3Grant Agreement Number: 825225

Safe-DEED

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D2.5 Quantify and Demonstrating the Economic Value of MPC

Deliverable number	*D2.5*
Dissemination level	***Public***
Delivery date	*30th November 2021*
Status	*Final*
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Changes Summary

Date	Author	Summary	Version
01.09.2021	Harm Minnema	First draft	0.1
22.09.2021	Hosea Ofe	Second draft	0.2
28.09.2021	Hosea Ofe	Third draft	1.0
03/11/2021	Mark de Reuver	Internal WP2 review	1.1
04/11/2021	Hosea Ofe	Ready for review	2.0
08/11/2021	Dieter Decraene	Reviewer	2.1
12/11/2021	Gert Breitfuss	Reviewer	2.2
18/11/2021	Hosea Ofe	Final Edits	2.3
23/11/2021	Hosea Ofe	Submission	2.4

Executive Summary

The Deliverable 2.5 (D2.5) objective is to quantify and demonstrate the economic value of technologies that ensure privacy. In particular, D2.5 explores the economic value and impact of MPC. MPC is a privacy-preserving technology that enables sharing data between parties without disclosing the output given by the respective parties. MPC addresses the problem of privacy commonly encountered in the exchange of personal and business data subject to privacy regulations. A section of this report is devoted to demonstrating numerical and practical examples of MPC usage to ensure readers understand the workings of MPC.

Although MPC is promising as a privacy preservation technology, its economic impact (e.g., value creation and revenue-generating potential) for businesses is unknown. Understanding MPC's economic impact on business is essential, considering businesses will not simply implement new technology. This helps companies understand the overall dynamics when MPC is implemented and shows them the potential of MPC.

Business models are discussed to understand how MPC could create value. The report builds on three implementation structures of MPC's business opportunities derived from the deliverables in T2.1: using MPC to share data between departments, share data between two firms with a joint interest, and sell data between firms in other industries. The business case will be based on the ability to use one or multiple of these BMs. This report determines how companies potentially create value by implementing MPC. In conclusion, MPC has potential for businesses of all sizes. Based on insights from the framework, companies can implement MPC by further using a cost-benefit analysis to support/or not to support MPC implementation.

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List of Abbreviations

BM: Business Model

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

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Introduction

Data are strategic assets for companies. For example, companies can analyze data collected from different sources to gain insights and improve business domains, such as strengthening marketing and new business opportunities[1]. Think about upcoming trends such as big data analysis and machine learning. The importance of data is likely to grow as data-driven business models gain importance. This means that companies are continuously seeking new ways to analyze and get reliable data.

However, companies are generally reluctant to share their data for reasons such as not wanting competitors to access the data and concerns about losing control of the data [2,3]. Competitors can use data to gain a competitive advantage over rivals, for example, through reverse engineering and combining insights from the data with other new data. Furthermore, companies cannot easily buy and sell data because there is no good working data market in Europe[4]. Companies do not trust some data suppliers and data aggregators[5]. More fundamentally, it is hard for companies to share data because they have to comply with the General Data Protection Regulation (GDPR). The EU Charter of Fundamental Rights stipulates that companies must protect personal data for all EU citizens[6].

Privacy-preserving technologies can solve this problem. Imagine that it is possible to share all information without giving up sensitive corporate data. Imagine that businesses could work together and share data to benefit from the data set mutually without compromising privacy or revealing sensitive business data. These examples give insight into the potential of privacy-preserving technologies for data owners. However, concrete explanations of the economic impact of privacy-preserving technologies or why companies should adopt/implement these technologies from a business standpoint are less clear[7].

This deliverable D2.5 provides answers to questions clarifying the business impact of MPC. MPC is one of the major types of privacy-preserving technologies, which is central in the Safe-DEED project. In

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[1] O. Kwon, N. Lee, and B. Shin. Data quality management, data usage experience, and acquisition intention of big data analytics. International Journal of Information Management, 34(3):387-394, 2014. doi: https://doi.org/10.1016/j.ijinfomgt.2014. 02.002.

