thanks a lot guys. I think everybody needs to find the right balance to keep doing great work and to keep achieving your goals. To all the new friends I made during my time at TU Delft, it

was an amazing time and I can't wait to see you again at the Beestenmarkt!

And remember dear reader, the paper that you see before you is the work of many iterations and improvements. At first, it might seem too much and it might be overwhelming. It might even seem that you cannot do it yourself but with the help of good supervisors and friends the possibilities are endless. When you do your next big project, remember to do it one step at a time and then it becomes possible to achieve an end-result to be proud of. These are my final words. Signing off!

Harm Minnema,
May 2021

Executive Summary

Data is becoming more important because of the increased possibilities of analysis and the increase in possibilities of data sharing. Companies are already using data for their analysis and they see more potential in it. Therefore, they are collecting more data and also sharing more data. This means that there will be more data available for whoever seeks to benefit from it. New opportunities arise with the possibility of more data sharing. This data is collected from all different sources and can give insides into different fields, such as strengthening market competition and opening new business opportunities.

The privacy-preserving technology that enables data sharing of this thesis is secure multi-party computation, from now on referred to as MPC. MPC is a cryptographic technique that enables a secure computation which is done as follows. If Company A wants to compute the function f with inputs from Company B and Company C, it is possible to do the computation by using MPC with the homomorphic encryption method. Company A, Company B, and Company C will not have their data revealed to the other parties when f is computed via MPC because their data is encrypted before they send it. They can even keep their datasets separate and private. The function will be $f(x_a, x_b, x_c)$. The MPC will send back the results. Company A can now decrypt the results of the function and analyze the dataset and draw conclusions from it while still keeping its data private. Thus, MPC ensures private and secure data sharing between multiple parties without the need for a trusted third party.

The economic impact of privacy-preserving technologies is not known. This was the main focus of the thesis. The literature states that MPC has potential benefits but it fails to mention quantifiable aspects affected within businesses. It also does not mention relevant business-related applications of MPC. Businesses will not simply implement new technology. They base that decision on the potential benefits and costs of that technology. The objective of this research was therefore:

Create a framework to categorize revenues and costs of using MPC. The framework should be able to inform decision makers within businesses about the quantifiable aspects that should be considered before implementing MPC.

The main research question was derived from the objective. The main research question was:

What are the categories of costs and revenues of using multi-party computation technology for a company?

This thesis gathered data from the existing literature and did multiple interviews to answer the research question. A literature study was done on business models and business cases and applied to MPC using the Business Case Method of Meertens et al. (2014). Data for the benefits and costs were extensively sought within the literature. Categories were made such as the cost of data. Aspects were found that influenced these categories. How these aspects influence the category was then described. This resulted in a framework of aspects that influence categories and categories that influence the cost or the revenue.

This framework was extended and validated by gathering additional data from interviews. These interviews were held with people who worked in the telecommunication industry, knew much about data, or who knew much about implementing new technologies within businesses. The quotes that were given were open coded using atlas.ti as a tool. The real-life setting of telecommunication companies was used to apply the framework on. This showed that the framework was complete, validated and useful in real-life settings.

Ultimately, the thesis led to theoretical and practical contributions. The existing literature of MPC only contained information about auction-based pricing, tax-fraud detection, and satellite collision prevention. This thesis added a business case analysis to it. The biggest contribution to the literature is the created framework.

The practical contribution for managers is the identification of the quantifiable aspects. The final framework consisted out of the following categories: *consumer interactions, sales, risks, the costs of data, legal costs, technology costs, and miscellaneous*. The aspects that influence the economic impact are *more personalized services, increased revenues per person, boost the ability to address specific target*

markets or specific consumers, boost the ability to predict trends, selling data, new opportunities, costs of acquiring data, costs of storing data, cost of securing data, sensitive information, rules and regulations for MPC, technology implementation costs, employee costs, operation costs, decision-making process costs, data leaks, reliability, and risk of competitors and can be found in figure 6.3. Managers can now look at the framework and apply it to their companies to check the economic impact. They can quantify these aspects and do a cost-benefit analysis to see if the implementation is worthwhile doing. Business can do this by doing a cost-benefit analysis. This is the biggest contribution of this thesis. The Safe-DEED project could also use this framework in their project for deliverable 2.5 'Quantificationn of the economic impact' because the quantifiable aspects are already identified in this thesis.

Managers can also look at the real-life case of telecom companies and see how they could benefit from MPC. Companies can see how they should apply the framework to their company. These real-life examples were deemed very important by the interviewees. Therefore this thesis recommends more research in real-life scenarios to create more support from other companies. MPC is useless if no other companies want to share their data.

The intermediary structure was consensually chosen to be the preferred implementation structure. The responsibilities will lay with the intermediary which takes some risks away from the companies. This alternative should also be cheaper overall. Therefore, this thesis recommends the intermediary structure. The billing structure for such an intermediary is also identified in this thesis. It is recommended to have a periodical payment structure. It saves on monitoring costs compared to pay per data and it helps businesses with getting started with the technology. They could try out some data and increase willingness to try out MPC.

In conclusion, MPC has a huge potential for businesses of all sizes. The economic impact of the implementation of MPC is found using qualitative methods. Companies can now decide for themselves if they want to implement MPC by looking at the business case and the quantifiable aspects that are displayed within the created framework. They should quantify the different aspects and decide for themselves if they want to implement MPC. They could do a cost-benefit analysis to identify the potential profits. Chapter 5 should be read by managers to understand how each aspect affects a company and chapter 7 should be read for the final conclusions and recommendations.

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Abbreviations

BM:	Business Model
CEO:	Chief Executive Officer
CRM:	Consumer Relationship Management
CSR:	Corporate Social Responsibility
CFO:	Chief Financial Officer
CTIO:	Chief Technology Innovation Officer
GDPR:	General Data Protection Regulation
HE:	Homomorphic encryption
MPC:	Multi-party Computation
PSI:	Private Set Intersection
Safe-DEED:	Safe Data-Enabled Economic Development
Telecom:	Telecommunication

Chapter 1

Introduction

The introduction chapter will discuss the starting point of why this research came to be. It will provide background information on the need for privacy-preserving technologies and it will examine the understudied aspects of the economic impact.

1.1 Background

Data is becoming more important because of the increase in the possibility of data sharing. Think about communication, but also data transfers. Companies can share, trade, spread, and analyze data on everything they keep track of. This data is collected from all different sources and can give insights into different fields, such as strengthening market competition and opening new business opportunities (Kwon et al., 2014). A reason for the increase in data sharing is that the world as we know it is becoming fast changing and more globalized (Atzori et al., 2010). Data and data usage is also becoming more important for big companies and small companies (Schomm et al., 2013). Data-driven business cases for these companies are growing in importance and society is becoming more digital. Think about upcoming trends such as big data analysis and machine learning. The new methods with enormous potential are based on data (LeCun et al., 2015).

This means that corporations are continuously looking for new ways to analyze and get reliable data. However, companies do not want to give competitors their data, when they want to analyze the whole market. The reasons for this are obvious, the companies do not want their competitors to have their data because they are afraid to lose their power or lose control of the data (Safe-Deed, 2018; Linaker and Regnell, 2020). Competitors can use data to gain a competitive advantage over their

rivals. They could gain a benefit from it, because of the superior analysis they can make with this new data. Also, because of spillover effects, competitors can gain more knowledge of the rival's overall functioning. An example of this could be for taxi companies. Competitors will put more cars in areas where other companies have many pick-ups if they see a hotspot area within the data. Accordingly, no company wants to give their competitor an advantage over them freely, thus, they will not share their data. It is hard to share data for companies because they have to comply with regulations such as the General Data Protection Regulation, from now on referred to as GDPR. The EU Charter of Fundamental Rights stipulates that it is impossible to simply share all data because of the right to protect personal data for all EU citizens (European Commission, 2020) .

Companies cannot easily buy and sell data, because there is currently no good working data market in Europe (Fricker and Maksimov, 2017). This blocks the data economy because data is an essential resource for it. This leads to incomplete or wrongly composed datasets of the markets, which leads to wrong predictions when using these datasets. Therefore, datasets are not used as much as they could be if they were correct. Some data suppliers and data aggregators are not always trusted by the companies (Muschalle et al., 2013). Open data marketplaces are also not a good source for data currently so they are not always used (Kittlaus and Clough, 2009). There are multiple reasons for this. The scholarly efforts providing elaboration of business cases for open data currently lack rigorous analysis (Zeleti et al., 2014). Also, the comparison of open data models are minimal (Janssen et al., 2012). So how could they obtain better and more reliable data for themselves in the future?

One of the possibilities could be to use privacy-preserving technologies. Imagine that it is possible to share all information without giving up sensitive corporate data. It can be seen as follows, imagine that company A has had a marketing campaign together with company B- and company C to promote their bars. They want to know if that campaign was a success or not. They can individually analyze their data on sales revenue and compare them before and after. However, they are hesitant to share their revenues with the other companies because of the reasons mentioned earlier. Privacy-preserving technologies can solve this problem. The businesses could work together and share data to benefit from the big data set mutually. It could help understand the revenue raise and compare if their revenue rose more than that of A B or C. Also, customer behavior could be analyzed or technology could even enable smarter logistics such as the delivery of goods. This example gives insight into the possibilities of privacy-preserving technologies for data-owners, but there are more. A

more in-depth example is provided in paragraph 2.2. These seemingly positive aspects lead to the question, why haven't all companies adopted this technology already?

1.2 Practical Problem

Problems mentioned in the introduction when companies share data are that companies give away power by sharing data, it opens them up to vulnerabilities that could help their competitors, and they need to follow GDPR. The solution is also given in the introduction, namely privacy-preserving technologies. MPC is such a privacy-preserving technology used within the Safe-DEED, Safe Data-Enabled Economic Development, project. This project is part of the European Union's Horizon 2020 research and innovation program (Safe-DEED, 2018). MPC can securely compute the sum of revenues without leaking the individual revenues of the parties involved. Thus, MPC can create new business opportunities for all the parties involved without the negative side effects of sharing data with competitors. This is an example of a privacy-preserving technology that could be implemented in the future.

The practical problem that the research will focus on is the problem that the companies have with this technology. Companies will not simply buy or use any new technology. They need to know the potential, added revenue, risks, and costs of any technology before they will implement it. They need to know these quantifiable aspects to calculate the potential profits to see if the project is worthwhile doing.

Currently, the cost and benefits of MPC are not known within companies. These unknown costs and benefits hamper the implementation of MPC (Tulenheimo, 2015). Legal costs and costs of the product are examples of potential costs for MPC that they want to know before they are willing to implement it. Companies also need to know how the aspects affects the costs. Will they reduce them or increase them? There are probably more costs that should be included and considered to make a good decision. The same goes for the beneficial effects. There is no place where to find all the beneficial effects of MPC. The alternatives of implementation of MPC should be described as well. Different alternatives might have different costs and benefits. So, this thesis will tackle the problem of identifying all the costs and benefits that are involved in implementing MPC. This will result in businesses knowing which costs and benefits there are and making it possible for them to make a conscious choice about implementing MPC.

1.3 Scientific Problem

The problem is that there is not enough research done on the economic impact of privacy-preserving technologies to know what the costs and benefits are. This thesis will provide a framework of costs and benefits to map this out. Some explorative qualitative studies have been conducted on the economic impact of privacy-preserving technologies in the Safe-DEED project (De Reuver et al., 2020). They did a workshop with practitioners and scholars, qualitative interviews with data marketplace operators, and qualitative interviews with data owners. However, this study is not in-depth enough for companies to make such a big decision about implementing privacy-preserving technology. The study lacks quantifiable aspects or a framework containing quantifiable aspects that companies could use to check if they would potentially benefit from using MPC. Therefore, more qualitative research about quantifiable aspects must be done on the economic impact of privacy-preserving technologies. This thesis will fill in the gap of qualitative research by providing the unknown economic impact of MPC. Looking at the cost and benefits is known to be a good method for this (Boardman et al., 2017).

Big data and data-driven business models are known for becoming a key resource for companies (Hartmann et al., 2016). This data could strengthen market competition and open new business opportunities (Kwon et al., 2014), therefore it is becoming more important. There are some MPC implementations that have the theoretical functionality of MPC right. However, they lack the scalability and performance to be used for real-world situations. They only work in theory at the moment (Safe-DEED, 2018). The applications that currently are using MPC in real life are limited to auction-based pricing (Bogetoft et al., 2009), tax fraud detection (Bogdanov et al., 2015), and satellite collision prevention (Hemenway et al., 2016). This thesis will provide a new insight for a real-life application of MPC by filling in the knowledge gap of the usability and profitability for a company when using MPC within and between businesses. There are already some business models of MPC known (De Reuver et al., 2020). These business models are some qualitative ideas on the types of benefits and costs, but quantifiable aspects are lacking within these models. A business case is yet to be made. This thesis will look at business models and do a full business case analysis. Furthermore, this thesis will make concrete categories of revenue creation and costs of MPC when it is implemented. This is not done before and it should contribute to extending the knowledge of the economic impact of privacy-preserving technologies.

1.4 Objectives

The economic impact of privacy-preserving technologies is not fully known as mentioned in paragraph 1.2. There is not enough qualitative research on this matter. Companies do not know the impact of privacy-preserving technology on every component of their business. They want to know this before they will implement the technology. They are profit-orientated and want to know the affected quantifiable aspects. These aspects are not yet identified within the literature. All parts that influence costs and benefits should be found and looked at individually to identify their impact.

The objective of this research will therefore be:

Create a framework to categorize revenues and costs of using MPC. The framework should be able to inform decision makers within businesses about the quantifiable aspects that should be considered before implementing MPC.

1.5 Research Questions

The main research question is derived from the objective mentioned in paragraph 1.4. The main research question cannot be answered on its own because of the multiple aspects. Therefore, various subquestions are necessary. The answers to these subquestions will lead to answering the overall research question and meet the research objective. The main research question will now be discussed and the deduced subquestions will follow.

The main research question for this master thesis will be:

What are the categories of costs and revenues of using multi-party computation technology for a company?

To answer this question subquestions are needed. The subquestions for this master thesis will be:

1. What business case could be used by companies for MPC technologies?
2. What revenues will the business case of MPC create?

3. What are the costs for MPC?
4. What are the risks that are influenced by MPC?
5. How do the costs and revenue of MPC compare to each other?

When looking into the economic impact of privacy-preserving technologies it is essential to look at the business case. A business case defines why the project is done, what the alternatives are, how it should be implemented, and the costs and benefits of the project. Therefore, the first thing to do is setting up a business case. The first research question should provide this. Then the second research question will answer how the business case creates extra revenue. Different possibilities are possible such as better marketing, better customer engagement, and many more options that should be looked into. These options will be categorized and then discussed how they affect revenue in research question 2. The same will be done for the costs. They will be analysed in research question 3. The fourth research question is about the risks that MPC brings to the table. Risks can result in potential costs and could therefore financially harm businesses. Therefore, the risks should also be mapped out to find the economic impact. The additional revenue, costs, and risks will be put together into a framework. The last subquestion compares the costs and benefits of the technology to answer the main question ultimately. This is done by applying the created framework to a real-life business.

The thesis will first have a literature review on the history of MPC, workings of MPC, business models, and business cases. Then the methodology will address how the research will be conducted. The next chapter will discuss the business case that was identified in chapter 2. The chapter thereafter will be for the framework development. The literature that explains the costs and benefits of implementing MPC will be researched. The aspects that affect businesses when implementing MPC will be presented and explained how they affect businesses. This chapter will end by putting the aspects together in a framework. This framework will be tested and validated in the next chapter with expert interviews. The framework will be adjusted accordingly to the answers of the experts and tested on a business. This business will be a telecommunication company. This thesis will end with conclusions and recommendations. The full methodology of the research will be discussed in chapter 3.

Chapter 2

Literature Review

The contents of the current literature will be reviewed in this chapter. Which technology will be used and how this technology works will first be explained. This will give a better understanding of how the technology works and it will be easier to understand its possible impact. Secondly, the literature about business cases and business models for privacy-preserving technologies will be described to know if there are already business cases and what is already known about the economic impact.

2.1 Including Literature

A large part of doing literature research is acquiring the literature itself. This paragraph will explain how the literature search was done for this chapter and how the different literature was selected. The articles used in this chapter were acquired by doing a systematic search on Scopus. The following keywords were used to find the needed literature: *“data valuation”, “data valuation AND marketplaces”, “data markets”, “privacy-preserving technologies”, “data sharing companies”, “MPCs”, “uses of privacy-preserving technologies”, “business cases for privacy-preserving technologies”, “business cases in a data market”, “Safe-DEED project”, “MPC Technology”, “Business case for technology”, Business model creation”*.

The search for literature was not limited to these words. Synonyms and combinations of search words were also used such as *”Benefits MPC, Drawbacks MPC, Costs MPC”*. Sometimes there were many results. They were sorted by citations so the papers that were cited the most were the ones that were read first. These highly cited papers were deemed qualitative enough and well-accepted within the research community and therefore selected for this thesis. After selection, they were briefly

read and judged based on relevance to this research. If a paper was proven to be highly cited and relevant, it was used in this thesis. Once a paper or interviewee provided a new aspect or category, search terms were added in the terminology that they provided. About eight papers were included this way from the 20 that were read.

The second way that papers were acquired was through the Safe-DEED project. The Safe-DEED project strives to:

‘Bring together technology, business, and legal researchers to advance the state-of-the-art in privacy-preserving algorithms and data valuation, to enable data-centric business model innovation, and increase trust by a better understanding of the legal and ethical frameworks under which data services operate.’

The Safe-DEED project has multiple aspects to it because of its size. Therefore, there are multiple parties involved with each one solving a different problem area. Three companies provide vertical pilot use-cases for secure MPC and data valuation technologies, these companies are FNET, IFX, and LST. The research centers that will be developing the technology itself are KNOW, EUT, and RSA. The legal and ethical considerations are done by the Katholieke Universiteit Leuven or KUL. The problem that remains is that of the business cases and the economic values of this technology. The TU Delft is responsible for this part of the study. For this master thesis at the TU Delft, I will be filling in the knowledge gaps about the economic impact.

The Safe-DEED project is divided into seven work packages or WP. The objective of the master thesis will be to contribute to work package 2 of the project. The objective of WP2 according to their own website is: *‘WP2 quantifies and demonstrates the economic value for users and buyers organizations of the developed privacy-preserving technologies. Therefore, we will develop new multi-actor business cases for privacy-enhancing and data valuation technologies and a decision-support tool for designing and testing business cases.’*

The Safe-DEED project helps this research by providing a variety of knowledge on MPC and by giving some business models. The project already has multiple deliverables in different fields that are accessible to this research. The knowledge of the deliverables could help with finding categories. For example, the deliverable D3.1 *‘Legal Framework and Ethical Issues’* could help with finding the effects on the legal

costs. These deliverables will provide very relevant information for the foundations of the framework. Therefore, several deliverables from the project were read and used. Papers were also provided by kind members of the Safe-DEED project. These five papers were all relevant and used.

The third way papers were acquired, was by looking at who cited the papers that were used. This method could introduce newer papers and maybe provide new insights. The new paper could prove that the old paper was outdated or prove its significance. About twenty papers were found using this method out of five were usable.

The final way literature was found, was by using the snowball method. This is a method where the citations of an already used paper are looked upon. The original paper was chosen to be a good and relevant paper and it had to have its references from somewhere, so looking at the bibliography also provided new relevant papers. Thirty papers were found using this method and about ten were used.

2.2 The Technology

The technology used to preserve privacy is that of MPC as mentioned in the introduction. This paragraph will look at the literature available on the workings of the technology and the influences. MPC is relevant for the privacy of the data and the combining of data from multiple actors. The technology allows the computation of data from multiple actors which could have a significant impact. The Safe-DEED project aims to improve and test MPC for real-life cases so that it could be used and implemented. The technology is not fully operational, however, a proper working technology will be the base for this research. This will give a better view of the impact of implementing it in a company. The history of MPC will be discussed first. After this, the technology will be explained with some figures to give a better understanding.