[2] Programme Safe-DEED. Research proposal: Safe-deed: Safe data enabled economic development. Project from the European Union's Horizon 2020 research and innovation program under grant agreement No 825225, 2018.

[3] J. Linaker and B. Regnell. What to share, when, and where: balancing the objectives and complexities of open source software contributions. Empirical Software Engineering, 25:1{42, 2020. doi: 10.1007/s10664-020-09855-2.

[4] S. A. Fricker and Y. V. Maksimov. Pricing of data products in data marketplaces. Lecture Notes in Business Information Processing, pages 49{66, 2017. doi: https://doi.org/10.1007/978-3-319-69191-6 4.

[5] A. Muschalle, F. Schomm, F. Stahl, and G. Vossen. Marketplaces for data: An initial survey. ACM SIGMOD Record, 42(1):15{26, 2013.

[6] EU European Comission. Data protection in the eu, 2020. URL https://ec. europa.eu/info/law/law-topic/data-protection/data-protection-eu_en.

[7] Bogetoft, P., Christensen, D. L., Damgård, I., Geisler, M., Jakobsen, T., Krøigaard, M., . . . Pagter, J. (2009). *Secure multiparty computation goes live.* Paper presented at the International Conference on Financial Cryptography and Data Security.

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particular, D2.5 provides an overview of how MPC, which is the technology developed and used to preserve privacy within the Safe-DEED project, is of economic value for companies

Report Structure Overview

D2.5 overall objective is to "report on the quantified impact of the developed technologies on business model metrics as developed in WP2 as well as generic economic indicators of trust, value creation, adoption, and turnover". The comprehensive report is structured as follows.

D2.5 Quantification of the economic impact of Privacy-Preserving Technologies		
Project goal: Report on the quantified impact of the developed technologies on business model metrics as developed in WP2 and generic economic indicators of trust, value creation, adoption, and turnover.		
	OVERVIEW	**Relevance for Report**
Chapter 1	**Background of MPC** ▪ Private Set Intersection and Homomorphic Encryption ▪ Demonstrating Privacy-preservation using MPC ▪ Demonstrating MPC using Ridesharing ▪ Demonstrating MPC using a numerical example	Provides a background to understand MPC workings and rationale for its subsequent use in telecommunication industries to explore its business impact.
Chapter 2	**Background Business Case Analysis** ▪ The Business Driver ▪ The Business Objectives ▪ Alternatives ▪ Effects, Risks, and Costs ▪ Alternative Selection ▪ Implementation Plan	Provides an understanding of the steps for using the business case as a methodology to identify how MPC implementation potentially affect business economically
Chapter 3	**A Framework for Quantifying MPC Business Impact** ▪ The Revenue ▪ The Cost ▪ Risks	Identifies categories of costs, risk, and revenue for basing the impact of MPC implementation on businesses
Chapter 4	**MPC Business Opportunities and Business Case**	Provides an overview of business opportunities of MPC implementation.

Chapter 5	**Research Design** ▪ Research context ▪ Participants ▪ Interview questions ▪ Data analysis	Provides an overview of the data collection process and the analysis on the business impact of MPC.
Chapter 6	**Results** ▪ Revenue ▪ Added Revenue ▪ Costs ▪ Risks ▪ Additional Risks	Provides an overview of the different categories of risk, cost, and revenue that constitute a basis for a framework for quantifying the business impact of MPC implementation.
Chapter 7	Discussion	Provides reflections of the results and recommendations for MPC implementation.

1 Background of MPC

This section provides a background on MPC, which is the technology developed and used to preserve privacy. Although MPC is covered in technical terms extensively in WP4, this section describes MPC from a business perspective, which serves as a basis for the economic analysis. MPC allows the computation of data from multiple actors. The Safe-DEED project aims to improve and test MPC for real-life cases. The two critical aspects of MPC is ensuring the privacy of inputs and safeguarding data against adversaries. Two cryptographic methods can be used in MPC. Private set intersection(PSI) and homomorphic encryption(HE).

1.1 Private Set Intersection and Homomorphic Encryption

PSI refers to when two parties hold a private data set while wanting to find the intersection of their sets without revealing anything except the intersection itself. The most computationally efficient PSI protocols use oblivious transfer and hash function, a mathematical algorithm used to encrypt data[8]. The most efficient protocols for PSI are from Pinkas et al[9].

HE allows participants to evaluate the computations on encrypted data without decrypting it first. In theory, doing MPC computations through a HE scheme is considered an efficient and straightforward approach[10]. However, the practical side of the approach is underdeveloped. In practice, 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"[11](p.1). The party with the smaller dataset can then decrypt the result. This implementation is inefficient because the computational costs grow with the input's size and with the depth of the circuit, which is the length of the longest path from input to output[12]. We next use examples to demonstrate how MPC works.

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[8] H. Chen, K. Laine, and P. Rindal. Fast private set intersection from homomorphic encryption. Proceedings of the 2017 ACM SIGSAC Conference on Computer and Communications Security, 2017. doi: https://doi.org/10.1145/3133956.3134061.

[9] B. Pinkas, T. Schneider, and M. Zohner. Scalable private set intersection based on extension. Cryptology ePrint Archive, 930, 2016.

[10] S. Ghanem and I. Moursy. Secure multiparty computation via homomorphic encryption library. Ninth International Conference on Intelligent Computing and Information Systems (ICICIS), 2019. doi: https://doi.org/10.1109/icicis46948. 2019.9014698.

[11] H. Chen, K. Laine, and P. Rindal. Fast private set intersection from homomorphic encryption. Proceedings of the 2017 ACM SIGSAC Conference on Computer and Communications Security, 2017. doi: https://doi.org/10.1145/3133956.3134061.

[12] H. Chen, K. Laine, and P. Rindal. Fast private set intersection from homomorphic encryption. Proceedings of the 2017 ACM SIGSAC Conference on Computer and Communications Security, 2017. doi: https://doi.org/10.1145/3133956.3134061.

1.2 Demonstrating Privacy-preservation using 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 output is analyzed without disclosing the input given by all the individual partners[13]. Only authorized parties access the encrypted data[14]. Privacy, correctness, independence of inputs, fairness, and guaranteed output delivery are key requirements for the computation [15](p. 5). These requirements ensure a correct outcome for the parties[18]. As shown in figure 1 multiple data providers send encrypted data to the MPC engine which does the computation and sends the results to authorized parties. A demonstration of MPC working is shown using two examples: Ridesharing (Figure 2) and a numerical example (Figure 3).
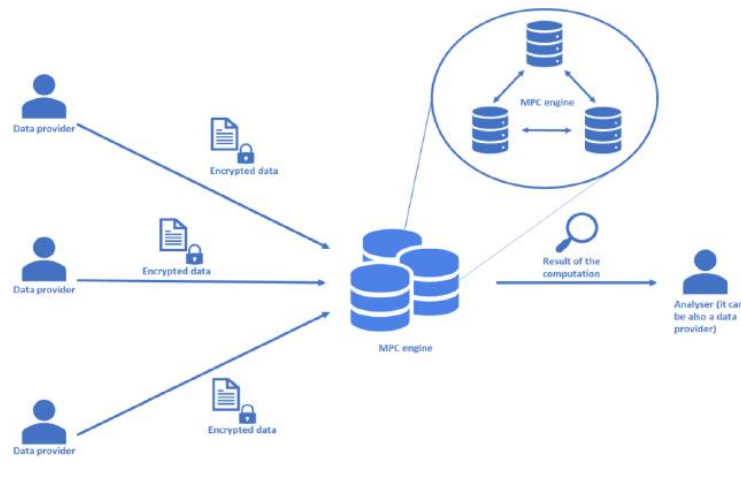
Figure 1: General MPC process[16]