2.2.1 The History of MPC

The origin of MPC lays with the millionaire's problem. Two millionaires wanted to know who was the richest in a secure manner. They did it by using a secure comparison function to determine who was the richest among them (Yao, 1982). The two key aspects of the algorithm were to ensure the privacy of the inputs from the millionaires and to safeguard the data against adversaries. Goldreich et al. (1987) developed

the two-party-computation protocol further in a multi-party computation protocol. They were the first to create MPC. Yao (1982) and Goldreich et al. (1987) both used Oblivious Transfer (Evans et al., 2018) as a cryptographic technique within their protocols. A simplified explanation of Oblivious Transfer is the following: Company A has multiple secret inputs and Company B can select one of them. The function of the protocol will not reveal which one of the secret inputs Company B selected and it will also not reveal what the other inputs were (Evans et al., 2018). Oblivious transfer became the cornerstone for MPC technology.

The next technology that was used as a protocol by Beaver et al. (1990) and Ben-Or et al. (1988) utilized secret sharing. Multiple parties hold their private share of a value so that they can be recovered by the participants at the end of the computation. The participants can recover their share of value by using their encryption keys (Beaver et al., 1990). This method protects against bad parties from obtaining the secret values from the output values and making unauthorized operations. This makes it more secure than the classic two-party computation (Lam, 2020). These original schemes have evolved into the current technology of MPC.

2.2.2 Definition of MPC

MPC technology works by using a cryptographic technique where multiple parties join together for a computation. The parties carry out a secure joint computation without revealing each party's dataset. The result should be an output that is meaningful and could be analyzed, without disclosing the input given by all the individual partners (Zhao et al., 2019). Only the authorized parties can access the encrypted data (Bachlechner et al., 2018). According to Lam (2020), "*MPC uses mathematical algorithms in which the computation problem is defined by a set of parties P_1, \dots, P_n , each with their private inputs X_1, \dots, X_n , jointly computing a function $f(X_1, \dots, X_n) = y$. In other words, it can enable competing businesses (P_1, \dots, P_n) to perform data analytics ($f(X_1, \dots, X_n) = y$) on shared data whilst keeping their individual datasets (X_1, \dots, X_n) private from each other. Every party P_n , will not have their data input X_n revealed when the function $f(X)$ is performed via MPC*" (p. 31). This means that parties such as P_1, \dots, P_n can be competing businesses and still perform data analytics ($f(X_1, \dots, X_n) = y$) on shared data. They can even keep their datasets (X_1, \dots, X_n) separated and private. Even P_n cannot access their data input, X_n , when the function is computed via MPC. Lindell and Pinkas (2009) state the requirements for such a secure computation are the following (p. 5):

1. Privacy

2. Correctness
3. Independence of inputs
4. Fairness
5. Guaranteed output delivery

These requirements should ensure the correct outcome for the honest parties regardless of dishonest parties (Lam, 2020).

Figure 2.1 shows a general MPC process. There are multiple data providers who send their encrypted data to the MPC engine. The MPC engine does a computation and sends the results of the computation to the parties who are authorized to receive the data.

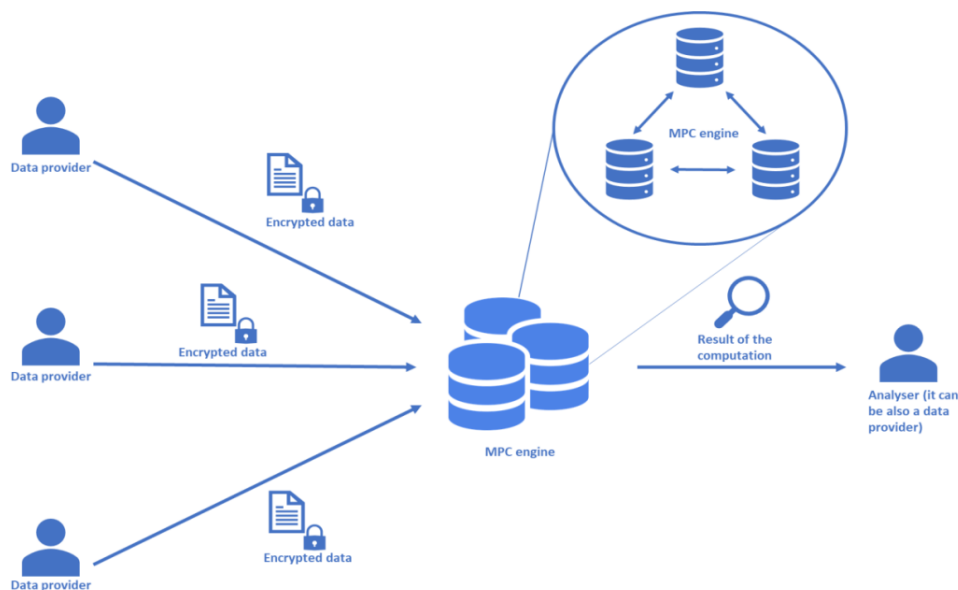


Figure 2.1: General MPC process (Dolci, 2020, p16)

A more practical example is given in figure 2.2. It shows a computation description of an example that will now be given on how the technology works with a figure that is retrieved from (De Reuver et al., 2020), which was originally from (Bestravos et al., 2017).

Figure 2.2 shows a description of an example that will now be given on how the technology works with a figure that is retrieved from (De Reuver et al., 2020), which was originally from (Bestravos et al., 2017).

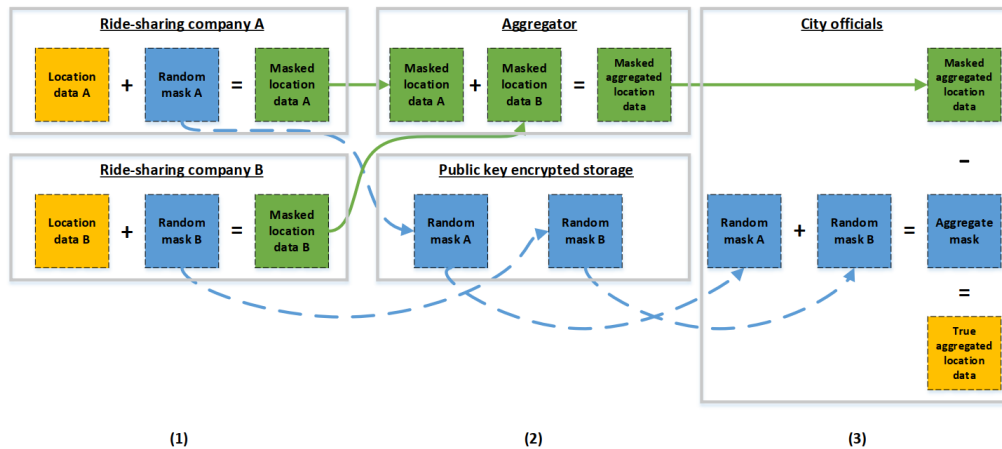


Figure 2.2: An example of MPC usage given by (De Reuver et al., 2020) who adapted it from (Bestravos et al., 2017) (p. 10)

Figure 2.2 shows an example of how MPC works in practice. This example shows how city officials try to understand how ride-sharing vehicles have influenced traffic congestion within the city. The information from the ridesharing companies, column 1, is crucial for the analysis. The data on when ridesharing is used, where these drives go, and how many people move per vehicle are all needed to make the right analysis. Unfortunately for the city officials, this is all confidential and private data that companies do not want to share, because of the reasons mentioned in the introduction.

MPC can come to their aid in this case. The companies can allow aggregation of their real data without disclosing the individual data. This real data is depicted within the yellow boxes. They do this by applying a random number to their data which can be seen in the blue boxes. This will make sure that the original value of the data is not readable anymore for their competitors. An aggregator will then aggregate all the data of the different ride-sharing companies as seen in column 2. The random new ‘masked’ data is the only aggregated data, so not the original data. These are the green boxes within figure 2.2. The city officials will then receive the aggregated masked data of all the participants from the aggregator and the aggregated mask. They can then transform the aggregated data into text aggregated results, as seen

in column 3. They can now make heat maps for the traffic areas with this data, without having to excess the data of the ride-sharing companies.

2.2.3 Numerical Example

A numerical example of a computation will now be given to show how MPC works. Company Alice, Company Bob, and Company Charly want to find out if their average salaries are above or below the average of the other companies. Company A's average income is 30,700, Company B's average is 36,500, and Company C's average is 22,800. The total average, in thousands is: $(30,7+36,5+22,8) / 3 = 30$. They do not want to share their own average directly with their competitors. So, they split up their information:

$$A = -10 + 24 + 16,7 = 30,7$$

$$B = 10 + 0 + 26,5 = 36,5$$

$$C = 6 + 0 + 16,8 = 22,8$$

They will now exchange data. Figure 2.1 also shows this process. Multiple data providers send their encrypted data to the MPC engine. This MPC engine can be owned by a third party or any of the other alternatives. These alternatives are discussed in paragraph 4.3. It does not matter for the numerical example which party computes the results because they are not visible for that party. The MPC engine does the computation and sends the results to the parties who are authorized to receive the data. They will all compute the average of their received data. The computed averages are openly shared between them. The averages are then summed up together. Once combined, they provide the overall average salary of the three companies. Figure 2.3 shows what a company can see.

The full computation can be seen in figure 2.4. This full computation is not visible by any party. It is presented to show the readers of this thesis how a full computation looks like and what is behind the question marks from figure 2.3.

	Share 1	Share 2	Share 3	Secret
Alice	?	24,000	?	A
Bob	?	0	?	B
Charlie	?	0	?	C
Average	2,000	8,000	20,000	30,000

Figure 2.3: Numerical example of what a single company can see

	Share 1	Share 2	Share 3	Secret
Alice	-10,000	24,000	16,700	A
Bob	10,000	0	26,500	B
Charlie	6,000	0	16,800	C
Average	2,000	8,000	20,000	30,000

Figure 2.4: Numerical example of the full computation

2.2.4 Private Set Intersection

There are two cryptographic methods that can be used in MPC. The first one is called Private Set Intersection, from now on referred to as PSI. PSI refers to a situation where two parties hold a private data set whilst wanting to find the intersection of their sets without wanting to reveal anything except the intersection itself. The most computationally efficient PSI protocols use oblivious transfer, as explained in paragraph 2.2.1, and hash function which is a mathematical algorithm used to encrypt data (Chen et al., 2017).

”The limitations to these techniques lie within the communication complexity. It scales linearly with the size of the data set. This will give problems if PSI is used between a constrained device with a small set, such as a cellphone, and a larger service provider such as Whatsapp” (Chen et al., 2017, p. 1). Even though, PSI has grown and become practical because of new publications such as Dong et al. (2013). They found a way to use PSI and make it efficient and scalable because most of the operations can be parallelized easily. The most efficient protocols for PSI are from Pinkas et al. (2016). ”The protocols are extremely fast, but the communication

complexity is still linear with both of the datasets. So, when one set is significantly smaller the communication overhead becomes a sincere problem” (Chen et al., 2017, p. 1).

2.2.5 Homomorphic Encryption

Homomorphic encryption, from now on referred to as HE, scheme allows participants to evaluate the computations on encrypted data without having to decrypt it first. Doing MPC computations through a HE scheme is considered an efficient and simple approach in theory (Ghanem and Moursy, 2019). However, the practical side of the approach is underdeveloped. The idea of not having to decrypt the data at first has been around for a long time (Rivest et al., 1978), but only a few researchers made practical applications close to reality (Chen et al., 2017). It seems to solve the problem of communication costs of PSI. The party with the smallest dataset sends its encrypted dataset to the party with the larger dataset. ”The larger party evaluates the intersection circuit homomorphically and then sends back the encrypted result” (Chen et al., 2017, p. 1). The party with the smaller dataset can then decrypt the result. The problem with this implementation is that it is inefficient because the computational costs will grow with the size of the input and with the depth of the circuit, which is the length of the longest path from input to output (Chen et al., 2017).

2.3 MPC Business Models and Business Cases

Business models help companies with capturing and creating value (Bouwman et al., 2008). They need these models because the technology does not have value on its own (Chesbrough, 2010). The value is added by the business models because they help to make explicit how the technology lets the company capture the value (Bouwman et al., 2008). The current literature indicates that the use of MPC could be beneficial (Bachlechner et al., 2018; De Reuver et al., 2020; TNO, 2020) without going into too much detail or providing the full picture. Business models should be able to capture these benefits and turn them into profits. However, no current literature states how this is possible and what it explicitly affects. De Reuver et al. (2020) has laid the foundation of some business models these will be explained in paragraph 2.4.3. The same goes for business cases, no business case specifies the case of MPC. The literature does not state how MPC influences a company specifically, only in general. This paper will try to make a framework for companies to specify the economic impact of MPC.

Although extend literature provide exploratory examples of plausible benefits for MPC, little research has addressed the economic impact of privacy-preserving technologies in detail. The following conceptual model gives insight into how the economic impact is influenced. The amount of categories and aspects is unknown in the literature and can change during the research process. Chapter 3 will explain how the research will be done.

2.4 The Business Model

A long time ago, innovation meant that a company had invested in internal research, hired the smartest inventors, and then waited for new products to be made. Unfortunately, it is not that simple anymore. The costs of developing, creating, and shipping new products have risen significantly (Chesbrough, 2007). Examples of this are new drugs, new factories, or launching new products in a competitive market. It simply costs more money than before. The product lives are also shorter than before which makes matters worse. This means that even great technologies might have a hard time earning a satisfactory profit before they become obsolete. It is therefore even more important to couple a good technology with a good business model nowadays (Chesbrough, 2007). That is why it is also important to understand what a business model is when analyzing the economic impact of MPC. The coming paragraphs will therefore explain what a business model is and what it does.

2.4.1 The History of the Business Model

The definition of a business model has not always been the same. Therefore, the history of the business model will briefly be discussed in this paragraph so that there can be no misconception of what is meant with the term further on. The first mention of the term business model comes from an academic article in 1957 (Bellman et al., 1957). "The article is about the construction of business games for training purposes. The term is mentioned as follows: *“And many more problems arise to plague us in the construction of these business models than ever confronted an engineer”*. The meaning of business models is here connected to a simulation of the real world or at least a representation of reality" (p. 3). The first academic article that used the term business model in its title was from Jones (1960). The term is used here as a reflection of a simplification of reality to educate managers on technology. Business models are not mentioned a lot in the years after this article but gained interest in the low 1990's.

Ghaziani and Ventresca (2000) state that in this period the business model spread to ICT, marketing, management, and banking. It is also used in various frameworks such as business plans, globalization, value creation, and organization design. This is where business models become interesting for this thesis. The business model terminology starts to be connected with technology-based companies from this point. They made it possible to economically materialize the potential of technology, exactly what this thesis will do for the potential of MPC. It became possible to value internet companies. This was not possible before, because before they were valued based on their past performances, which a new internet company did not have. The term also became used in other industries than the online industry. The internet and ICT changed how companies do business drastically and around 2007 other industries were also analyzed and confronted with the term business model. These industries include but are not limited to music and airlines (DaSilva and Trkman, 2014).

The term is currently used for basically any kind of human endeavour with an ever-expanding range of possible interpretations because it is integrated into such a wide variety of industries. The term business model is used for political parties, terrorist organizations, the preservations of nature, and many more (DaSilva and Trkman, 2014). The next paragraph will therefore mention how the term business model will be used in this paper and how this paper defines it.

2.4.2 The Definition of Business Models

As paragraph 2.4.1 shows, the term business model evolved with time. The business model became especially important for new technologies. It is now time to define ‘business model’ for this thesis. The term will from now on be referred to as BM or BMs. BMs regarding technologies are described in a sub-section of the literature. There is a lot of literature containing definitions of BMs. Unfortunately, few conceptualizations link BMs and technological innovations such as MPC (Athanasopoulou et al., 2019). Also, no consensus has been reached just yet over the definition of the BM (El Shawy and Pereira, 2013). There are most definitely certain aspects that almost all BMs mention. Every company big or small has a BM, whether they explicitly mention it or not. A BM does two critical things: it creates value and captures it. It defines multiple activities that vary from consumer satisfaction to obtaining materials. Whatever activity is done, it should lead to a new product or a service that creates additional net value. The additional net value is crucial because without the creation of additional value other parties will not need another company’s product or service. Chesbrough (2007) also made a framework on the

functionality of a BM (p. 2). "The functions of the BM are:

1. Articulate the value created for users by the offering.
2. Identify the users whom the offering is useful for and what purpose.
3. Define the structure of the value chain required by the firm to create and distribute the offering, and determine the complementary assets needed to support the firm's position in this chain. This includes the firm's suppliers and customers, and should extend from raw materials to the final.
4. Specify the revenue generation mechanism(s) for the firm, and estimate the cost structure and profit potential of producing the offering, given the value proposition and value chain structure chosen customer.
5. Describe the position of the firm within the value network (also referred to as an ecosystem) linking suppliers and customers, including identification of potential complementors and competitors.
6. Formulate the competitive strategy by which the innovating firm will gain and hold advantage over rivals.

"

The core of the BM is value creation. The BMS try to define how value is obtained or captured. This is also the start of the definition for the models concerning technological innovation. The early models state that the technology has no value in itself, only when it is coupled with a viable BM (Athanasopoulou et al., 2019). It is also the other way around, new technologies are necessary for companies to redesign their BMs. Baden-Fuller and Zott (2001) even states that BMs are the link between firm performance and technological innovation. Even the most used BM called Business Model Canvas, figure 2.5, does not explicitly mention the connection with technology. VISOR from El Shawy and Pereira (2013) does mention technologies as an integral part of the BM.

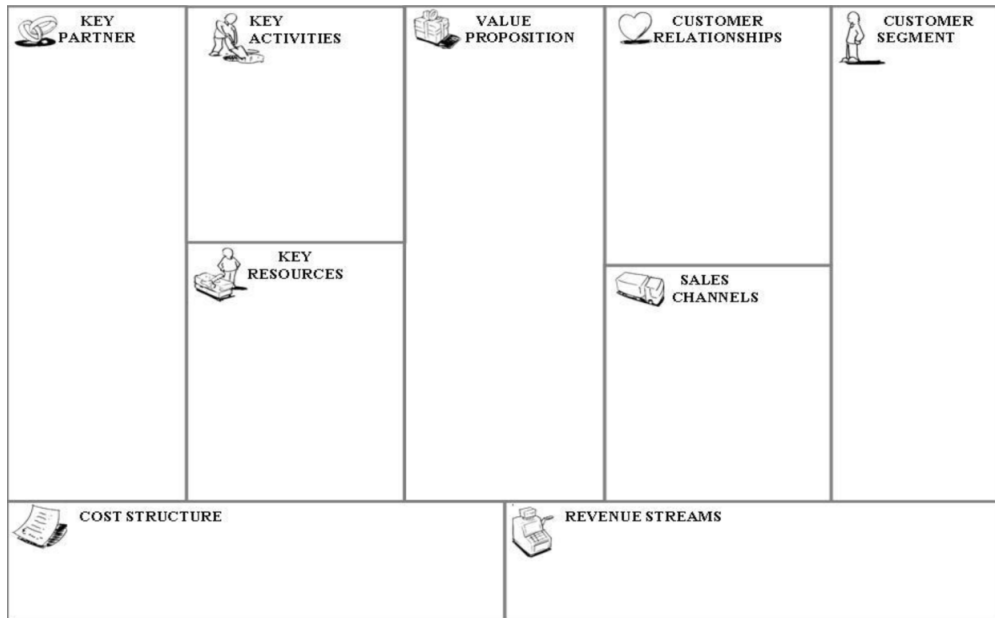


Figure 2.5: Business Model Canvas from (Osterwalder et al., 2010) retrieved from Lima and Baudier (2017) at p. 5

The Safe-DEED project made its own Business Model Canvas. This model focuses on data sources, analytics, data product, customer benefit and financial implications. Companies can fill in the boxes by answering the provided questions within them to make a business model canvas that is applicable on their company. An example of this canvas is given in figure 2.6. This model will be used in the framework because of its specific focus on MPC technology and generalizability to other companies. This canvas might not be a vary disruptive one but it might help shift the focus to the right areas.