1.2.1 Demonstrating MPC using Ridesharing

Figure 2 shows a computation description of an example of how MPC works[17]. This example shows how city officials try to understand how ride-sharing vehicles have influenced traffic congestion. The information from the ridesharing companies, column 1, is crucial for the analysis. Unfortunately for the

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[13] C. Zhao, S. Zhao, M. Zhao, Z. Chen, C. Ghao, H. Li, and Y. Tan. Secure multiparty computation: Theory, practice, and applications. Information Sciences, 476:357{ 372, 2019.

[14] D. Bachlechner, K. La Fors, and A. M. Sears. The role of privacy-preserving technologies in the age of big data. WISP 2018 Proceedings, 28, 2018. URL https://aisel.aisnet.org/wisp2018/28.

[15] Y. Lindell and B. Pinkas. Secure multiparty computation for privacy-preserving data mining. Journal of privacy and Con_dentiality, 1(1):59{98, 2009.

[16] R. Dolci. Realizing platform control in data marketplaces through secure multiparty computation: A qualitative study exploring the use of secure multi-party computation (mpc) as an instrument for realizing platform control in data markets. Master thesis at TU Delft, 2020.

[17] A. Bestravos, A. Lapets, and M. Varia. User-centric distributed solutions for privacypreserving analytics. Communications of the ACM, 60(2):37{39, 2017.

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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.

Figure 2: An example of MPC use[18]

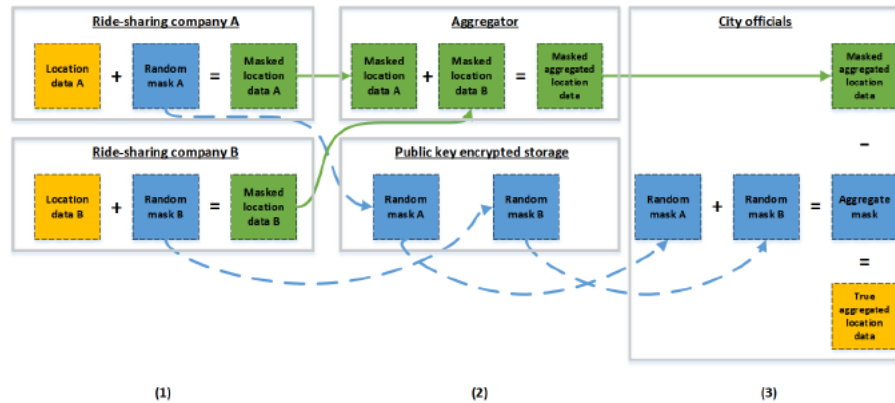The companies can allow aggregation of their actual data without disclosing the individual data. This real data is depicted within the yellow boxes. They do this by applying a random number to their data which can be seen in the blue boxes. This will make sure that the original value of the data is not readable anymore for their competitors. An aggregator aggregates 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. The city officials receive all the participants' aggregated masked data from the aggregator and the aggregated mask. They can transform the aggregated data into text aggregated results, as seen in column 3. They can now make heat maps for the traffic areas without having to excess the data of the ride-sharing companies.

1.2.2 Demonstrating MPC using a numerical example

To further demonstrate how MPC works, a numerical example of computation is explained. For example, suppose companies A, B, and C want to determine if their average salaries are above or below the average of 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 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

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[18] G. A. De Reuver, W. Aghari, G. Breitfuss, D. Decreane, A. Bruni, and Y. Markopoulous. Business models for use cases and generic business models. Project from the European Union's Horizon 2020 research and innovation program under grant agreement No 825225., 2020.

Figure 4 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. The MPC engine does the computation and sends the results to the authorized parties 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 summed together. Once combined, they provide the overall average salary of the three companies. Figure 3 shows what each company can see. The complete computation can be seen in figure 4. This full computation is not visible by any party. However, it is presented for this report's readers to show what a complete computation looks like(i.e., what figures are behind the question marks from figure 4).

	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 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 4: Numerical example of the full computation

2 Background Business Case Analysis

Companies typically make a business case to find a worthwhile project[19]. By doing a business case analysis, it is possible to find the objectives of a project and all its impacts [20]. This helps with making sure that relevant factors affecting the economic impact are considered. Also, it helps with finding aspects that affect real-life companies. Business cases are developed to map out specific projects to exploit new opportunities or to solve particular problems. The business case of MPC is needed to identify areas (revenues, risk exposure, and costs) within businesses that are potentially affected.

2.1 Business Case

When searching for `business case' or `business case analysis, most cited articles on Scopus are about corporate social responsibility (CSR). For example, a business case has been defined as "the bottom-line financial and other reasons for businesses pursuing CSR strategies and policies"[21] (p.1). Leatherman et al.[22] 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'[23] (p. 18).

Business cases are developed in the early stages of projects to map out why, what, and how a project should decide if the project is worthwhile doing[24]. Compared to the more general business model, the business case gives insight into a specific project. It gives an overview of the case, and it should identify the creation of additional value[25]. Traditionally, business cases for IT projects were made to obtain funding. This leads to opportunistic predictions to ensure funding. Besides financial profits, a business

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[19] J.Ward, E. Daniel, and J. Peppard. Buiilding better business cases for it investments. MIS Quarterly Executive, 7, 2008.

[20] L. O. Meertens, E. Starreveld, M. Iacob, and B. Nieuwenhuis. Creating a business case from a business model. Business Modeling and Software Design. BMSD 2013. Lecture Notes in Business Information Processing, 173, 2014. doi: https://doi.org/ 10.1007/978-3-319-06671-4 3.

[21] A. B. Carroll and K. M. Shabana. The business case for corporate social responsibility: A review of concepts, research and practice. International Journal of Management Reviews, 12(1):85{105, 2010.

[22] S. Leatherman, D. Berwick, D. Iles, L. Lewin, F. Davido_, T. Nolan, and M. Bisognano. The business case for quality: Case studies and an analysis. Health a_airs (Project Hope), 22:17{30, 03 2003. doi: 10.1377/hltha_.22.2.17

[23] S. Leatherman, D. Berwick, D. Iles, L. Lewin, F. Davido_, T. Nolan, and M. Bisognano. The business case for quality: Case studies and an analysis. Health a_airs (Project Hope), 22:17{30, 03 2003. doi: 10.1377/hltha_.22.2.17

[24] A. B. Carroll and K. M. Shabana. The business case for corporate social responsibility: A review of concepts, research and practice. International Journal of Management Reviews, 12(1):85{105, 2010.

[25] J.Ward, E. Daniel, and J. Peppard. Buiilding better business cases for it investments. MIS Quarterly Executive, 7, 2008.

case also helps in (1) setting priorities among different investments and resources, (2) ensuring commitment from the business managers to achieving the intended investment benefits.[26] (p. 4)

2.2 The Business Case Method

The business case as a methodology is helpful because it provides the financial outcome and the processes and steps that can be followed when seeking to assess the economic value and impact. 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 steps that need to be identified. This fits the needs of this report well. For example, MPC can have different implementations and payment structures. The economic impact would differ across the implementation options. Therefore, this business case definition is chosen to be suitable for this report. According to Meertens et al.[27](p. 48), the business case method consists of eight components listed below and discussed subsequently.

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1. *The business driver:* The cause, problem, or opportunity that needs to be addressed.
2. *Business objectives:* The goal of the business case states 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 comes 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." Meertens et al.[28](p. 48).