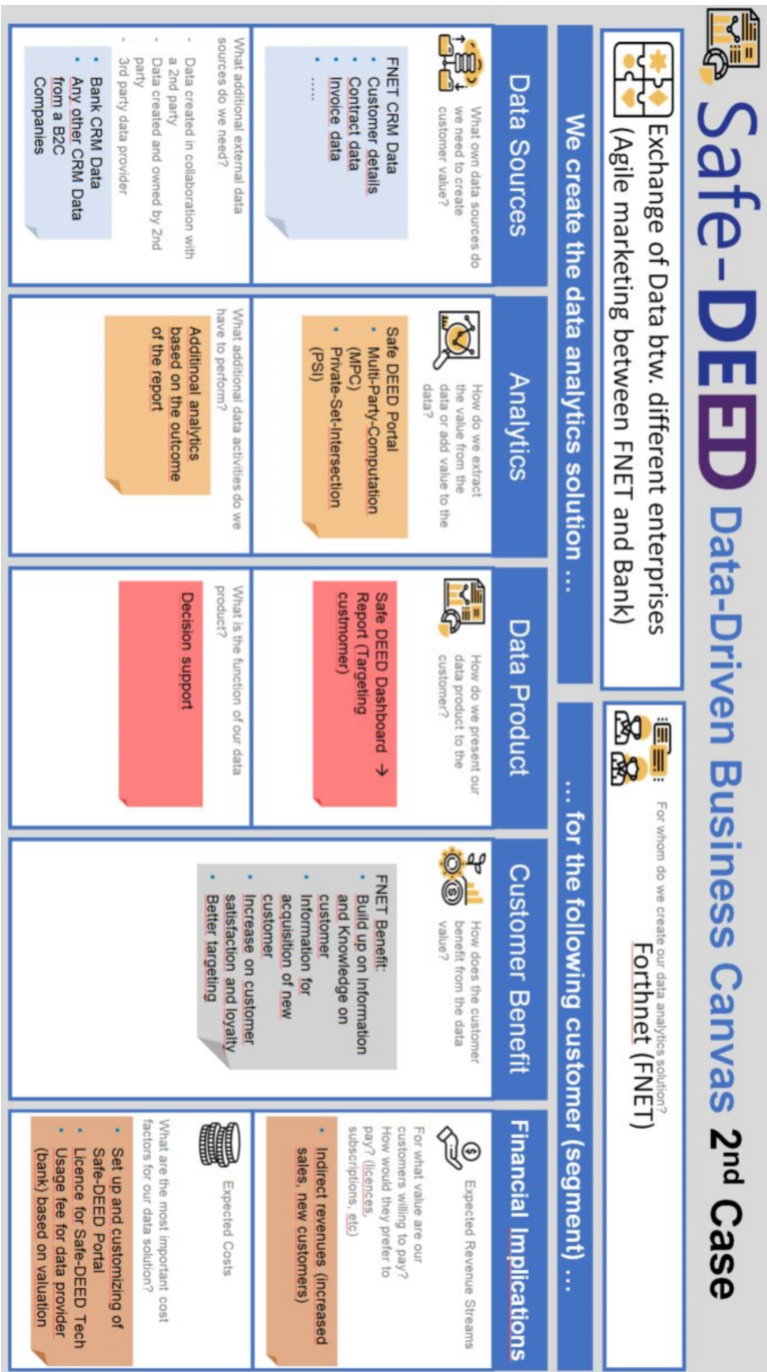


Figure 2.6: An Example of a Business Model Canvas from (De Reuver et al., 2020) (p. 7)

2.4.3 Business Models Identified by the Safe-DEED Project

The Safe-DEED project was the only research that made general business models for MPC within a very explorative study (De Reuver et al., 2020). These business models provided insights for this study about how MPC could be used within companies. The goals of companies became more clear thanks to the identification of these models. De Reuver et al. (2020) also stated that there was not much qualitative research about the implementation of business models for privacy-preserving technology within the data economy.

The business models that were identified by the Safe-DEED project are the following:

The first BM was identified in De Reuver et al. (2020) and included data sharing between departments. They state that departments can share data between themselves which was not allowed before if they use privacy-preserving technologies. This could lead to new business opportunities. An example is data such as customer behaviour. This data is normally not available for the marketing department without the consent of the customer. It is however possible to share this data with privacy-preserving technologies. This could lead to added revenue. Another reason why data anonymization between departments could be beneficial is when the company or department themselves may not trust their employees. They could let their employees work with the masked data. This could potentially lead to fewer legal costs. This shows that there are benefits to using MPC.

The second BM is about sharing data between two firms who have a joint interest. These could be two different firms, but they can potentially benefit from a joint marketing program. The example of a bank and a telecom firm is given in this research. They state that if they have an overlapping geographical approach, they could target each other's clients (De Reuver et al., 2020).

The last BM is that of selling data to firms in other industries. The data that a company owns has value. Other companies in different sectors could potentially want data such as customer details or contract data. This data could potentially be sold. This comes close to a data marketplace and could be a source of income (De Reuver et al., 2020).

These business models indicate how companies can create value using MPC. The coming paragraph will discuss the business case. The business case will be about the implementation of MPC. How it creates value comes from these three BMs. What can be achieved by sharing data between departments, sharing data between two

firms who have a joint interest, and selling data to firms in other industries will feature in the business case analysis in chapters 4 and 5.

2.5 The Business Case

Archer et al. (2018), Bogetoft et al. (2009), Safe-DEED (2018), and TNO (2020) all indicated that there is a lack of real-life situational studies on business cases for privacy-preserving technologies. The literature does not provide it at the moment even though the importance of a good business case is very high (Ward et al., 2008). There is more known about the data market and the data valuation as Fricker and Maksimov (2017) showed in their literature review, but that study did not find business cases which this thesis will address. So this paragraph will be about what a business case is and describe the components of a business case.

2.5.1 The Definition of the Business case

Business cases are developed in the early stages of projects to map out why the project is being done, what the project is about, how the project should be done, and who is needed to decide if the project is worthwhile doing (Carroll and Shabana, 2010). The business case will give, in comparison to the more general business model, insight into a specific project. It gives an overview of the case and it should identify the creation of additional value (Ward et al., 2008). Traditionally business cases for IT projects were made to obtain funding. This led to opportunistic predictions to ensure funding. To make a business case more robust, other properties were also included in the business case (Ward et al., 2008). According to Ward, next to the financial profits a business case also needs: (p. 4)”

1. to enable priorities to be set among different investments for funds and resources.
2. to identify how the combination of IT and business changes will deliver each of the benefits identified – a benefit realization plan.
3. to ensure commitment from the business managers to achieving the intended investment benefits.
4. to create a basis for review of the realization of the proposed business benefits when the investment is complete.

”

This thesis tried to identify the business case further to see how other research had defined and used business cases. The found business case studies did not define business case analysis that specifically. The most cited articles on Scopus when searching for ‘business case’ or ‘business case analysis are about corporate social responsibility or CSR. C. and Shabana (2010) defines a business case as: ‘The business case refers to the bottom-line financial and other reasons for businesses pursuing CSR strategies and policies’ (p. 1). The study of Leatherman et al. (2003) researched the costs and benefits of healthcare improvements. They state ‘A business case for a health care improvement intervention exists if the entity that invests in the intervention realizes a financial return on its investment in a reasonable time frame, using a discounting’ (Leatherman et al., 2003, p. 18). These two examples define the business case simply as the financial result of a project. Other found literature used similar definitions for the business case. This thesis needs a more defined approach and definition of how to analyze a business case. This is needed to produce a better understanding of the project of implementing MPC.

2.5.2 The Business Case Method

Meertens et al. (2014) created the Business Case Method. This framework is the combined use of the characteristics Ward mentioned and the proven business case methods of (Harvard, 2010). The business case of Meertens et al. (2014) provides a more complete overview of the business case because it combines both methods. It provides a good insight into the goal of the project, the outcomes and the potential options. It is not just focused on the financial outcome but provides eight steps that need to be identified. This fits the needs of this thesis well. MPC can have different implementations and payment structures and the economic impact is the main research objective. This is covered by the Business Case Method. Therefore, this business case definition is chosen to be suitable for this study instead of the definitions provided in paragraph 2.5.1. This business case will be worked out in full in chapter 4. The eight components that will be looked at are the following (Meertens et al., 2014, p. 48): ”

1. **The business driver.** The cause, problem, or opportunity that needs to be addressed.
2. **Business objectives.** The goal of the business case stating which objectives are aimed for.
3. **Alternatives.** Representing the options to reach objectives

4. **Effects.** Positive and negative effects that come with the pursued alternative.
5. **Risks.** Risk that come with the pursued alternative.
6. **Costs.** Costs that come with the pursued alternative.
7. **Alternative selection.** Based on gathered data the best alternative is chosen.
8. **Implementation plan.** Plan which explains when and how the alternative is implemented.

”

2.6 Takeaways of the Literature Review

This paragraph will shortly sum up the takeaways from this chapter as it provides the theoretical base and starting point of this thesis. MPC is a privacy-preserving technology that can be used to share data between parties without disclosing the output given by the individual parties. The workings of MPC are presented to understand the technology. This helps companies understanding the overall dynamics when MPC is implemented and showing them the potential of MPC. Both options ‘PSI’ and ‘Homomorphic Encryption’ are presented for the same reason.

Business models are discussed to help understand how MPC could create value. Three BMs of MPC were identified within the literature. These were about using MPC for sharing data between departments, sharing data between two firms who have a joint interest, and selling data between two firms in other industries. These three ways of creating value help this thesis because they are the starting point for the economic impact. Enabling data sharing between departments has an influence on the economics of a company. The same goes for sharing data between two firms who have a joint interest and selling data between two firms in other industries. Doing this should create additional value to companies. The business case will be based on the ability to use one or multiple of these BMs. This thesis will try to find out how companies will create value and which aspects are affected along the way of implementing MPC.

The business case is the next step for the identification of the economic impact. The business case builds onto the three identified business models. It provides a more in-depth insight into specific projects. The BM ‘sharing between departments’

is very broad. The business case will provide the specifics needed to find out more about the impact of the project. How sharing data between departments, sharing data between two firms who have a joint interest, and selling data between two firms in other industries will result in benefits and costs will be explained within this business case. This will be done by looking at eight components of the project. These are the business driver, the business objectives, the different alternatives for implementation of MPC, the effects, the risks, the cost, which alternative to select, and how MPC should be implemented.

They come from the Business Case Method of Meertens et al. (2014). This thesis has chosen this approach because these eight components capture the needed information to understand how MPC will have an economic impact on businesses. Other definitions just focused on the financial outcomes when researching business cases. This method will be fully worked out in chapter 4 and 5. The following figure 2.7 shows an initial conceptual model. This model shows how the economic impact is influenced and will be researched within this thesis.

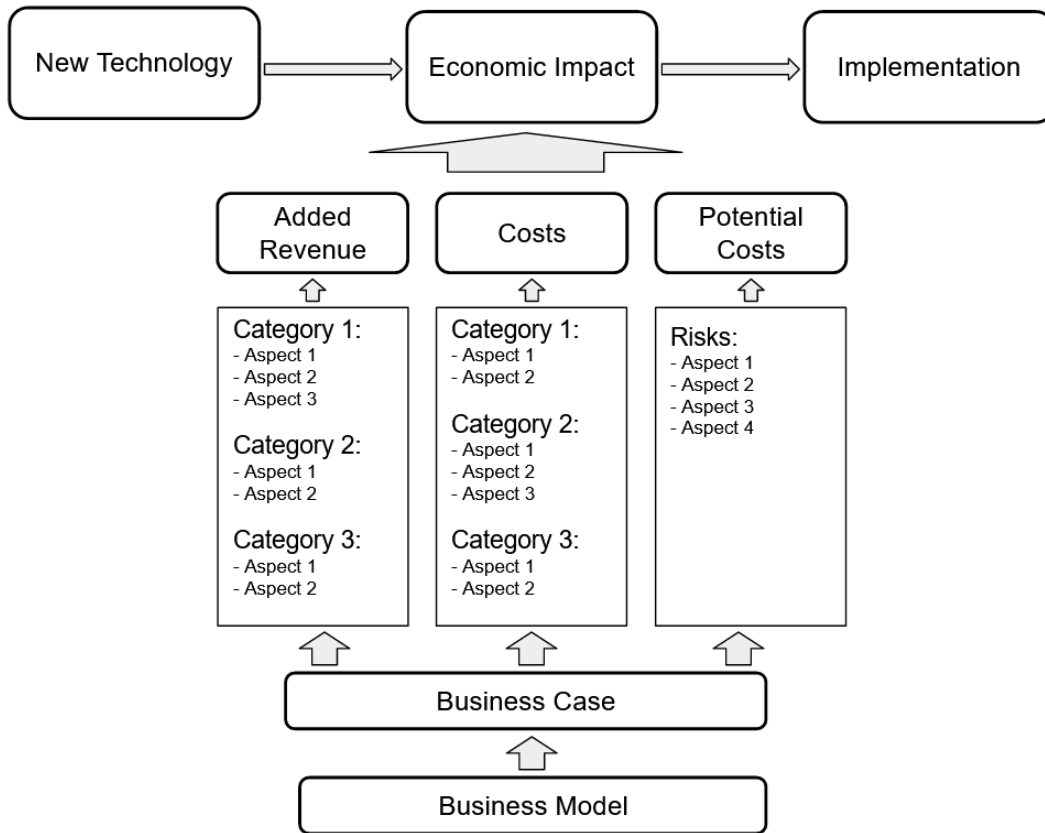


Figure 2.7: An initial conceptual model

Chapter 3

Methodology

The research strategy and structure will be discussed in this chapter. The research strategy will contain the research methods and a more in-depth view of how the research will be conducted. The research methods that are used to answer the research questions mentioned in paragraph 1.5 will be discussed in this chapter.

3.1 The Research Structure

The business model and business case will be discussed first. They will be explained and defined for this thesis. The business models will be the starting point and will come from the literature and mostly from the developed business models that are part of the deliverable: D2.2 *Business models for use cases and generic business models of the Safe-DEED project*. The business model can be found in paragraphs 4.1 and 4.2 of D2. The study should help this research by providing some business models that they have made. These models will help with making and finding different categories and aspects because they provide examples of uses of the MPC within businesses and how they affect them. The business case will be discussed thereafter to identify what the project is about and to see if it is worthwhile doing.

How the business case will create revenue will then be explained. Where the added value comes from will be discussed and categories of different areas that impact the revenue will be made. Examples of such categories are sales or customer satisfaction. This is all exploratory and will come from doing literature research. When these categories are made, there will be a more in-depth look into the aspects within these categories to get a more detailed view. Aspects of customer satisfaction could be a better recommendation section which leads to the desired higher revenue. All

the categories will be analyzed one by one by looking at existing literature on the economic impact of new technologies. A visual example of the structure of the analysis is given in figure 3.1. The categories, aspects, and their impacts will then be discussed with experts and experts from the telecommunication company to see if there are things the literature might have missed or if they have another view on the impact of certain aspects.

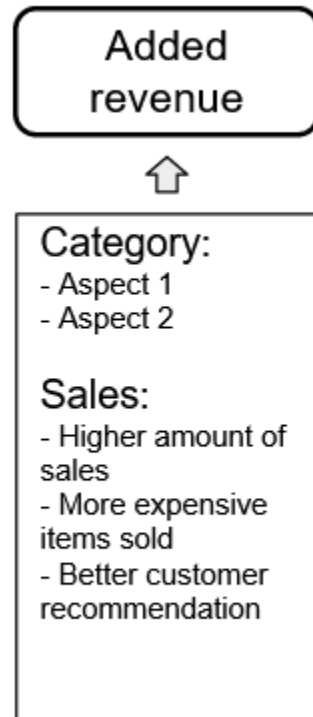


Figure 3.1: Example of the impact structure. 1. Added revenue 2. Category 3. Aspect

The costs are also important, and they will be looked at when the profits are clear. The costs will be divided into costs and risks as can be seen in figure 2.7. Risks can be seen as potential costs and are therefore included into the framework. This is done to make a more usable framework. Companies need to know what the fixed costs and potential costs are. A small company might like MPC if it has low costs but if there are too high risks involved they might not implement the technology in fear of the risk. Also, risk averse companies might avoid the technology all together because

they are afraid that a scandal might smear their company's name. Therefore, it is important to divide these two aspects of cost to make the framework more usable for real-life situations. These aspects and categories will also be validated by experts.

It is important to both identify the fixed and variable costs of MPC. The fixed costs will be the technology's cost price and the recurrent costs that are fixed every year. The variable costs will be the costs that come with scaling and the costs that are dependent on the company's size. Companies need to know what the fixed costs and the variable costs are. A small company might like MPC if it has low fixed costs and a bit higher variable costs. They might not like it if it has high fixed costs, because it would become relatively more expensive for them. The same approach and research method will be taken as for the added revenue and the example given in figure 3.1. Categories will be made for costs which will include both. An example of variable cost could be legal costs. They will be searched for within the existing literature. The prices of the MPC will be discussed with members of the Safe-DEED project. Otherwise, the costs of similar technologies will be looked at. Also, a question within the interview will be what the estimated willingness-to-pay is for their company. When categories are clear they will be worked out in detail with all the different aspects affecting the categories. These will then again be checked and discussed with experts and experts from telecommunication companies.

Finally, when the business case is clear, the benefits and costs are all mapped out in categories and analyzed in detail, then the final evaluation can be done. This will be done in the final subquestion. The framework will be applied to telecommunication companies and the benefits and costs will be discussed. It is done to see what the economic impact is when using MPC in a real-life situation. From there, a clear answer can be given to the question: *What is the economic impact of privacy-preserving technologies?* The final conclusions and discussion will be described thereafter. The thesis will end with recommendations for future research.

3.2 The Subject on which the Framework Will Be Applied

The framework of the economic impact of MPC will be applied to the real-life business of a telecommunication company. They have large amounts of data which makes the potential benefit of using the technology larger than a small bakery for example. The telecommunication company is a data-owner which means that they have data

that could be analyzed and sold, but they could also share their data between their own departments. Telecom companies are also already in the data provider business. They already have the infrastructure in place if it comes to handling data which will be helpful. Telecom companies are large firms that could potentially finance larger implementation costs. A smaller company might not have the resources to set up and implement the technology. Therefore telecom companies will have a head start in comparison to other companies If they want to invest in new projects. That is why they could be a potential big player who might be interested in implementing the technology. Therefore, they are chosen to apply the framework on. This case will not be comparable for the use of smaller companies. The benefits might differ and the potential costs of implementation might be too high for them. The implementation for a large company might also be a bit more complex. It will be generalizable for large companies that already are used to handling data.

The option to use data could be a motivation for them to look into new technologies that enable the potential of the data. The data collection will come from multiple sources and include the interviews done for the researches of (De Reuver et al., 2020) and from the work of (Dolci, 2020). The researchers have already provided access to this information for this research. There will also be interviews with experts that work specifically at telecom companies to understand the specific scenario of MPC implementation within the telecom industry. The use of these multiple sources of evidence will contribute to the reliability of the study (Yin, 2013).

3.3 Interviews

There will be interviews with several key players and players within telecommunication companies. The interviews will be held with people in different fields within different companies to get different views and experts on a variety of subjects. The specific questions that are asked can be found in paragraph 3.3.3. These questions are broad questions and they are altered in order to suit the specific knowledge of the interviewee. The questions should start a discussion and more questions can be asked within that discussion to find the meaning and higher the usability of the interviewee's answers. The main objectives of the interviews are:

1. Validating the framework that was conducted from the literature
2. Expanding the framework that was conducted from the literature with the aspects that were mentioned by the experts

3. Checking if the framework is applicable for the real-life situation of a telecommunication company

3.3.1 Interview Protocol

The framework validation was done by doing semi-structured interviews. Some prospects were referred by Mark de Reuver and Hosea Ofe. Also, the contact details or first contact was sometimes laid by them. The top 9 largest telecom providers of the Netherlands, based on a quick google search, were contacted to do an interview and 9 other experts that were recommended were contacted. Four of the recommended experts agreed to have an interview, none of the largest telecom agreed to have an interview. Fortunately, two experts within the contacts of Mark de Reuver and Hosea Ofe worked at a telecom company.