2.2.1 The Business Driver

D2.5 aims to identify the quantified impacts of MPC and identify generic areas of value creation for MPC. A driving rationale behind D2.5 is to solve the broader problem of reluctance of organizations to share data. Implementation of MPC should make it possible to share data between companies and departments. MPC makes it possible to combine multiple datasets and thus gather more available data.

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[26] J.Ward, E. Daniel, and J. Peppard. Buiilding better business cases for it investments. MIS Quarterly Executive, 7, 2008.

[27] L. O. Meertens, E. Starreveld, M. Iacob, and B. Nieuwenhuis. Creating a business case from a business model. Business Modeling and Software Design. BMSD 2013. Lecture Notes in Business Information Processing, 173, 2014. doi: https://doi.org/ 10.1007/978-3-319-06671-4 3.

[28] L. O. Meertens, E. Starreveld, M. Iacob, and B. Nieuwenhuis. Creating a business case from a business model. Business Modeling and Software Design. BMSD 2013. Lecture Notes in Business Information Processing, 173, 2014. doi: https://doi.org/ 10.1007/978-3-319-06671-4 3.

Providing a basis for quantifying MPC impact is thus necessary as companies are driven by an interest in generating value in adopting new technology. For example, companies can use that extra data for better insights, such as strengthening market competition and opening new business opportunities[29]. Articulating the benefits organizations could gain from implementing MPC is thus a key business interest. Companies are generally reluctant to share their data for multiple reasons. These reasons are:

1. Fear of competitors using the data or losing control over data (Safe-DEED, 2018).

2. Competitors can use data to make better analyses and gain a competitive advantage over their rivals[30].

3. Competitors can gain more knowledge of the rival's overall functioning[31].

4. It is hard to share data for companies because they have to comply with the GDPR[32].

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[33].

2. Open data marketplaces are also not a good source for data currently, so they are not always used[34, 35].

Businesses are unwilling to share their data without MPC, resulting in fewer data sources because of the aforementioned reasons. These are the current issues that companies are facing when they want to share their data.

2.2.2 The Business Objectives

A business objective refers to what a project seeks to achieve. D2.5 objective is to explore the "quantified impact of the developed technologies on business model metrics as developed in WP2 as well as generic

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[29] O. Kwon, N. Lee, and B. Shin. Data quality management, data usage experience, and acquisition intention of big data analytics. International Journal of Information Management, 34(3):387{394, 2014. doi: https://doi.org/10.1016/j.ijinfomgt.2014. 02.002.

[30] J. Linaker and B. Regnell. What to share, when, and where: balancing the objectives and complexities of open source software contributions. Empirical Software Engineering, 25:1{42, 2020. doi: 10.1007/s10664-020-09855-2.

[31] J. Linaker and B. Regnell. What to share, when, and where: balancing the objectives and complexities of open source software contributions. Empirical Software Engineering, 25:1{42, 2020. doi: 10.1007/s10664-020-09855-2.

[32] EU European Comission. Data protection in the eu, 2020. URL https://ec.europa.eu/info/law/law-topic/data-protection/data-protection-eu_en.

[33] S. A. Fricker and Y. V. Maksimov. Pricing of data products in data marketplaces. Lecture Notes in Business Information Processing

[34] Smith, G., Ofe, H. A., & Sandberg, J. (2016, January). Digital service innovation from open data: exploring the value proposition of an open data marketplace. In *2016 49th Hawaii International Conference on System Sciences (HICSS)* (pp. 1277-1286). IEEE.

[35] H. B. Kittlaus and P. Clough. Software product management and pricing. Springer, 2009.

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economic indicators of trust, value creation, adoption, and turnover" [36] (p. 48). D2.5 builds on insights from D2.2, "Business models for use cases and generic business models."