The type of interview is semi-structured interviews. These interviews have pre-defined questions, these can be found in paragraph 3.3.3. The intention is to focus on a subject while still keeping it an open question from which a discussion can emerge from. The questions can not simply be answered by yes or no because they are formulated to be open questions. The answers need to open to provide insight into the why and how aspects and categories influence the economic impact. These open questions also stimulate the interviewee with providing there own narrative of why and how MPC has economic impact. The questions leave some space to ask follow-up questions and get deeper into the subject. This fits perfectly for this qualitative research. The interviews are used to validate the framework that will be made from the literature, to expand the framework, and to apply the framework to telecom companies. So, open questions and discussion can provide great insights. The insights and conclusions were immediately written down to ensure this first impression was not lost. These were later revised and judged again.

The prospects were first emailed with some information about the project and why and how they could contribute to the research. The email also contained two dates that could be chosen if they accepted. The final version of this thesis would be sent to them if they would be interested. The full email can be found in appendix A. Experts were not sent information on MPC before because Dolci (2020) and Jeevan (2019) showed that they did not have time to read it and the supervisors warned that it might scare them away. An invitation was sent with the date and the link to the meeting if they accepted. The first questions were about what they thought the benefits and costs were. The developed framework was presented later

to ensure there was no confirmation bias and not to hamper their creativity for new aspects that influence the economic impact. This data was analyzed with atlas.ti. The quotes that were given were open coded using atlas.ti as a tool. The codes were reduced after an iteration process by merging or deleting some codes. First-order concepts were written down. They were grouped up by looking at similarities and differences. Similar codes were grouped up and refined as second-order concepts. The final step was to merge second-order concepts to generate aggregate dimensions. The full description of the data analysis of the interviews can be read in paragraph 6.1

The developed framework was validated and extended by the interviews. The last thing to do was to apply the framework to the case of a telecom company. How this affected a telecom company was based on the interviews. This showed how MPC can affect a large company with a lot of data and data infrastructure as discussed in paragraph 3.2

3.3.2 Participants

The interviewees were chosen based on *judgement sampling* to see if they fit the objective of obtaining the necessary expert knowledge. Judgement sampling is a variant of purposive sampling and can be used to gather specific information which is not easily accessible (Sekaran and Bougie, 2016). This information can be obtained by interviewing specific experts who do have the knowledge and insights into these subjects. They needed to have knowledge about any of the categories within the developed framework and preferably work at a telecom company. The targeted experts were chosen because they were experts on different parts of the framework. One expert was for instance more knowledgeable on the business side and he would provide more in-depth answers to the business-related aspects of the framework. The experts that were contacted had either a business role, knowledge about data and data security, legal, or worked at a telecom company. This ensured that all parts of the framework could be discussed with experts in that field of study. The four experts that were interviewed can be found in table 3.1. Unfortunately, two interviews were scheduled but they kept postponing until after the deadline for this thesis.

Expert Interview Number	Expertise and Background	Relevance
Expert 1, from now on referred to as E1	This expert helped with a deliverable within the Safe-DEED project on MPC. This, in combination with his work at a telecom company, made him a prime target to interview.	The expert possessed knowledge about MPC and he could also help with the implementation of the developed framework on telecom companies.
Expert 2, from now on referred to as E2	The second expert is a senior manager at the Cybersecurity and Privacy team.	She could help with explaining legal requirements and costs, and also could provide additional insights into the risks of using MPC with her knowledge of data security.
Expert 3, from now on referred to as E3	E3 is a strategist, leader, and business developer at a large telephone company. His expertise laid within technology implementation and he worked at a telecom company which made him a very interesting expert to speak to.	He could provide insight into the process and costs of implementing new technologies, share his vision on how MPC would affect a telecom company, and he knew much about data.
Expert 4, from now on referred to as E4	The fourth interview was with a Head of an Innovation centre. He had 18 years of experience in developing strategic solutions and special projects focusing on Innovation and Research. He participated in strategic planning, identifying future opportunities and meet long-term corporate goals.	This expert was deemed fit to ask questions about this new innovation and how he would identify the opportunities it had.

Table 3.1: Expert interview numbers, expertise and background, and relevance

3.3.3 Interview Questions

The interviews were set up as follows. First, the interviewee is asked if they are familiar with the MPC technology itself. After that, MPC is defined and explained to ensure the participant has the same definition as this thesis. If understood correctly, the first question is asked. The questions that were asked are the following:

1. How does MPC affect their specific domain?
2. Why would MPC affect their specific domain like that?
3. Why does your opinion differ from the literature?
4. What aspect of question 1 is the most important for their company?
5. Why is that aspect the most important one?
6. Which aspects are you missing from the framework?
7. Why should those aspects be included?
8. Are there aspects that should be excluded?
9. Which implementation structure of MPC would you prefer and why?
10. Which payment structure would you prefer?
11. Are there any insights that you believe to be relevant for the economic impact of MPC that were not discussed yet?

Question 1 and 2 are used to find the answers to the benefits and costs of MPC. The questions are asked before presenting the framework to not direct them to the already found categories and aspects. The interviewee must come up with impacts of their own and not simply agree with the framework. They are asked about their domain to get another point of view on the matter. Their domain can be found in table 3.1. When the questions about the framework are asked, then they are asked about their opinion on the framework within telecom companies if applicable to their expertise. The second question is only asked if the interviewee did not explain immediately why MPC would affect their domain like they described in question 1. **Question 3** is asked in case there is a discussion about an aspect or category. The discussion should lead to new insights that might alter the framework. If the interviewee has a different opinion of the effect of an aspect, the effect should be reevaluated within the literature and other interviews.

The purpose of **questions 3 and 4** is to find what is important within companies that are looking at implementing MPC. The answers are compared to the discovered answers from the literature. The found literature can be read in chapter 5. The questions should provide clear answers on what is important and the impact of the mentioned aspect will be discussed in more depth because of it. This will be documented so that future research knows to critically look at these specific factors or ensure they are quantified. Discussing the most important aspect and why it is the most important might also provide new insights into benefits and costs.

After these four questions, the framework will be presented. The framework was intentionally not presented before to counter confirmation biases and to let the interviewee come up with their own interpretations. The intention was to let them first come up with all the impact MPC might have that they could think of. After they explained what they thought the impacts would be, the viewpoints of the framework that were not discussed yet were presented and discussed. The impacts that were found within their domain in the literature and the effects on the economic impact will be presented. **Questions 6-8** will be asked to find out what their opinion is of the produced framework. **Questions 6** might look like the same questions as question 1 however, presenting the framework might let them think of other aspects that they did not think about before. Otherwise, they just answer no and the framework can be considered complete according to the interviewee.

The purpose of **questions 9-11** is to find the specific benefits of the different deployment alternatives. Question **9** refers to the different implementations such as peer-to-peer structure or intermediaries with single computing server or intermediaries with multiple and independent computing servers. They might discuss aspects that were not yet mentioned in the framework. The findings can also be useful for future research. If all the respondents answer that they prefer the peer-to-peer structure, it might be the best place to start their research. Question **10** is about if they would prefer a time based subscription or a pay per use or a different form of payment. The final question will be an open question and the interviewee is asked if they have opinions or other matters they would like to share about this topic that were not discussed yet to ensure they have shared all their insights.

Chapter 4

The Business Case

This chapter will be the starting point of the study and will answer the first research question: What business case could be used by the telecommunication companies for MPC technologies? The modeling approach that will be taken is a business case analysis. The arguments and definitions are supported by the literature as shown in chapter 2. The different literature indicated that companies normally make a business case to find if a project is worthwhile doing (Ward et al., 2008). By doing a business case analysis it is possible to find the objectives of a project and all the impact that it has (Meertens et al., 2014). This can help with making sure that all the factors affecting the economic impact are considered. Also, it helps with finding aspects that affect real-life companies because they also use this framework. Therefore, it was deemed useful to do for this research. This will be the starting point for the framework development.

Every company has a business model which determines how a company generates revenue. This is explained in paragraph 2.4.1. Besides business models, there are also business cases. These business cases are developed to map out specific projects to exploit new opportunities or to solve certain problems. The business case of MPC influences the revenues and the costs, this can be seen in figure 2.7. Therefore, it is important to clarify what they are and how they apply to the case of MPC. This chapter now will address the Business Case Method of Meertens et al. (2014). According to Meertens et al. (2014) the Business Case Method Consists out of (p.48): ”

1. **The business driver.** The cause, problem, or opportunity that needs to be addressed.
2. **Business objectives.** The goal of the business case stating which objectives

are aimed for.

3. **Alternatives.** Representing the options to reach objectives
4. **Effects.** Positive and negative effects that come with the pursued alternative.
5. **Risks.** Risk that come with the pursued alternative.
6. **Costs.** Costs that come with the pursued alternative.
7. **Alternative selection.** Based on gathered data the best alternative is chosen.
8. **Implementation plan.** Plan which explains when and how the alternative is implemented.

”

4.1 The Business Driver

The goal of the project is to solve data sharing problems. The project will try to accomplish this goal by implementing new technology. This new technology, MPC, should make it possible to share data between companies and departments. It becomes possible to do more data analysis if there is more data available. The usage of MPC makes it possible to combine multiple datasets and thus gather more available data. This means that companies can use that extra data to do better analysis which gives better insides into different fields, such as strengthening market competition and opening new business opportunities (Kwon et al., 2014). This project tries to solve the data sharing problem between companies. They normally do not want to share their data for multiple reasons. These reasons are:

1. They do not want their competitors to have their data because they are afraid to lose their power or lose control of the data (Safe-DEED, 2018).
2. Competitors can use data to make better analysis and gain a competitive advantage over their rivals and gain a benefit from it (Linaker and Regnell, 2020).
3. Spillover effects. Competitors can gain more knowledge of the rival’s overall functioning, which leads to them gaining a competitive advantage (Linaker and Regnell, 2020).
4. It is hard to share data for companies because they have to comply with regulations such as the GDPR (European Commission, 2020).

Another problem is the inability to acquire data from data markets because:

1. Companies cannot easily buy and sell data, because there is currently no good working data market in Europe (Fricker and Maksimov, 2017).
2. Open data marketplaces are also not a good source for data currently so they are not always used (Kittlaus and Clough, 2009).

Businesses are unwilling to share their data without MPC which will result in fewer data sources because of the reasons mentioned above. These are the current issues that the companies are facing when they want to share their data.

4.2 The Business Objectives

The business objective will state what the project seeks to achieve for the company. The objective is to enable data sharing. This can be achieved by using MPC. This will have a positive impact on data-driven business models because they benefit from the inclusion of multiple data sources. The data-sharing will result in the availability of more data, with more data the insights will become more meaningful and enable more opportunities (Koutroumpis et al., 2017). This means that MPC could be used to take the next step towards data sharing within and between businesses. It has the potential to gather and use more data which has additional benefits that will be explored more in the effects section of the business case and chapter 5.

4.3 Alternatives

The alternative section is about the available options to reach the objectives. The business case and the subject of this thesis are MPC. Therefore, this paragraph will focus on the different forms of MPC. There are multiple ways to implement and use MPC and each of them has its benefits and costs. This paragraph will only explain the alternatives; paragraph 5.7.1 will explain the different costs of the different implementation structures. Alternatives should be included in the business case because of their differences. Each alternative has different costs for implementation. This could lead to different outcomes if it is quantified. All alternatives should be assessed to explore and map out all the potential costs and benefits. De Reuver et al. (2020) provided figures 4.1, 4.2, and 4.3 (p. 17).

There are multiple ways the project can be done. The implementations and figures 4.1, 4.2, and 4.3 of the MPC implementations are from the Safe-DEED deliverable '*Business models for use cases and generic business models*' (De Reuver et al.,

2020). They state that there are three ways to implement the technology in a data marketplace. These different technical alternatives are important for the business case because they have different economic impacts within the framework. The legal costs might differ in the different implementations, the implementation costs might differ and there might be more differences that influence the costs and benefits of MPC. Therefore, the different implementations should be understood and then the economic impact of each of them can be analyzed. The implementation structures will be described now; the benefits and costs of each implementation will be described in chapter 5.

The first implementation is the ‘peer-to-peer’ structure. This means that if company A wants to buy data from company B it is possible to have a direct exchange between these two companies with MPC. The structure can be seen in figure 4.1. All of the companies can directly buy, sell, or exchange data to each other which is depicted by all the direct lines between the dots in the figure.

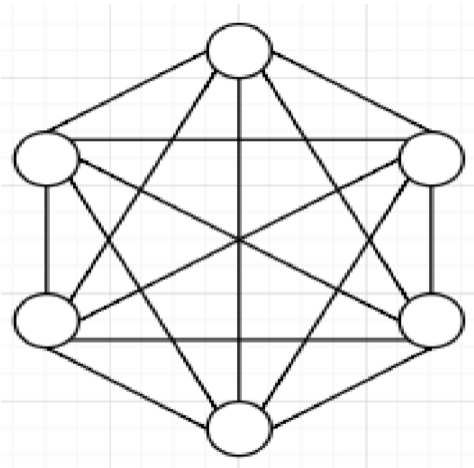


Figure 4.1: peer-to-peer structure

The second way of implementation of MPC is the ‘intermediaries with multiple and independent computing server’ structure. Instead of Company A buying directly from Company B, they go to intermediaries. These are multiple entities that are distributed and can provide multiple and independent computing servers for the MPC. A schematic drawing of such an architecture can be seen in figure 4.2.

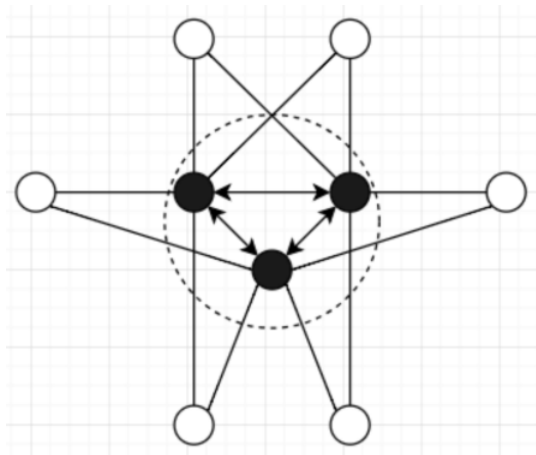


Figure 4.2: Intermediaries with multiple and independent computing servers

The final way of implementing the use of MPC is through the use of a single intermediary with a single computing server which can be seen in figure 4.3. It works almost the same as the use of intermediaries with multiple and independent computing servers. However, in this case, they use a single computing server instead of multiple servers. This makes it more direct and simpler, but it comes with other risks that will be mentioned in chapter 5.

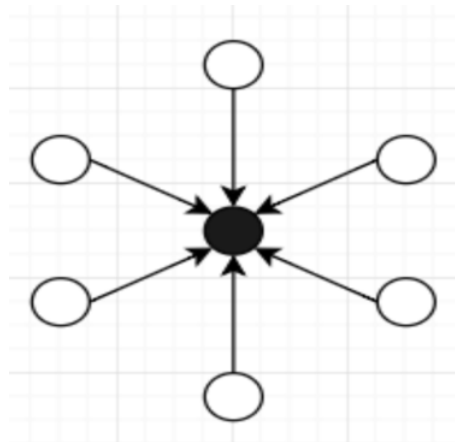


Figure 4.3: Intermediaries with a single computing server

4.4 Effects, Risks, and Costs

These three effects are too significant to be discussed within a paragraph. Therefore, they are now put into subsections and later on addressed in detail.

4.4.1 Effects

The description of the effects from the Business Case Method does not fit this study that well. The effects are normally all the positive and negative effects that come with the pursued alternative. However, this thesis is trying to grasp the economic impact and tries to make a framework for it. The effects will therefore be measured in costs and profits. This component will therefore be analyzed as the additional revenue creation and because of its importance have a full chapter dedicated to the creation of additional revenue. This can be found in chapter 5.

4.4.2 Risks

Risk is also an important factor in accessing economic impact. To give a simplified example, would you rather have 50 percent chance to win 500.000 euro or 99.99 percent chance to win 400.000 euro. Most economics would say the additional risk is not worth the additional money in this situation and go for the 400.000. This example shows the importance of risk and thus risk reduction could be seen as an economic factor. That is why section 5.8 will state the different risks that are associated with MPC and define how they affect the company.

4.4.3 Costs

Exploring the costs is obviously important when exploring the economic impact. The costs give an overview of the needed investment and are needed to calculate the profit a company expects to make. The additional costs or the reduction of certain costs are too extensive to mention in a paragraph, so they can be found in chapter 5.

4.5 Alternative Selection

Companies can make a well-weighted decision after all the costs, benefits, and risks are known. Not all companies might choose the same decision. The alternatives have different benefits and costs which will be explained in chapter 5. This makes it impossible to choose an alternative within this framework. This paragraph is

there to emphasize that companies should look at these costs and benefits of the different options of MPC. This thesis itself will explain all the costs and benefits of the different implementations on which the selection can be based.

4.6 Implementation Plan

When the best alternative is selected, the technology needs to be implemented. It is important to develop a plan for the implementation. Objectives, roles, tasks, resources, dates, and responsibilities are the key components of the implementation plan. These mostly differ from project to project and are hard to grasp in a framework and are therefore not explained in more detail. The different roles and responsibilities that are part of the implementation plan (Meertens et al., 2014) are more conventional and are easier to generalize. These will therefore be explained further. The cost of implementation can be found in 5.7.1.

There are several key stakeholders needed to decide if the project is worthwhile doing and they will decide if the project will be implemented. These people will first need to give their blessing on the project before it can start. First, the new technology needs the support of the chief technology innovation officer, from now on mentioned as CTIO. The CITO manages the internal innovation processes where new technologies and strategies are developed. They create new business opportunities with the new technologies (Smith, 2003). He is therefore important in the process of implementing technologies such as MPC. The CTIO should be the one to introduce the technology and be the one who focuses on implementing it within the company.

The CFO, chief financial officer, is responsible for the financial affairs of a company. Therefore, the CFO is also important within the decision-making process. He will look at the financial implications of the project to justify if he agrees with the undertaking of the project. This is for multiple reasons (Geiger and North, 2006).

1. To ensure affordability he will compare the project costs against the projected benefits.
2. To ensure the initial investment costs can be made the balance is checked.
3. To see if the whole project is affordable.
4. To predict the future cash flow.
5. To check the return on investment, ROI.

All the points mentioned above have a big impact on the future of the company and are therefore needed to be taken into account when deciding on the project. The CFO will therefore be needed in the decision-making process and should have information on the impact of these factors.

The CEO, chief executive officer, is the person who is ultimately responsible for taking managerial decisions. The introduction of disruptive technology such as MPC needs to have the blessing of the CEO before it can be implemented (Kaplan et al., 2012).

Those three roles are the most important within the decision-making process. The CTIO gets more important when the project has made it through and will be implemented. He will then implement it and make sure the rest of the company is informed of the new technology. The data analysts themselves will not be needed in the decision-making, because there will not change much for them. The data will be mock-up data when using MPC, but the analysis and conclusions will be done the same as explained in paragraph 2.2.3.

Chapter 5

Framework Creation of the Economic Impact from the Literature

This chapter will address the economic impact of MPC. The impact on the revenue is discussed first and the impact on the costs is discussed second. The impact found within the literature will be concluded at the end of this paragraph within figure 5.2. Prior research on MPC and economics has been qualitative and there is a need to make a framework with quantifiable aspects. The economic impact is too large to be identified and quantified at once. Therefore, the economic impact will be divided into qualitative categories of the different ways the MPC influences the economic impact. The categories will have several aspects that influence them. The categories and aspects will come from a literature research and then will be checked by and expanded from the answers given in interviews.

This chapter was created to describe the revenue creation, costs, and risks of MPC. Benefits, costs, and risks are also part of the business case analysis so they are very important to identify in this thesis. They were found by doing literature research. Sources were gathered via Scopus, Google Scholar, Researchgate, and the deliverables of the Safe-DEED project. The TU Delft repository was also used as a resource. The TU Delft repository provided multiple studies on MPC. These were read through in full and their references were checked for potential interesting articles. Three thesis studies were deemed useful and used within this thesis. Each thesis provided around 10 to 15 interesting papers from their references that were read more in detail. About 3 to 5 references per thesis ultimately found their way

into this thesis.

The search items of paragraph 2.1 provided the base of the literature study. Other keywords that were used to create the framework were: “*Legal costs for privacy*”, “*Legal costs within companies*”, “*Implementation Processes*”, “*Implementation costs*”, “*4G implementation process*”, “*5G Implementation Process*”, “*Personal Data Analyses*”, “*Targeted Marketing*”, “*Trend analysis*”, “*Private Data Potential*”, “*Data Sharing Potential*”, “*Advertisements Costs*”, “*Advertisement Benefits*”, “*Data Risks*”, “*Fixed and Variable Costs of Data*” and combinations of these words. These keywords often provided hundreds or thousands of papers. Instead of scrolling through all of them, they were systematically read. The first option was to try and add additional keywords in the search bar. Most of the time, that ended up in either no results, still hundreds of results, or irrelevant results. Therefore, a different approach was taken. The keywords were matched that seemed most critical, such as “legal costs within privacy” or “legal costs for new technologies”. This still provided more than a hundred results but the search results became more relevant. Then the step towards relevant and scientifically impactful papers was laid. The search results were filtered by most cited. The top 50 for each search result were read based on their title and abstract. This method was very useful. These often-cited papers were mostly very broad and not about a niche subject. This made them often very useful and exactly what this thesis needed. About 20 papers were found using this method that made it into this thesis. These papers were read again in full. The aspects that they described were noted and in a broad sense somewhat categorized. The references that these papers had were also read based on their relevance. This so-called snowballing method was quite effective. Another about 40 papers were identified to be possibly useful. These were read and about 20 of them were used. These papers were read in full again and put into the categories that were vaguely made. Then the categorization part was done by making several categories based on the findings. This was an iterative process and in the end, it was done by making the categories first and then shoving the found aspects around.

5.1 The Revenue

The coming paragraphs will discuss the revenue creation for the framework of economic impact of MPC. This thesis is trying to identify the economic impact for businesses and a general overview of the revenue increase when MPC is implemented, which is missing in the literature. Revenue creation is obviously what interests most companies. Where can they get additional revenue? How can they capture additional

value? This chapter will provide several categories that are affected when MPC is used within a company. The goal of this chapter is to create a general overview of the different categories that have an economic impact on companies. These categories will be built out of different aspects that specify why and how the category is affected and thus how additional revenue is created. The found categories and aspects will, later on, be verified and expanded by doing expert reviews. Thereafter, the framework for addition revenue creation will be applied to the specific case of a telecom company.

5.2 Consumer Interactions

The first category is the consumer interaction. This is a marketing orientated benefit that can be gained by using MPC. The literature state that consumer and consumer interaction has always been important for companies (Tsai, 2005). They have always been important because they are the ones companies will eventually sell their product to. This is no exception when looking at implementing MPC. How will MPC contribute to consumer interaction?

MPC makes it possible to share more data and consumer data can also be shared. Recently made frameworks show the impacts consumers might have. According to Tsai (2005), they support the interaction of consumers within research and development, manufacturing, price formulation, channel arrangement, consumer service management marketing management construction, and communication program execution” (p.4). She stated that these aspects could improve a consumer’s sensory, emotional, social, and intellectual experiences for consumers which will lead to a larger brand value. The sharing of data using MPC could allow companies to attain these benefits. The study of Clazolari and Pavan (2006) shows mathematically a Pareto improvement when two firms share unrestricted data between them. The study shows that it may reduce market distortions and even increase social welfare, including the consumer’s. Consumers may even suffer privacy costs when there is less personal information shared with third parties. The consumers might want to share their data to receive discounts and recommendations for products of their liking’s. These examples show the importance of data sharing for the consumer. A quote that shows the importance of consumer data for companies is the following:

”It’s a marketer’s dream - the ability to develop interactive relationships with individual customers. Technology, in the form of the database, is making this dream a reality. Now companies can keep track of customer preferences and tailor advertising and promotions to those needs. For instance, a grocery store system could note that

a customer recently purchased a sample size of dishwashing detergent and could offer him a coupon to buy the large size” (Blattberg and Deighton, 1991, p.7).

This quote shows the importance and the benefits of databases and the use of them. The following subsections were inductively derived from the literature. They will address the usage of consumer data and the potential benefits of using MPC.

5.2.1 More Personalized Services

The use of MPC results in companies having more, consumer, data. The use of the additional consumer data will lead to more enhanced personalized service which is positive for the consumer (Acquisti and Varian, 2005). The same study shows that the additional data had a beneficial effect on the company’s profits, but only when it is used to enhance the personalized services. The result is a win-win scenario: the consumers will get better service and the companies will have higher profits because of it. This is in line with the train of thought from paragraph 5.2 that consumers are important for more than just buying products. The customers will also become more loyal to a brand if they are satisfied if the personal service is considered excellent (Acquisti and Varian, 2005). The risk of them switching to a different brand and service will be lower and the amount of private revenues will increase. They will rather buy a product from the brand they always buy than switch to the competitor if done correctly. More on private revenues in the next paragraph.

5.2.2 Increase Revenues Obtained per Person

The revenues a company can obtain per single person is an aspect that can be increased. In other words, how much a company earns per customer. These revenues might go up with additional data obtained by MPC (Taylor, 2004). They use the additional data to infer the individual consumer’s preferences and then they can engage in price discrimination or targeted advertisement. These sale techniques will enhance the probability that a consumer will opt to buy, which will lead to higher revenue per consumer.

The additional data on itself does not generate extra revenue. Acquisti and Varian (2005) researched a two-period model. The companies could track consumers and gather additional data from them. The consumers could hide and anonymize their behavior by using anonymous browsing, deleting cookies, and using anonymous payment tools. They measured the difference between having additional data on consumers and not having additional data with this method. They concluded that

the additional data was only profitable for the merchants if it is used to provide consumers with enhanced personalized services. Thus, the data must be able to enhance personalized services in general.

5.2.3 Boost Ability to Address Specific Target Markets or Specific Consumers

Firms can significantly benefit from learning about their past, current, and potential customers. Rich datasets provide such information that can improve the marketing capabilities of a company. It boosts the ability to target markets or customers (Blattberg and Deighton, 1991). The targeted advertisements might also be less intrusive than the old-fashioned non-targeted advertisements (Goldfarb and Tucker, 2010).

MPC can provide companies with rich datasets. The companies can then increase revenues through new coupon strategies and targeted offers. An example of such a new initiative is the success of Groupon (Pitta, 2010). They focused on the proven techniques of coupons, but they tried numerous variations to hit different markets. An added effect will be increased consumer loyalty when companies address them to their likings. The consumer switching costs will also increase when data is used to improve personalized services (Ball et al., 2006).

5.3 Sales

The second category is sales. This category is interesting for the sales departments of companies for creating additional revenue. Sales teams are always working on selling as much as possible and jumping on new trends or new ways to sell more. They will be pleased with the possibilities that MPC provides. The following paragraphs will explain the impact of MPC on the sales.

5.3.1 Boost Ability to Predict Trends

MPC makes it possible to gather a larger amount of consumer data. This makes it possible to better predict trends such as customer demand for certain products (Linden et al., 2003). Inventory management will also benefit from this because they should have enough inventory to meet the demand. They will also not have more inventory than needed if they predict it right. This will result in customers always being able to buy the product. It will also lower inventory costs because of the

better inventory balance. The second benefit of predicting trends right is maximizing returns on marketing investments. When a company knows which trends there are and which trends there will be, they can anticipate the demand. The sales team can prepare itself for this demand and provide the company with a sound strategy on how to play into this trend. Companies can make the product that will be demanded the most and they can make a bigger profit in comparison to the laggards.

The aggregation of the consumer's data is still of use to firms even if the data is not personally identified. They might find consumer trends based on the combined behavior of multiple individual agents. An example is comScore who analyzes web trends by combining survey and behavioral observations of millions of online consumers. They sell their data and the trends they observe to their clients. They can then use it for market testing, segmentation analysis, and competitive intelligence (Acquisti, 2010).

5.3.2 Selling Data

Organizations that gather and own data can directly sell this data to third parties with the use of MPC without losing control over the data. They can state that they are willing to share their data for a certain price and only when using MPC. This creates an additional form of revenue creation for companies who are currently not selling their data. They can sell this data to marketers, data aggregators, advertisers, or even consultants who want to know more about the markets (Acquisti, 2010).

5.3.3 New Opportunities

New business opportunities may arise because of the new data gathered by MPC and the trends that have been unveiled because of the data sharing. The improved targeting of advertisements makes it possible to develop and sell more niche products (Acquisti, 2010). These products were potentially hard to sell because of their niche market. That niche market can now be targeted because of the additional data and better targeting mentioned in paragraph 5.3.1. Revenues will go up because of these new business models, new content, or new products. It is also beneficial for the consumer. They can have the niche products that they wanted but could not acquire. The products where demand was not deemed high enough and it was too risky to develop can now be made because better analysis on these niche products can be done and new markets and buyers can be identified (Blattberg and Deighton, 1991).

5.4 The Cost

Costs are a crucial aspect of a business case. Therefore, the coming paragraphs will discuss costs for the development of the framework on the economic impact of MPC. This thesis is trying to identify the economic impact for businesses and a general overview of the costs of implementing MPC, which is missing in the literature. This chapter tries to find the impact on costs if MPC was implemented in businesses. The costs give an insight into the needed investments for the project and the costs once the technology is implemented. The investment costs are the costs that are needed to implement the project and the variable costs are the costs that are needed once the technology is implemented, both are important. The investment costs are needed to know how many financial resources should be acquired in order to implement it. It becomes a bigger obstacle to implement a project when the investment costs are higher. The variable costs should also be accounted for. It should be clear how much money should be budgeted to use the technology. Otherwise, companies could have a situation where they have implemented the technology with all the costs that come with it, but they can't use it because the implementation costs depleted the whole budget.

5.5 The Costs of Data

The introduction mentioned the fast expansion of the digital world. Data is becoming more important for companies, so they are also collecting more and more data. MPC gives this trend an additional boost. MPC makes it possible to share data and makes the potential benefits of data even larger. This means that companies want to have and save data even more. They will also try to acquire data from external sources to save it for future analysis and usage. As with everything in life, this comes with several costs. These costs are mentioned in these paragraphs.

5.5.1 Costs of Acquiring Data

Businesses might want to gather more data because they are now able to trade it or sell it when MPC is implemented. The additional gathering of data on itself costs money, think about cookies, purchase history, and consumer satisfaction. The data needs to be stored as well, the costs for this are described in paragraph 5.5.2. This thesis focuses on MPC and companies can get additional data from third parties with MPC. The acquisition of this data could also be costly. This paragraph will explain

how data can be acquired and how companies will pay for it if there is a place where data can be bought and sold.

There are multiple ways that companies might buy or sell data on the hypothetical marketplace. There could be a fixed price for the data. This would mean that if a company buys a certain amount of data it has a certain price. An example could be every 10GB of data on people who buy telephones costs 100 dollars. MPC usage could also follow a pay-per-use revenue model. This would mean that every time a company uses MPC it has to pay a certain fee. The last possible revenue model is a subscription based one. Companies pay a monthly or yearly fee to use the MPC technology and acquire additional data. No matter which revenue model will be chosen, the additional costs should be taken into account (De Reuver et al., 2020).

5.5.2 Costs of Storing Data

The benefits of additional data are mentioned in chapter 5 but that same additional data also brings additional costs with it. The more data a company owns the more storage space it needs to save that data. The costs of storage have fortunately been decreasing because of the evolution of information and communication technologies (Byrne and Corrado, 2017). However, the amount of data gathered is increasing which is why it should be kept in mind. MPC makes it possible to analyze more and that makes it potentially profitable to start gathering more data to sell or use with the help of MPC. Then again, more data means higher storage costs. Fortunately, each company only needs to provide their data when using MPC. The outcome is what's important and needs to be saved and used. Also, the option to sell or trade the data that a company now has, makes them want to gather even more data. Each company has to think of the trade-off. Is the additional data storage cost worth its value in comparison to the revenue created by MPC?

Dutta and Hasan (2013) described the costs of storing data in six parts these parts will now be discussed. The first aspect of storing data is initial costs. These are the costs that are related to setting up the infrastructure to store data. Almost all businesses have already made these costs but for the completeness of the framework, this is still added. The costs that are related to the initial costs are networking equipment such as routers, server racks, cooling fans, disks.

The second cost is that of floor rent. The servers need to be placed somewhere and this takes space and thus money. The price for the rent can alter from place to place so different companies can have different strategies for it. Smaller companies normally hire some office space within a city for their services. The bigger companies

build their data centers outside of the cities. This is more cost-effective for them, but the costs are too high to build a data center for smaller companies.

The third cost is energy. Energy or power is needed to keep the networks, servers, and disks continuously running. It is also needed for the cooling and security of the data. This is an inevitable cost and the more data needs to be stored, the more power is consumed.

The fourth cost is service. Everything still needs to be maintained, updated, and checked every once in a while. The service costs are based on this. They should update software or repair hardware and this is also influenced by the experience of the employees. The more experience the better and cheaper they can maintain it.

The second to last cost are disposal costs. These are the costs connected to the disposal of equipment. After some time, hardware needs to be updated and disks might be changed. Some might still contain data which might make it sensitive for data leaks. A good way of ensuring the data does not fall into the wrong hands after disposing of a disk is simply physically destroying it. The disposing of equipment logically comes at a cost so it should be considered.

The final cost that should be explained is that of environmental costs. The environment became a hot topic the last few years. Storage of data requires on itself a significant amount of energy. The whole infrastructure should also be up and running nonstop. This not only costs energy on its own but the back-up systems also create additional emissions. The back-ups are heavy diesel generators that still emit a bit of exhaust (Dutta and Hasan, 2013). The energy and the emissions come at a price that should be accounted for.

These factors are affected with the increase of data and thus affected if companies store more data to use for MPC.

5.6 Legal Costs

Legal costs are an important aspect within companies. Companies have to comply with all kinds of different rules and regulations. They might also fit the profile for certain exceptions of rules or governmental support. The legal department will look at these cases and provide the company with advice on how to work or what to do. MPC will have an impact on how things are done but also needs to comply with several rules and regulations. This impacts the costs for the legal departments if they have to do more work it will become costlier but MPC might reduce the amount of labor needed and have a beneficial effect on the legal costs. How MPC influences the legal department will now be discussed.

5.6.1 Sensitive Information

Encryption is strong and a necessity for the protection of data. It is needed to ensure confidentiality and integrity of sensitive information within data storage, especially in the new and increasingly used data storage (Al Mamun et al., 2017). When parties fully trust each other everything is fine if they exchange encrypted data and the related keys. The problem comes when the parties do not trust each other. Here, MPC can unlock new possibilities within the domains where legal and procedural hurdles are prevalent (Fricker and Maksimov, 2017, p. 6). The legal department should address how to handle this sensitive information with third parties but also within their internal processes. The handling of sensitive information gives more work to the legal department and should therefore be considered.

5.6.2 Rules and Regulations for MPC

Several laws and regulations are in place for data usage and data sharing. The main one is GDPR or General Data Protection Regulation. The EU Charter of Fundamental Rights stipulates that it is impossible to simply share all data because of the right to protect personal data for all EU citizens (European Commission, 2020). The companies do have to comply with this regulation otherwise they will get fined. The legal department should check if all the regulations are met. This becomes a bigger task if MPC would be implemented and could therefore result in costs. The compliance with legal requirements is an ongoing process and should be considered and implemented in the framework. The deliverables D3.1, D3.2, and D3.3 of the Safe-DEED have identified the legal requirements necessary for the implementation of MPC.

5.7 Technology Costs

The technology itself could come at a cost too. The costs of MPC are not known at the moment. How much money companies have to pay or what payment method will be chosen is not known. This paragraph will try to mention the different costs that the technology could have so that this framework is robust for multiple possible implementations. It might even be the case that there will be multiple options for MPC and this paragraph will help with choosing one of them based on the cost structure.

5.7.1 Technology Implementation Cost

The technology needs to be implemented which comes at a cost. The costs are not the same for the peer-to-peer structure, intermediaries with multiple computing servers, or intermediaries with a single computing server that were identified in paragraph 4.3. The peer-to-peer structure needs more effort to set-up MPC and infrastructure for the data providers. Each data provider needs to implement the technology into their infrastructure which means that all parties have acquisition costs. Acquisition costs are the costs of buying the product. Acquisition costs are also the possible necessary pre-conditions that enable the new technology to function properly. Examples of additionally needed pre-conditions are the upgrade of soft- or hardware or the upgrade of them. This might be a too heavy investment for small businesses and an advantage for bigger companies. They can more easily pay these costs and profit from the advantage the smaller companies don't have. This might lead to a market where there are a few big players also called an oligopolistic market.

There are different costs when intermediaries with multiple computing servers or intermediaries with a single computing server are the way the technology is implemented. The costs of the implementation do not lie with the businesses that want to use MPC anymore. The costs will lie with the intermediaries. However, the higher the implementation costs for the intermediaries, the higher the price will be for the computations because the intermediaries need to make a profit from doing the computations as well. The costs of using MPC for businesses will not come from implementation costs in this situation but will come from the price of using MPC with intermediaries. The costs of this could vary from fixed price to subscription-based as mentioned in paragraph 5.5.1. The implementation itself can begin, when a deployment alternative is chosen. Implementation is always a process that takes time and work of people within a company. These costs will now be described.

5.7.2 Cost of Employees

There are two ways employees have an effect during the implementation. There are the employees whose job it is to implement the technology. These employees make decisions and make plans on if and how new technology should be implemented. If it is a major project, it requires more work for these employees which translates to more costs. They also lay out a plan on how to implement it which sometimes requires the hiring of new staff. This type of cost comes from the employees who have to work with the new technology. These people need to learn how to work with the technology. They might need training on how to use it which costs money. The

first times they use it they might be less productive because it takes some time to get used to. This hinders the overall productivity which brings higher costs with it. Also, with encryption, each employee might need an account for the platform which brings additional IT with it.

5.7.3 Operation Costs

When MPC is implemented the costs will not stop there. The planned costs are described above, but once the implementation plan is finished the technology itself still has operational costs. These are the costs that include but are not limited to support contracts, warranties, license costs, and every once in a while upgrade costs. These costs are recurrent and need to be forecasted and included in the costs. The use of MPC brings the benefit of having additional data but it also costs more time to compute and there might be more computations.

5.8 Risks

Risks are not direct costs or revenue loss but they should be accounted for as mentioned in paragraph 4.4.2. Risk is about potential costs and potential benefits and should be a part of financial planning. If certain risks are too high a company might need to consider insurance, an alternate approach or accept the risk. How high these risks are alters each case, so the framework will only provide general risks that are affected by MPC. The costs of risk could be estimated by multiplying the chance something happens and the costs that it would bring with it. If there is a 10 percent chance of losing 100.000 dollars the costs could be expressed as 10.000. By addressing and decreasing the chance the costs will go down as well, 5 percent of 100.000 leaves the estimated costs at 5.000. This is an example of why risks are important for the costs and why these paragraphs explain the risks that are affected by MPC.

5.8.1 Data Leaks

A risk that every company that collects data has, is the potential of having a data leak or data breach. A data breach can be defined as:

According to Clearinghouse (2019) “*a security violation in which sensitive, protected or confidential data is copied, transmitted, viewed, stolen or used by an unauthorized individual*” (p. 1).

This could either be an accident or because of an attack either way it is paired with damages that need to be paid most often. Especially with the rise of data collection, it becomes a serious threat. Chambers (2018) even states: *“There are only two types of companies: Those that have been hacked and those that don’t know they have been hacked”* (p. 1).

Derek Manky even found that about 500.000 cyberattacks are happening in the world each minute. The potential costs lie within tangible and intangible costs. These costs are legal costs, settlements for the affected parties, regulation compliance, loss of reputation, restoring the affected systems, productivity, and intellectual property (Richardson et al., 2019). Executives even ranked cybersecurity as their highest concern within operations (Proivity, 2016). The costs of a breach are the reason for this. Businesses globally had to pay an estimated 2.9 trillion dollar by 2019 (Morgan, 2017). To give an example, Target was hacked in 2013. 70 million personal data of customers and 40 million credit cards were stolen. The damages were 200 million dollar for reissuing credit cards and they were named in 90 lawsuits and the CEO and other people lost their job because of the breach (Gonsalves, 2014). They had to invest hugely in cybersecurity to gain back confidence in their privacy reassurance.

A problem with cybersecurity is that it is expensive. According to Holmes (2007), the executive director of Sony Corporation stated *“it’s a valid business decision to accept the risk of a security breach. I will not invest \$10 million to avoid a possible \$1 million loss”* (p. 1). This is a valid argument and that comes back to the introduction of this section: risks can and should be calculated into costs. Richardson et al. (2019) even doubts the economic impact of privacy data breaches. However, this might be a bit short-sighted if there are solutions to prevent them these should at least be considered. Multiple sources indicate the severity and impact of breaches, so data leaks and breaches should still be taken into account. MPC could be such a solution to reduce the risks of data leaks. The encryption could help to prevent accidental leaks by employees or if data is transmitted or obtained by the wrong parties, it is still encrypted. Then again, the potential costs of data leaks and breaches should be higher than the costs of MPC if the angle is purely economical. Otherwise, it might not be worth it.

5.8.2 Competitor Entry to the Market

The additional costs also have a benefit even though that sounds contradictory. Companies that do not invest in accessing consumer data by using MPC will have a competitive disadvantage. The investments that must be made into MPC will

higher the entry barriers into the market. Competitor entry costs can be defined as an advantage of the currently leading companies within a market. The advantage comes from the large investments that new entrants need to make before they could join the market. (McAfee et al., 2004). This means that it will be harder for new or smaller companies to join the market and become the competition. The risk of new competitors will be lower for the current market-leading companies. This will mean that large businesses with large consumer bases are at an advantage and have more power when MPC is implemented. This will be a benefit for large multinationals but a disadvantage for smaller business owners if the costs of MPC are high.

If the price for MPC is lower, smaller companies might benefit more than larger companies. They will be able to access relatively more data compared to the larger companies. It might even open up new possibilities for small companies such as the ability to do data analysis when that was not an option before. The small company might not have enough data at first to do data analysis. The additional data from MPC might let smaller companies also do data analysis and compete on that level with bigger companies and gain market share. This eventually all depends on the affordability of MPC.

5.8.3 Who to Trust in each Implementation

When doing computations with other parties companies need to choose to put their trust in the other party. The different structures cover different areas of who to trust. The trust that is required by data providers within the peer-to-peer structure lies with the MPC software. The parties involved have their own MPC software which they can check if it runs correctly. They do not need to trust intermediaries to do the computation right and keep their data secret. Each party only needs to have trust in the technology. The data providers need to trust the intermediaries within the intermediaries with multiple computing servers structure. They need to trust the third party who will do the computation for them. They should trust them to not collude with the opposing party and that they will reveal the original, not encrypted, input data. The same goes for the intermediaries with a single computing server. The difference is that the companies need to have trust in the single server that it will not reveal the input data compared to multiple servers.

5.9 Miscellaneous

5.9.1 Cost of Advertisement

Currently, some companies might be over-investing in the acquisition of personal data (Taylor, 2003). Specific personal data can be used to reduce costs within online advertising. E-commerce advertisements can target specific consumers simpler than their offline counterparts can. The reason is the information on which the advertisements are based. The online behavior such as sites visited, behavior, and clickstream data on a given site can make the difference between a personalized ad and a random ad. MPC can make it possible to share this data between companies and let them both benefit from the dataset. The price of behaviorally targeted advertisements is almost three times higher than the price of untargeted advertisements (Beales, 2010). If they can analyze and target the right customers they can reduce the costs spend on communicating with consumers and the consumers can reduce the effort in obtaining useful information. The information and targeted advertisements might create new business models and services, or low-cost products (Goldfarb and Tucker, 2010).

5.9.2 Inventory Costs

Trend prediction can help create additional revenue as stated in paragraph 5.3.1. The additional data can also predict the demand. Multiple parties are interested in this, raw material suppliers, retail managers, and manufacturers for instance. It can be used to optimize the whole supply chain and decrease costs. Inventory costs are one of these costs that could be lowered. The MPC can provide a computation from the competitor's confidential data to forecast demand (Safe-DEED, 2018). That way companies already know which resources to buy, how many to buy, when they are needed, and for how long they need to store them. If all this is known, companies can cut down costs by not buying too many materials, not having huge inventories, and buying materials at the right time at the right price.

The framework can now be created by combining all the knowledge found above. The framework derives from the initial conceptual model. This can be seen in figure 5.1. The developed framework is composed out of the categories and aspects that were found in the literature. The framework that was developed from the literature can be found in figure 5.2. In chapter 6 the framework will be validated by experts.

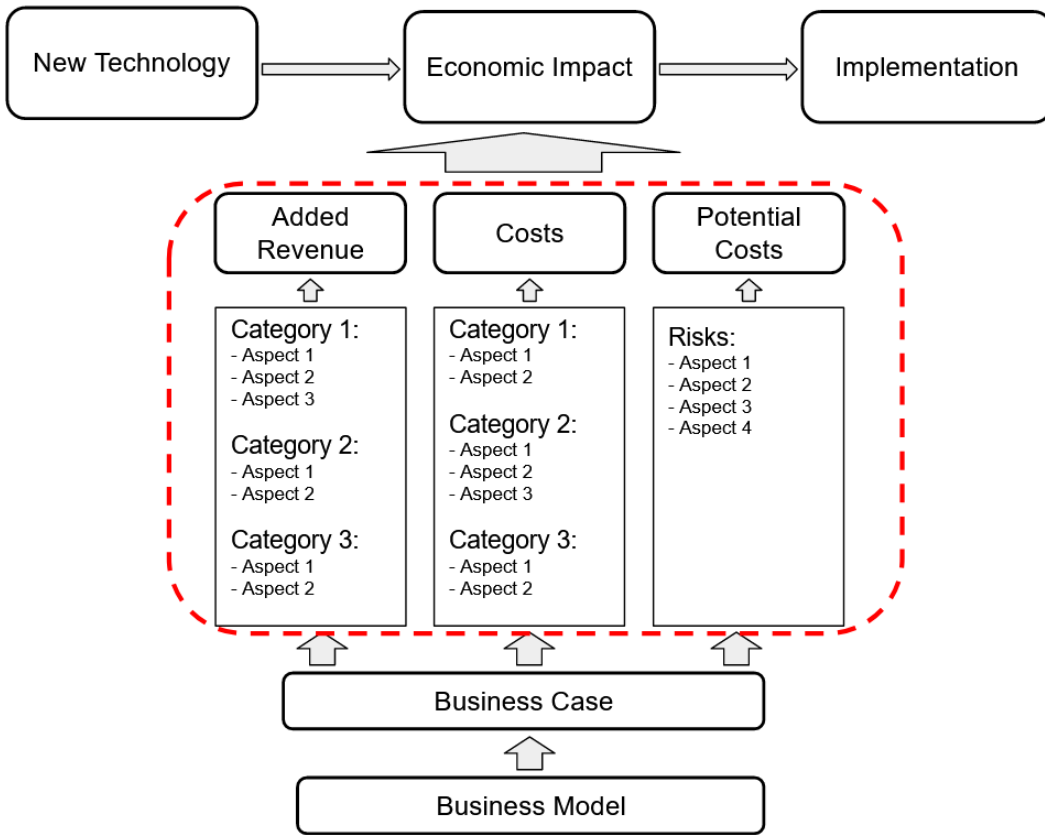


Figure 5.1: Conceptual model

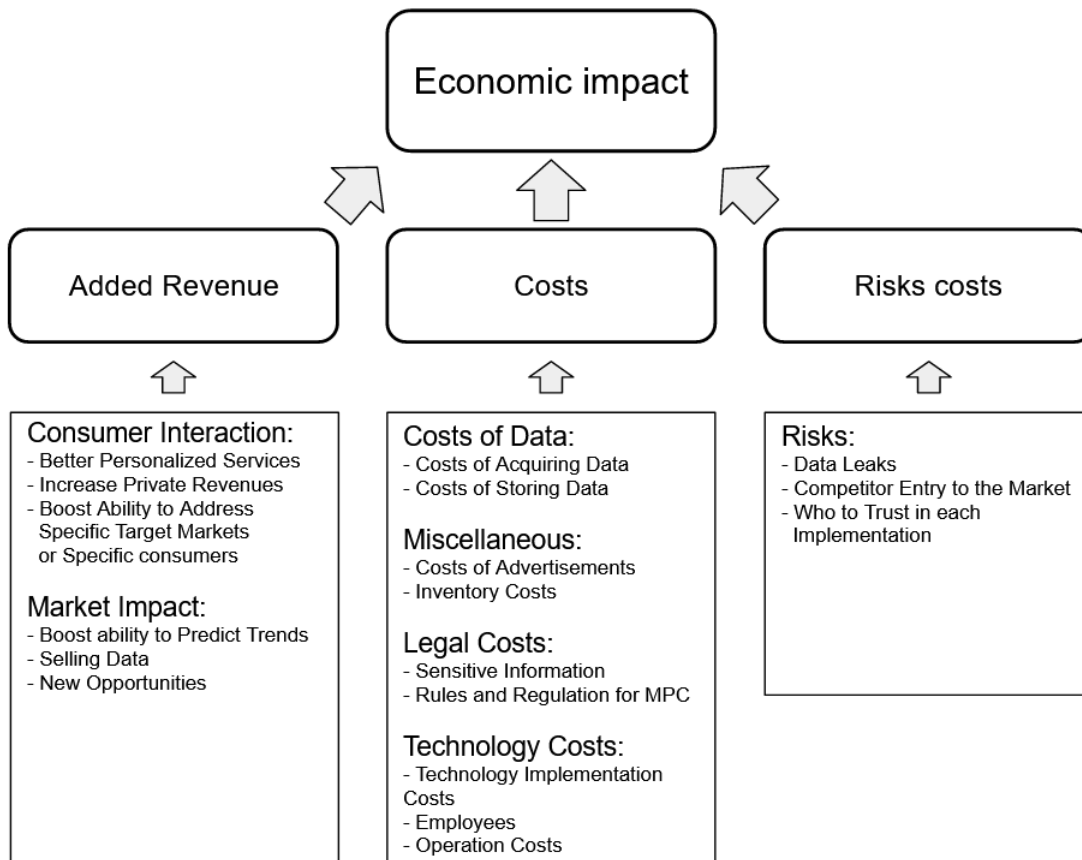


Figure 5.2: Framework derived from chapter 5

Chapter 6

Framework Validation

This chapter will be about validating the framework made in chapter 5 and can be seen in figure 5.2. The framework will be validated by doing interviews and an implementation of the framework on a telecom company. The next paragraph will describe how the data from the interviews was analyzed.

6.1 Data Analysis

The analysis was undertaken in four iterative steps. The first step was manually transcribing all of the interviews in full. The interviews were recorded and listened back while typing everything that was said. The transcriptions were read back and adapted somewhat to remove incomplete sentences. Other sentences were a bit adapted to improve readability. The text was tried to keep as close to the original to make sure that the interviewees' answers were not adjusted by the transcription. The core of the answers or sentences was never changed. Grammar was only improved a little or some words were left out if it would enhance the readability. Other errors were not adjusted if they did not affect the readability. The interviews were immediately deemed very useful and contained multiple insights. Therefore, the interviews were transcribed in full instead of summarized per interview to ensure no data was lost. All the data could then be analyzed.

The full transcribed interviews were read back while listening to the recordings before the second step. This was done to ensure nothing was missed and nothing was misinterpreted. It was also done to already identify some insights and learn from the experts. The research strategy for the analysis is the *Middle-Ground Approach* from Sekaran and Bougie (2016). The Middle-Ground approach was taken for creating

the codes. The initial code list consisted of the aspects identified from the literature. Codes were changed or refined during the research process as new codes and categories emerged inductively.

So, the second step was to openly code the fully transcribed interviews using atlas.ti software for data analysis. Atlas.ti was used for the open, axial and selective coding. This meant that the text was analyzed in full and certain sentences and quotes were assigned with descriptive codes. An example of the coding that was done is the following. *“Big companies will keep on storing data either in-house or in cloud services. So I don’t think that MPC will influence storing data.”* was coded as *“influence on data storage cost”*. An example of the coding can be seen in figure 6.1.

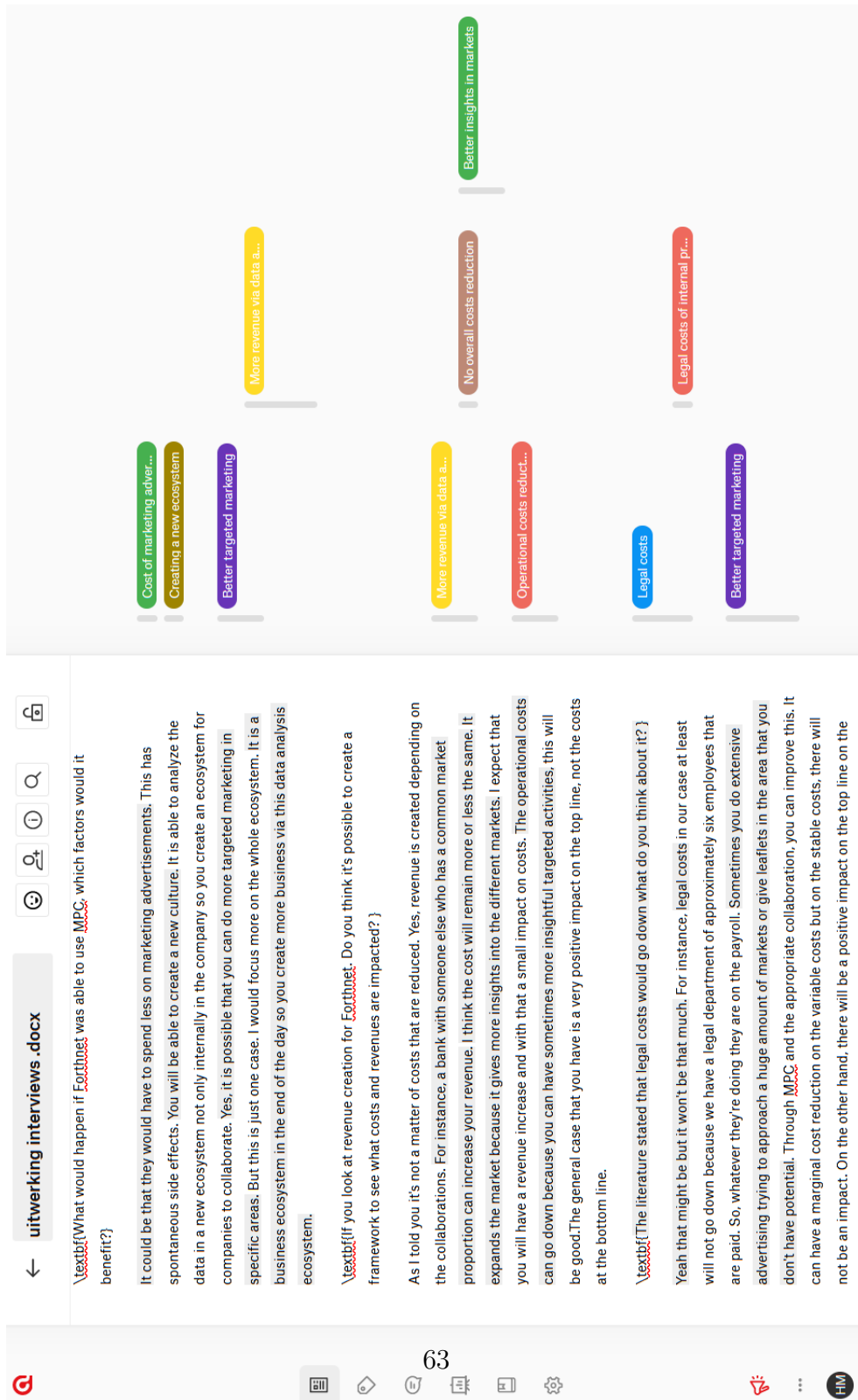


Figure 6.1: Example of coding in atlas.ti

This generated a total of 49 codes after the first time the interviews were all read and coded. This process was done two times to ensure all the needed information was labeled and put under the right category. After these rounds of coding the total analysis contained 56 codes. Then the marginal codes and redundant codes were merged. There were codes such as *'Implementation costs into systems'* and *'implementation costs of the technology'* that were merged into one code *'Implementation costs of technology'*. This was done for about 10 codes into 4 codes. This is a common step when coding qualitative data (Saldana, 2013). This process was done by looking at the codes that were only assigned to one quote and later also to the ones that only had two quotes. Multiple codes contained a single quote and were not merged because of the uniqueness of the quote addressing a specific aspect. There were multiple 'one quote' codes because of the number of interviews. There were only four interviews and not all interviews had the same expertise. The interviews sometimes focused on different aspects which caused only certain experts to talk about certain topics. Some codes were renamed to a different quote because it would fit better. Codes such as 'shows need of MPC' were not included in the first-order concept because of irrelevance but they were insightful and therefore not deleted. Other codes that were not deemed important for the framework or additional insights were discarded. The final step in this part of the process was using the *Redundant Coding* tool within the atlas.ti environment. This tool searches for duplicate coding entries. The remaining redundant quotes can then be assigned to the right codes. The outcome of this whole process is the generation of 24 first-order concepts.

The third step was about arranging the codes into groups. The codes were manually evaluated and revised for differences and similarities using axial coding. Similar codes were drafted together and written down on a piece of sketch paper. Different codes were linked and written down together within a drawn cloud as the first form of grouping. After all the codes were within one or more clouds, the sketch paper was put away. Not all codes were included in the final figure of first-order concepts, second-order concepts, and aggregate dimensions because they were explanatory. With explanatory is meant that these codes provided more information about the overall picture or the application of MPC within telecom companies. Codes such as 'shows need for MPC' were not usable for the framework creation but showed the relevance of MPC. The final version of grouping was done a few days later by looking at the sketch paper and making the final decisions on what to put where. This process was done a few days later to have a fresh look at the created groups and have a fresh view on what goes where. The choices were based on the feedback from the experts, feedback from the supervisors of this thesis, and rational thinking.

The outcome of this step were second-order concepts. The fourth and final step was to identify aggregate dimensions which the second-order concept influences by doing selective coding. The core categories and interrelations were found this way. The full figure with the first order concepts, second order concepts and aggregate dimension can be found in figure 6.2.

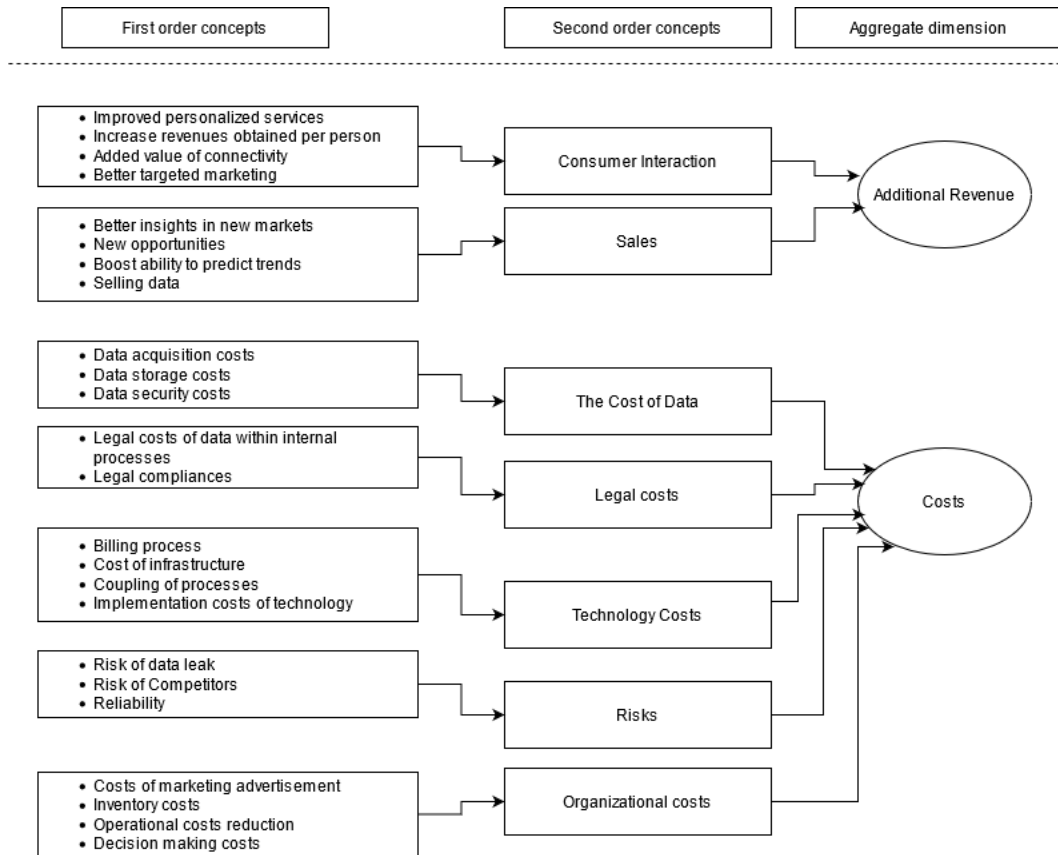


Figure 6.2: Outcome of the interviews from atlas.ti

The categories or second-order concepts were created as mentioned by discussing them with experts, feedback from the supervisors, and some rational thinking. Some categorizations are straightforward while others are more debatable. However, the framework does not become less viable if first-order concepts are put into another second-order concept. Or to put it differently, the framework does not become less viable if aspects should have been put into another category. Businesses will have to analyze all of the aspects regardless of the category they are placed in. Nonetheless,

this thesis has made grounded choices and these categorizations were considered the most fitting ones.

6.2 Results from the Interviews

The interviews gave new insights into the economic impact of MPC. The framework and all of the categories and aspects were discussed with the experts. This paragraph will first discuss the interpretation of the interviewees on the made framework. Their opinion on the made aspects and the explanation of their effect will all be discussed. The aspects will be validated, changed, or deleted based on their comments. Their explanation of the impact will be given as well if it differs from the literature. When this is completed, the additional aspects given by the interviewees will be discussed. These are aspects that were not found within the literature and therefore not yet implemented in the framework. These aspects and their influences will be discussed and implemented in the framework. This paragraph will end with the newly created framework which is based on the literature, validated by the interviews, and also extended by the interviews. The groundedness table can be found in appendix C.

6.2.1 Consumer Interaction

Better personalized services and increased revenues per person would improve as mentioned in chapter 5. E4 agreed when this was asked. The additional information on the consumer will allow this. The ability to address specific target markets and specific consumers were marked as very important aspects. E1 when asked about the most important factor for a tele company: *'Well it's always the higher revenue that comes from the new markets that you are able to target.'* Multiple sources indicated that exploring new markets was a fundamental benefit for them. The sources also indicated the addressing of specific customers as important. They gave handing out flyers or coupons within a certain area as examples which could be improved with MPC. E1 stated: *'Sometimes you do extensive advertising trying to approach a huge amount of markets or give leaflets in the area that you don't have but has potential. Through MPC and the appropriate collaboration, you can improve this'* Therefore, this aspect should definitely be included within the framework.

6.2.2 Sales

MPC makes it possible to better predict trends. The sources agreed with this statement without discussion. MPC also improves the ability to go try and go for new

opportunities according to the interviewees. E4 when asked about how they will benefit from MPC: *'To combine with other organizations and work together with them. Marketing as well marketing campaigns and we could even produce new services and new products or play into trends.'* The same goes for selling data. They say it would be a possibility but companies would probably only work with parties who are complementary. *'Well in terms of banks I don't see them ever selling their data. Not ever. In terms of sharing anonymized data sharing, yes in the future they maybe will with some specific organizations mostly public sectors for example. But I can see smaller companies doing so.'* - E4. This category was easily validated and no discussions arose.

6.2.3 The Costs of Data

The fact that there are costs for acquiring data is very logical. This was also confirmed by the interviewees. Transaction costs were mentioned by E1 as an aspect. He stated that: *'They (telecom companies) buy data and find correlation inside.'* The transaction cost was not made into a different aspect because it could fit under 'Costs of Acquiring Data'. The payment structure was also discussed with the interviewees. *'We would like to have a periodical subscription because you don't have to count events you only have to count 1 which is the date.'* They were all in favor of the periodical payment structure. The costs of acquiring data will therefore be a fixed amount every to be determined time.

The costs of storing data were indicated to not be of too large impact in terms of storage costs. Yiannes said: *'I don't think the MPC will affect the cost of storing data. Big companies will keep on storing data either in-house or in cloud services. So I don't think that MPC will influence storing data costs. The companies will not save huge amounts of additional data.'* Also, the companies already have data storage in place so they will not need that much additional storage space. However, small businesses such as bars who do not have a place to store their data do need to consider it. The aspect mostly impacts companies who do not possess sufficient. The aspect only impacts companies that do not possess sufficient or any data storage. This is enough to put it into the framework because it affects certain businesses.

6.2.4 Organizational Costs

The inventory costs will go down as predicted. The interviewees said data sharing will be done mostly with complementary parties. E4 stated: *'Yeah for us that is*

not really relevant but I can see how other companies could benefit from MPC with their inventory.' Inventory can be a good first step for sharing data because of the low risk. The shared data is not sensitive consumer data and other parties can't use that information to gain an advantage. The only data you share is of your planning and logistics. The impact is also only on the costs side which was deemed not that impactful but it surely has an economic impact and therefore mentioned in the framework.

The costs of advertisements were identified to drop as predicted by the framework and are therefore validated and still included. E1 stated: *'It could be that they would have to spend less on marketing advertisements.'*

6.2.5 Legal Costs

Legal costs were disputed within the interviews. E1 stated for instance that the costs would not be significant based on the huge size of their company. The legal costs could still be an aspect according to E3. There are two ways the legal costs are influenced. The first is making the data GDPR compliant and the second way is making sure all the internal processes are done correctly legally speaking. E3 stated: *'The internal process also needs to be within the requirements of GDPR and that can be quite costly.'* These two were also identified within the literature. The costs might not be significant for large telecom companies but they might be significant for smaller companies, therefore it is included in the framework.

6.2.6 Technology Costs

The technology implementation costs, employee costs, and operational costs were all validated by the experts. They agreed with the narrative provided by the framework when they were asked. The technology implementation costs also added that there would be additional costs for implementing MPC within the different systems of a company. *'There it gets costly because it has to be implemented into your CRM (customer relationship management) systems and your provisioning systems and the whole machinery.'*

6.2.7 Risks

The most mentioned aspect was 'Data Leaks'. The interviewees stated two different effects if a data leak occurs. The first consequence is reputational damage. E3 stated *'I think data leaks are a big risk and also your reputation will be at risk even if you*

meet all the GDPR requirements'. This is not an economic factor but it was indicated as a significant impact. The second consequences are the fines that will come from the leaks. The fines can for instance come from not complying with GDPR anymore. *'The customer may have not given consent to have this data shared with another company. That will be a non-compliance of GDPR and that will result in fines'* This aspect is therefore still included in the framework.

The competitors' entry into the market was discussed but the influence should be removed from the framework. Yiannes stated: *'The costs are low enough for anyone to step into the technology. I don't think the costs are too high.'* The implementation costs will not be of great significance for companies. It will not form a barrier to compete within or enter a market. Businesses could do a cost-benefit analysis and if they calculate that MPC is profitable they will simply use it. They will go to a bank and get a loan if the calculated potential benefits are large enough.

The aspect of 'who to trust in each implementation' will be transcribed to 'risk of competitors'. The interviewees stated clearly that the implementation should be with intermediaries and within this implementation. They also stated to not fully trust any party. E1 said: *'You never trust the other party fully never no matter what. So you have to trust the application and internal processes.'* The computations should be made with complementary companies and not competing companies. A company could however take a risk and collaborate with a competitor if they estimate to come out on top. This could result in a profit but could also cost market share if the competitor benefits more than predicted. Another risk is that big companies could use their scale to their advantage. They have more data and can acquire more data to grasp a bigger market share. The niches could then still be targeted by other companies. The smaller companies should ask themselves the question, how and if they would want to work together with the bigger companies.

6.2.8 Additional aspects

Next to the validation and removal of certain aspects, there were also new ones discovered within the interviews. The first aspect that was mentioned is the cost associated with the decision-making process. E3 described it as follows: *'So, we have an idea and what we do is we basically brainstorm with some people. We have some interviews with potential customers or other people involved and then we usually set up a prototype or a proof of concept to see whether it works and when we see potential we can then start to develop a product.'* This will also need to be done for MPC.

The decision should be made if the project gets a go or no go for implementation.

This thesis helps with providing information to use during the decision-making process but the process itself still costs time and money. This was somewhat mentioned within costs of employees but it is mentioned as a stand alone cost within the interviews. Therefore, costs of the decision making is a new category.

The other completely new aspect is that of reliability within the category risks. The technology needs to be very reliable for the companies. Data leaks and its costs are already mentioned but E3 also mentioned that the technology should be working at all times: *'People need to be able to rely on it so it needs to be working 100 percent of the time all the time. There might be some quality issues related to that. Or quality requirements that you have to fulfill. That will increase costs'*. Downtime or delays have a financial impact on businesses. Therefore, reliability should be added to the framework.

Also, companies do have to consider the additional costs of protecting the additional data, this was indicated by E2. She stated *In most cases a lot of investments is needed in the technical bucket so a lot of technical safeguards are needed*. The more data the more costs of protecting it. Overall, this might not be the biggest impact on costs but it should be included within the framework because it is still significant especially for smaller companies or companies who did not collect data before.

The conclusion of this paragraph is the final version of the framework. This version can be found in figure 6.3 and will now be projected on a real-life company.

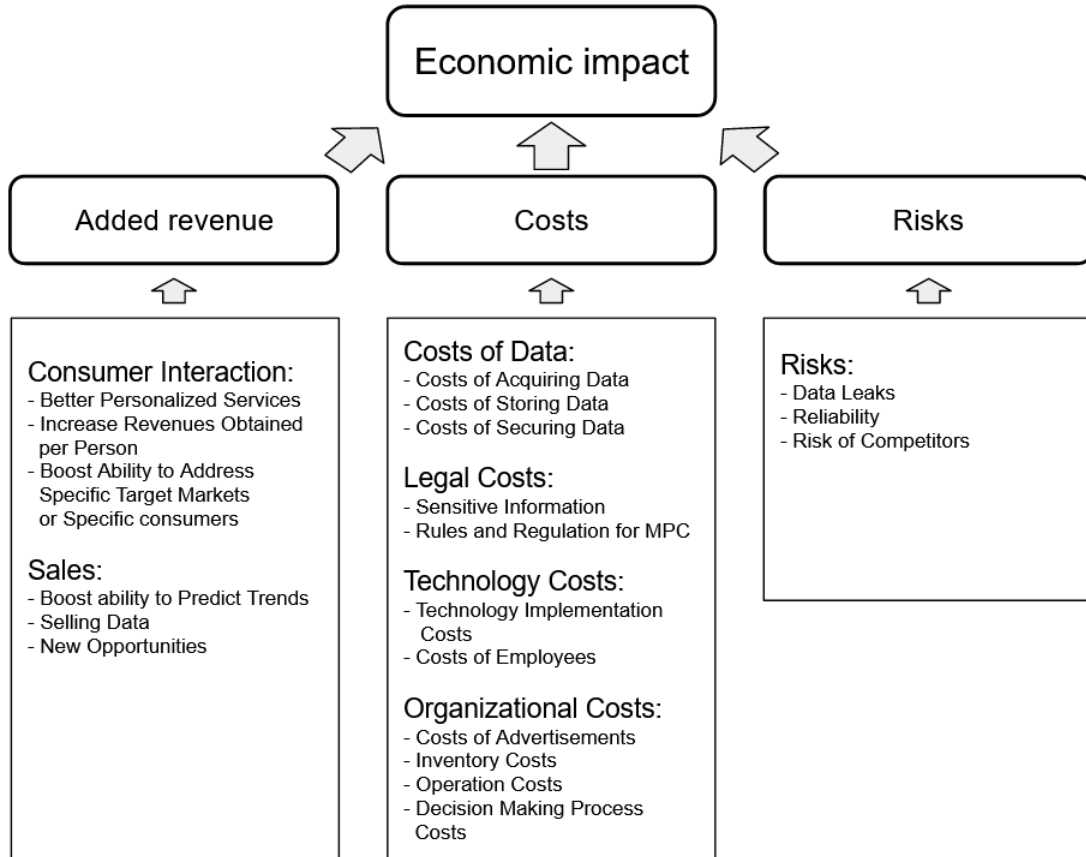


Figure 6.3: Final framework

6.3 The Recommended Framework Applied to a Telecommunication Company

This paragraph will discuss the application of the framework to a telecom company. The claims that are made in this paragraph are based on the framework and the answers supplied by the interviewees. The impact is derived from the interviews and were analyzed based on the description of paragraph 6.1

6.3.1 Added Revenue

The interviewees stated that they would not share with competitors but only with companies who might be complementary. So, T-mobile would not share data with Vodafone for instance. They would share data with banks or other retailers. That information allows telecom companies to boost their ability to target new markets. New area-specific markets could be targeted and customers could be targeted more specifically. The interviewees mostly spoke about area-specific marketing. These areas could be based on the shared information of banks. Higher-end products or services could be advertised within wealthier areas, whereas lower-end and discounted products might sell better in other areas. The marketing department of telecom companies can make strategies based on this data. The revenues obtained per person can also increase because of it. The additional information that they can obtain might help with engaging in price discrimination. They can do this to ensure the customer will not buy a new subscription at a different company.

Better personalized services were identified as a possible benefit. However, in terms of telecom companies they will not be a big factor. Telecom companies generally make products that serve large parts of the market and not customer-specific products. The amount of data, texts, or minutes are the only adjustable features when buying a phone subscription, not much more. The telephones that you can buy are also largely premade and not customizable. Therefore personalized services are not that much affected by the introduction of MPC. The telecom companies are not keen on selling their data either. They are large firms who rely on their reliable reputation and they do not want to give their competitors an edge. The profits that they would get from selling data could in the long run harm them if the competitors gain an advantage over them. So, selling data would not be an option for them. They will only share but with companies who might be complementary.

Identifying and optimizing new opportunities and new trends are big factors for telecom companies. They are continuously searching for the next trends and opportunities and MPC could help them with it. They could use new data to see if the applications of 5G are wanted within certain areas and discover where they should implement the technology first. Trends could also be important to identify. Not so much for the product that they are making because they do not need to maintain a large inventory but it is useful for predicting which bundles they should sell.

Telecom companies could benefit in a totally different way by becoming an inter-

mediary. This is not implemented within the framework because it is only possible for so few companies that it is not generalizable. It will be briefly explained now because it is of importance for telecom companies. Telecom companies already have the data-sharing infrastructure and a trustworthy reputation. Therefore, they could possibly fill in the role as a data marketplace. They would implement a subscription model, the same they do for the internet and phone subscriptions that are already in place. They could become the intermediary that collects the data and does the computations using MPC for other companies. The other parties that could do this are banks for instance. Starting a new company that wants to be an intermediary comes with three problems. The first problem is that they would need to make a big investment in infrastructure to send, store, and compute the data. It might not be cost-effective to start from scratch. The second problem is that they do not have a reputation yet which might reduce the potential amount of clients. The third problem is that they have no partners to start with. Big telecom companies on the other hand already have a large client database. Overall, telecom companies might be intermediaries in the future.

6.3.2 Costs

Most costs were deemed insignificant by multiple sources. They are still important to mention because it shows where there is an impact and where there is no change for a telecom company. The cost of acquiring data will probably be through a periodically based subscription model at an intermediary. All the experts agreed that intermediaries and a periodical subscription model would be the best implementation for MPC. It allows the company to make computations and share data without restrictions. The costs of storing data will not go up significantly according to the interviews because companies already have their data storage in order. MPC will not change the amount of data that will be stored drastically. Therefore, the costs of storing data will not go up.

The total costs of advertisements will go down because they can analyze and target the right customers. If they can analyze and target the right customers they can reduce the costs spend on communicating with consumers and the consumers can reduce the effort in obtaining useful information. This will lead to a lesser need for investments in advertisement and thus a lower total costs of advertisements. The inventory costs remain unchanged because it is not really applicable for telecom companies.

The legal costs are interesting. For a large company such as a telecom company, it is stated that it will not matter that much. The additional work can easily be overseen by the full-time employed legal staff. They do have to make sure that the data is according to GDPR standards, so it gives them some more work.

The most important category to look into are the technology costs. The decision making process will take time and money but the benefits could be significant. So, the process will be done thoroughly. The strategist in the company will have a look and decide if they will implement it. The technology implementation costs can be important if they want to become an intermediary. This is not the focus of the study so this will not be explored further. The tools to mask the data before sending it should be accounted for. The employees will also need some training to know how to work with the technology which costs time and money. The final costs are the operating costs. These are the costs that include but are not limited to support contracts, warranties, license costs, and every once in a while upgrade costs. The subscription could be as a lease contract so that all the operational costs are covered by it or the operational costs could come separately.

6.3.3 Risks

The risk about competitors is easily answered. Telecom companies should trust nobody fully but need to trust complementary companies enough to share data with them. They could trust competitors if they think they will benefit more from the shared data than the other party. It is a risk but it is possible. The only thing that every company fully needs to trust is the technology itself. They also need to try to take advantage of the economics of scale. The reliability is also very important for them. They have a reputation which they need to uphold and they do not want a tool that could have downtime or glitch in such big organisations. So, this should be accounted for as well.

The other risk is a big one. Data leaks could be harmful to the reputation of the company and could result in costs. There are fines associated with GDPR compliance. If data from the companies is leaked, that could have an impact on them financially. This could be partially resolved by doing the computations through a third party. They could be liable for the damages if it is their fault. The reputational damage would still be caused though.

Chapter 7

Discussion and Conclusion

7.1 Main Findings

The main contribution of this thesis is bringing the information together of the known economic impact of privacy-preserving technologies, categorizing it in a framework, and adding new information to the framework. This paragraph will discuss the conclusions from the different analysis.

7.1.1 The Business Case Analysis

The business case analysis showed the impacts of the project ‘implementing MPC’ and answered the first research question *What business case could be used by companies for MPC technologies?*. The goal or the business driver of the project is to solve the data sharing problem that companies have as mentioned in the introduction. The objective of implementing MPC in a business is to enable data sharing with other companies. This data-sharing will result in the availability of more data which will lead to more meaningful results and enable more new opportunities. Managers can see these positive effects and opportunities in the created framework. They can also see the costs and risks. They can base their decision of implementation on these quantifiable aspects. The identified categories are *consumer interactions, sales, risks, the costs of data, legal costs, technology costs, and miscellaneous*. The aspects that influence the economic impact are *more personalized services, increased revenues per person, boost the ability to address specific target markets or specific consumers, boost the ability to predict trends, selling data, new opportunities, costs of acquiring data, costs of storing data, cost of securing data, sensitive information, rules and regulations for MPC, technology implementation costs, employee costs, operation costs,*

decision-making process costs, data leaks, reliability, and risk of competitors. These aspects and categories can be found in figure 6.3. This list of categories and aspects are the answers to research questions 2, 3 and 4. *What revenues will the business case of MPC create? What are the costs for MPC? What are the risks that are influenced by MPC?* Managers can now base their decisions if they should implement MPC on these quantifiable aspects by doing a cost-benefit analysis. The end result of this analysis will be a profit or a loss. This will decide whether the technology will be used or not.

7.1.2 The Applied Framework

The application of the framework was presented in the introduction as a way to show how to benefits and cost compare to each other. This is part of research question 5 *How do the costs and revenue of MPC compare to each other?*. The framework was created from the literature review and the interviews and then applied to telecom companies. The application of the framework showed how each of identified aspects from the framework would affect telecom companies. It was stated that the additional revenue creation is more important than costs and risks. Companies should implement the technology if the benefits are significantly larger than the costs. That is why the area-specific marketing and other aspects within sales were deemed crucial. Telecom companies are often large companies and the costs would be less significant for them. This showed the economic impact for telecom companies when implementing MPC. Not all of the aspects of the framework were relevant or had an effect on telecom companies. This is not an issue. The interviewees also stated the importance of creating multiple real-life cases of the impact of MPC. Companies want to know previous success stories of other companies to ensure the benefits are not just theoretical. Managers could look at this applied framework to see how they can apply the framework to their company. They can also use this example if their company is similar to see how the aspects influences them.

The goal of this thesis was to create a general framework that could be used by all businesses to identify the costs and benefits of MPC. Therefore, the application of the framework can have different results for various companies. This thesis showed the results if MPC would be applied to a telecom company. Telecom companies could become an intermediary who does computations for other companies. This function of intermediary might be lucrative. Therefore, managers of telecom companies can additionally make a business case and cost-benefit analysis for becoming an intermediary to see if this could be profitable.

7.1.3 Recommendations for the Implementation of MPC

The framework and interviews provided insights into the costs and benefits of implementing MPC. The benefits but especially the willingness to implement the technology and the costs were influenced by the implementation structure of the technology. The following conclusions were derived from the interviews.

The interviewees clearly stated that there should be clear use cases and proof of concept within real-life situations before they would definitively decide if they would give MPC a chance. Thus, businesses that want to use MPC to share data with other companies should be able to provide exemplary cases of mutual benefits. They could show these examples to other parties to convince their partners to use this technology as well. No data will be shared if no company wants to do computations. The implementation of MPC will be for nothing if no company sees the potential of data sharing via MPC. The implementation of MPC will be useless if no parties are willing to share their data.

The intermediary structure was consensually chosen to be the preferred implementation structure. Therefore, this thesis also recommends this structure. The advantages of this structure lay within two factors. The first factor is responsibility. For example, if Company A wants to use MPC along with Company B and they use an intermediary, the intermediary is responsible for the risks. The technology costs and insurance of reliability lay with the intermediary. It is still a risk for both companies to engage in data sharing, They still put their respectable names on the line but most of the financial liabilities would lay at the intermediary. The second factor is the costs of computation. It is cheaper to have an intermediary do a lot of computations than having every company fully implement MPC and making their own computations. This would be the case in the peer-to-peer structure. To conclude, the preferred structure is with an intermediary.

The billing structure was considered as well. Telecom companies indicated that they would implement the technology and possibly act as an intermediary. The billing structure should be in place if an actor opts to be an intermediary. Not all trades will be simply 'data of company A traded for data of company B'. Therefore, it is important for the overall implementation that there is a method of payment in place which parties could use if they wish to acquire or sell data. The identified payment structures were: periodical payment, pay-per-use, and pay-per-data. The undisputed best payment structure is the periodical payment structure. The benefit is the ease of use. Pay-per-use and pay-per-data do need additional monitoring structures which is not desired. The periodical payment structure doesn't need additional monitoring

which is a benefit. Also, businesses could try out the data and test what they want unlimitedly. This is important, especially in the beginning. This lets companies try out the technology and increase the willingness to try out MPC.

The final recommendation is about reliability. The technology must be able to use at all times and should not have glitches. This would influence the useability and decrease the use of MPC. The technology must be impeccable. The reputation of a company is at stake and they could risk fines for not complying with GDPR if the data is exposed by accident. Therefore, the technology must be implemented robustly.

7.2 Theoretical Contributions

The main theoretical contribution of this thesis towards the field of research is the framework of the economic impact of MPC. The identified knowledge gap was the lack of knowledge about the economic impact of MPC. This thesis tried to fill this knowledge in several ways.

The first theoretical contribution was the made business case. Several business models were discussed and the applicable models for MPC were identified. The developed business case was built upon existing literature about business models and business cases. A pre-existing approach was taken, the business case method of Meertens et al. (2014), and a fully filled-in business case was the outcome. The business case analysis for MPC provided additional information about the business driver, the business objectives, the different alternatives for implementation of MPC, the effects, the risks, the cost, which alternative to select, and how MPC should be implemented. All this specific knowledge for MPC was added as a theoretical contribution.

This thesis added a business case for different usage of MPC. Future studies can use this business case as a starting point for their study. They could potentially compare their business case to that of MPC or copy it if their project is very similar. The business case can potentially be used for other privacy-preserving technologies as well. The business case also identified multiple alternatives and their benefits. This could help managers in the process of picking an implementation structure or start a whole new business case for each of the alternatives. This business case can best be used by companies to check if the project of implementing MPC is viable for them.

The biggest contribution of this thesis is the creation of the framework for the economic impact of MPC. The knowledge gap of the economic impact was filled in by the framework. The aspects that influence the economic impact when MPC is implemented were discovered. This was a big step towards filling in the gap. The theoretical framework that was created is depicted in figure 6.3. These aspects can be quantified within future studies. Cost-benefit analyses can be made from the quantifiable aspects provided by the framework. The framework could also function as an example for future frameworks on new technologies. The process of identifying quantifiable aspects and validating them could be repeated for different technologies. Parts of the framework might overlap if the technologies have similarities. The Safe-DEED project could also use this framework in their project for deliverable 2.5 'Quantificationn of the economic impact'. This thesis provided multiple quantifiable aspects. They could use these aspects and find more if needed and could then quantify them. This will save them time in finding the aspects themselves.

The next contribution is towards the conceptual knowledge of a real-life applicable situation if MPC would be implemented. This was obtained by using the framework and applying it to telecom companies. The application of the framework showed how the framework should be applied to a business. The final contributions are the suggested implementations in real-life for MPC. These could be the base for future studies that want to identify or explore real-life scenarios. These scenarios were identified to be crucial for the implementation of businesses.

7.3 Practical Contributions

The practical contributions will be discussed in this paragraph. The main contribution of this thesis towards managers and decision-makers is the identification of the economic impact if MPC would be implemented. The introduction stated that companies have problems with data sharing even though data is becoming more important for them. Several problems such as: not sharing data because of the angst of losing power, spillover effects, regulatory problems, the lack of possibilities for data acquiring, and more could be of the past if companies would implement MPC. This technology could solve the problems allocated with data sharing between companies by resolving these concerns which managers have when sharing data. This thesis identified and explored the economic impact of this privacy-preserving technology to research the possibility of its implementation in real-life scenarios by decision-makers.

The solution that was suggested to solve these problems was MPC. However,

decision-makers will not simply implement MPC within their company without knowing what it does and if it is profitable. They can use this thesis to understand what MPC is. They can also check the business case analysis to check if it is comparable and also applicable to their company. The business case method could otherwise be used by them to analyze their specific business case.

If a company wants to implement MPC, there is a framework to check how they are affected financially by the introduction of MPC. The framework is a general framework. Managers from different companies can use it as a tool to check which and how the different aspects will affect their company. This may vary from business to business. The framework can be used as a checklist to check all the aspects. Some aspects might have a bigger effect on their company and some a smaller effect compared to other companies. Businesses could quantify each of the different aspects and calculate if the implementation of MPC is worthwhile. Therefore, this framework will boost the ability to decide if the implementation of MPC is worthwhile doing.

The final practical contribution this thesis made was the addition of the application of the framework to telecom companies. The addition of real-life situations was deemed of utter importance within the decision-making process. Telecom companies can read paragraph 6.3 and decide if they deem MPC worthwhile to implement. Other managers can look at this paragraph to see how they could evaluate their company based on the framework.

7.4 Evaluation of Limitations

The research has been done thoroughly and carefully to not miss any data and to create the best possible research. However, this research also has its limitations. The results and conclusions are not irrelevant because of the limitations but they should be well addressed to ensure the right nuance. Also, future research could look at these limitations and try to fill in the gaps.

The first limitation is about the alternatives. MPC was the privacy-preserving technology that was analyzed. This thesis did not compare this privacy-preserving method to other technologies. These other technologies could have different effects on companies that are not included within the created framework. The alternative selection for companies is only focused within the MPC implementation spectrum. The framework is therefore only useable for the implementation of MPC. The framework might be a good starting point for future studies on the economic impact of

other privacy-preserving technologies if they have large similarities to MPC.

The literature review has been done systematically as described in paragraph 3.1. Several methods of finding information have been used and this thesis gathered information from many different sources. However, there is always a chance that some literature might be missed that could have added a new aspect or insight. This thesis is written in the belief of having covered the needed, available, and relevant literature.

There are also some limitations within the interviews. Only four interviews were done with experts which impacts the validation. The interviewees were very hard to come by. A lot of people were contacted but not that many wrote back. Calling offices of large telecom companies did not work as well. They simply hung up or said to write an e-mail which did not respond to. This hindered the application and validation of the framework because information was needed from telecom companies. The experts that were interviewed validated the framework and were uniform on the impact of almost all aspects. The experts were also very sure of their answers. Therefore, the answers and results of those aspects are valued as robust.

Unfortunately, they did not provide many new insights. This could be because most of the experts did not know MPC beforehand. They were explained using a presentation and an explanation during the interview. Experts were not sent information on MPC before because Dolci (2020) and Jeevan (2019) showed that they did not have time to read it. Also, the supervisors warned that it might scare them away. The short explanation might have impacted their ability to identify the capabilities, benefits, costs, and risks of MPC. E1 was already familiar with the technology and this interview provided the best insights. The full framework could be discussed with him and he also provided more in-depth answers. There was no need to explain the technology again during the conversation as was the case with some other interviews. The interviews with the experts who did not know much about MPC beforehand were much shorter. They also provided more general answers to the questions. Sometimes, they just stated their general policy without referring to MPC at all. Even without the additional information send beforehand, it was still very hard to find interviewees. Two interviewees even kept postponing until the deadline of this thesis was exceeded because of their busy schedule. Requiring the experts to read the information on MPC in advance could be beneficial for the quality of the conversation but it probably makes it harder to find experts willing to participate in the study.

The final problem with the interviews was their point of view. They were all working for a large company or institution. The framework would be applied to a large telecom company in this thesis but the framework had to be a general framework. Therefore, insights from a smaller business would have been useful. Information on the impact for smaller businesses was not specifically asked, this could hinder the generalizability of the framework.

The applied framework on telecom companies might also not be fully generalizable. The framework itself is generalizable. All companies should at least consider all the aspects. The applied framework to the telecom companies is not fully generalizable. Telecom companies were chosen based on their potential as explained in paragraph 3.2. Their potential is so large that they might become intermediaries for MPC. This is probably only generalizable for other telecom companies, banks, and large data companies because it needs a lot of infrastructure and investments to become an intermediary. The need for real-life scenarios and applications is mentioned several times in the interviews. Smaller or middle-sized businesses might not see this as an example on which they can form their opinion about MPC.

For example, the cost of data was insignificant for telecom companies because they already have a large system in place. This is not the case for smaller businesses such as a local pub. Middle and smaller companies might also struggle with legal costs. The local pub does not have a legal team but should get informed if all rules and regulations are met when using MPC. The impact of the risks is also lower for smaller companies. Their name will not be damaged significantly or become the headline in a data leak scandal. The technology costs are also relatively more significant for smaller companies and should therefore be looked at in another application of the framework.

Most companies will probably only share with companies who are complementary instead of competitive. This is generalizable between large, middle, small companies. The aspects of consumer interaction and sales are also generalizable. The same goes for the organizational costs. These are much higher for large companies but also apply the same for smaller companies. To conclude, some aspects are generalizable but the addition of more applications of the framework would benefit the usability and generalizability.

The performed research was done with qualitative methods. The framework was created from literature and validated by interviews. The companies will need quantitative data to ultimately find if the implementation of MPC is worth their investment.

This research does not provide quantitative results or real-life quantitative examples and could therefore not be used for quantitative examples. The businesses should use the created framework and quantify the aspects themselves by doing a cost-benefit analysis.

7.5 Future Research

The economic impact of MPC is a broad subject that is only just explored within this thesis. Many topics can be further explored after this research. These will be discussed in this paragraph.

The framework could be developed further within future research. More interviews could be done to increase the overall reliability and to explore different markets. This thesis focused on telecom companies because of their potential mentioned in paragraph 3.2. New research might focus on different sectors or sizes of companies. The interviewees mentioned that MPC might be received differently by various companies. This thesis focused its implications on telecom companies, a new study might use this framework and apply it to a variety of different companies to check its robustness and validity. This could be done by doing multiple business cases or by doing many interviews with multiple companies. The variety of companies is essential here.

Other privacy-preserving technologies might have the same economic impact as MPC. Future research could find out if this framework is also useable for the implementation of other privacy-preserving technologies or even other types of technology.

It is not possible to make calculations for the impact of MPC on the whole European economy at once. The EU has too many different companies with too many variables to all calculate at once. Therefore, this general framework was made to be tested on a smaller scope. The framework can also be checked on a larger scope. This thesis studied a single company that could use MPC to create more revenue to provide clearer answers. When research is completed for single companies, it is also possible to try to research the economic impact of MPC on the EU market.

This research provided the different aspects that are affected by the introduction of MPC. The effects were described by providing a qualitative change to the specific aspects within the categories. Future research can use this study to know what they need to quantify to calculate the exact economic impact for a company. The SafeDEED project might do this in their deliverable 2.5 'Quantificationn of the economic

impact'. The interviewees and companies spoke very clearly about the go or no go decision for a new project or technology. It should be profitable. Even if there are costs, if the expected profits are higher than the costs, the companies tend to go for it. One of the interviewees also said that even if a company could not afford a new technology themselves they will get a loan if the profits are substantial. This proves that increased revenue creation is very important for companies. They will base their decision on quantified results of the output which the technology will give. Therefore, quantified cost-benefit analyses should be done for interested companies to show them if it is profitable enough.

This also correlates with the next topic that could be explored further. The interviewees mentioned that there should be more real-life scenarios with real output to show the impact of MPC. These tryouts can be company-driven, data marketplace driven, or end-user driven. This will create success stories on which companies can base their decision of implementing the technology. Otherwise, companies might assume it is just a technological issue and not a potential business investment. Future research can address this problem by doing real-life testing of the technology and sharing the results of the economic impact.

The final research that will be recommended is exploring the costs and technical ability to ensure the technology is flawless. This was mentioned within the interview as an important aspect for companies. They would not like to risk their reputation because of the use of faulty technology. So, research should be done on how likely the technology will fail and what the costs are of keeping it up and running at all times.

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Appendix A

Contact e-mail

Dear,

In the data economy, trust and privacy preservation are key issues. Privacy-preserving technologies are emerging, but it remains unclear whether their benefits outweigh the costs. Therefore I am researching the costs and benefits of privacy-preserving technologies for my master thesis at TU Delft. The thesis is part of the Safe-DEED project which is a project financed by the EU. Based on the literature, I have created a framework of costs and benefits. Now, I would like to test that framework within the telecom industry. I am therefore reaching out to several experts to have an interview about the costs and benefits of implementing a new technology. It would help me greatly to see if my framework is valid.

Would you be willing to have a 20-minute interview on Friday or somewhere next week?

When the thesis is finished, I could provide you with the full report and the outcomes of the research.

Kind regards,

Harm Minnema

(my phone number)

(my email adress)

Appendix B

Short Summary of the Interviews

E1 had prior knowledge of MPC. This interview covered all the aspects of the framework. It was a highly usable interview. He stated that the costs would not be of large importance for big companies. The legal costs for large companies were not labeled as a large factor. Most costs were not deemed a large factor. When the benefits outweigh the costs it will not be a big problem. The addressing of new markets and targeted marketing was deemed very untactful. The preferred implementation structure would be an intermediary structure.

E2 spoke mostly about GDPR compliance, risks, and about the legal costs. The handling of additional data comes at a risk which mostly lies with GDPR compliance and this could also result in higher legal costs. Data security was an additional cost which was not identified before.

E3 had mostly the same opinions about the impact of MPC when implemented as E1. The costs are important but the additional revenue is more important. The new trends, opportunities, and targeted marketing were all highly impactful according to E3. E3 also provided insights into the decision-making process and the overall process of implementing new technologies.

E4 had the same view as E1 and E3. The marketing as well marketing campaigns would be affected and they could even produce new services and new products or play into trends if MPC would be implemented. He also added that their company would be hesitant to share data because of rules and regulations. The aspects of risks and organizational costs were also discussed with him.

Appendix C

Groundedness Table

The groundedness table shows the first-order concepts and the quotes associated with them. The quotes come from the interviews but are paraphrased. Multiple experts came with the same argumentation and conclusions for some aspects. These quotes are only written once in the table because it does not improve the argument by stating it four times.

Appendix C: Groundedness Table	
First order concepts	Representative quotations
Second-order Concept: Consumer Interaction	
Better personalized services	MPC could definitely lead to more personalized services. The more information companies have from a person the more they can provide a personal service.
Increase revenues obtained per person	The revenue obtained per person could indeed increase. If companies are able to provide a consumer with the needs he or she deems relevant, it is possible to bind a consumer to our company. A satisfied consumer will not easily switch to another provider. Brand loyalty is a term that is used in this context.
Boost ability to address specific target markets or specific consumers	The biggest impact will be addressing specific target markets or specific consumers. It would be a great success if we can target geographical areas where we don't have a large market share with specific products.
Second-order Concept: Sales	

Boost ability to predict trends	The ability to predict trends would be improved because of the additional data. They can play into these trends for larger profits
Selling data	They (large telecom and banks) will almost in no circumstance sell or trade their data. Especially not to competitors. We will work together with complementary companies. They saw that small businesses might do this.
New opportunities	The expert provided an example of a few years ago. They were not sure whether to implant this new technology because it was too niche. Years later they were able to do a market analysis and they were able to confirm the potential of this technology. The expert saw the potential of additional data of MPC. He stated that it could improve the ability to try new products and go for new opportunities.
Second-order Concept: The costs of data	
Costs of acquiring data	It is obvious that you need to pay for the data that you wish to acquire. The best payment structure would be a periodical fee. This could be a yearly or monthly fee that does not matter that much. It saves in monitoring costs compared to pay per data or pay-per-use.
Costs of storing data	Most companies already have a data storage place so it will not be affected that much. However, smaller companies that did not store data might need to open up a cloud location.
Costs of securing data	Data security is very important and comes in three buckets, technical costs for the protection, making people aware of keeping the data safe, and the processing and procedure costs for the data.
Second-order Concept: Legal costs	
Sensitive information	The legal department should advise how to handle sensitive data. This advice comes at a price of course. We (large telecom company) have our own staff so it will not be that much for us.

Rules and regulation for MPC	The rules and regulations should be checked when sharing data. GDPR should be looked at specifically. This can be done by a legal department but costs time and money.
Second-order Concept: Technology costs	
Technology Implementation costs	It takes time and effort to implement new technology into their systems. Examples are given of previous projects and it is quite straightforward. It takes time and effort.
Costs of employees	During this process of implementation, they should also get their staff informed about the new technology and how to handle data from now on.
Second-order Concept: Organizational costs	
Costs of advertisements	The cost of advertisements might go down because you need fewer advertisements. You can better target the markets or consumers and the need for large marketing campaigns with high costs will become less.
Inventory costs	This did not apply to the interviewees. They did not work at companies that worked with a lot of inventory. They stated that they could see the inventory costs of other companies decrease because of MPC as mentioned in the literature.
Operation costs	The operational costs should be accounted for in the calculations of the costs. The distribution of the operation cost per department should be mapped out.
Decision making process costs	They usually run into something, an idea, or a capability in their networks for example 5g. The way they look at what they can do with it is in terms of business applications. So, they have an idea and they start with brainstorming with some people. they have some interviews with potential customers or other people involved. Then, they usually set up a prototype or a proof of concept to see whether it works and to see the potential. This whole process costs a lot of time and meetings for decision-makers.
Second-order Concept: Risks	

Data leaks	There are two effects of data leaks. The first consequence is reputational damage. Data leaks are a big risk and your reputation will be at risk even if you meet all the GDPR requirements. This is not an economic factor but it was indicated as a significant impact. The second consequences are the fines that will come from the leaks. The fines can for instance come from not complying with GDPR anymore. The customer may have not given consent to have this data shared with another company. That will be a non-compliance of GDPR and that will result in fines.
Reliability	People need to be able to rely on it so it needs to be working 100 percent of the time all the time. There might be some quality issues related to that. Or quality requirements that you have to fulfill. That will increase costs. Downtown or delays have a financial impact on businesses.
Risk of competitors	The technology enables rivals to share data. However, companies will be hesitant to share data with them. They prefer to share and trade with complementary companies. A company could however take a risk and collaborate with a competitor if they estimate to come out on top. This could result in a profit but could also cost market share if the competitor benefits more than predicted.