2.2.3 Alternatives

There are multiple ways to implement and use MPC, and each has its benefits and costs. Alternatives could lead to different outcomes(costs, revenues, and risks). All alternatives should be assessed to explore and map out all the potential costs and benefits. Figures 8-10 provide three alternatives for implementing MPC [37]. The implementations options of MPC implementations are from the D2.2. These different technical alternatives are essential for developing a business case for MPC because they have different economic impacts. For example, the legal implementation costs of MPC across these different implementation options are likely to differ. The three alternatives are discussed subsequently.

Peer-to-peer' implementation: The `peer-to-peer' implementation structure implies that companies A and B can directly exchange data with MPC (see figure 5). All companies can directly buy, sell, or exchange data, depicted by all the direct lines between the dots in figure 10.
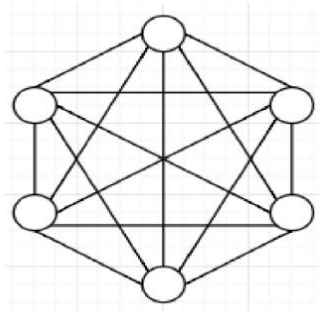
Figure 5: peer-to-peer structure

The second way of implementing 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 6.

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[36] Programme Safe-DEED. Research proposal: Safe-deed: Safe data enabled economic development. Project from the European Union's Horizon 2020

[37] G. A. De Reuver, W. Aghari, G. Breitfuss, D. Decreane, A. Bruni, and Y. Markopoulous. Business models for use cases and generic business models. Project from the European Union's Horizon 2020 research and innovation program under grant agreement No 825225., 2020.

Figure 6: Intermediaries with multiple and independent computing servers

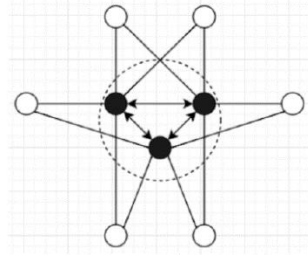The final way of implementing MPC is through a **single intermediary** with a single computing server(see figure 7). It works almost the same as the use of intermediaries with multiple and independent computing servers. However, in this case, they use a single computing server instead of multiple servers.
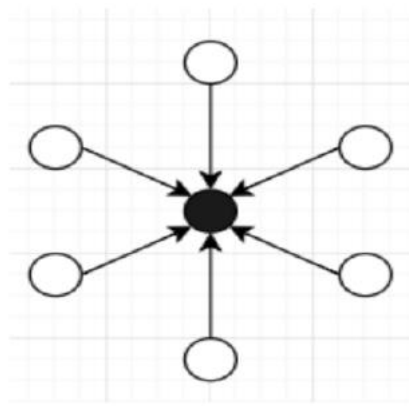
Figure 7: Intermediaries with a single computing server

2.2.4 Effects, Risks, and Costs

Effects: Effects generally refer to positive and negative impacts resulting from the pursued alternative. However, because the real-life implementation of MPC remains scarce, D2.5 adopts a qualitative approach in discussing the impact of MPC. Instead, it provides a framework of qualitative categories that can be quantified to assess effects related to MPC implementation. Therefore, this component is analyzed for additional revenue avenues, cost, or risk that MPC implementation generates.

Risks: Risks are events whose occurrence are hardly predicted and have a negative consequence for a company. Risk occurrence has implications on potential costs and benefits. For example, minimizing financial risk entails designing procedures for identifying risk, leading to increased costs for companies. Thus risks are relevant aspects when considering MPC implementation.

Costs: Costs are important when exploring the economic impact. The costs give an overview of the investment needed to calculate the profit a company expects to make. Identifying costs associated with MPC implementation is thus vital.

2.2.5 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. This makes it impossible to choose an alternative within this framework. This paragraph emphasizes that companies should look at these costs and benefits of the different options of MPC. This report explains all the different implementations' costs and benefits on which the selection can be based.

2.2.6 Implementation Plan

When the best alternative is selected, the technology needs to be implemented. It is important to develop an implementation plan. Objectives, roles, tasks, resources, dates, and responsibilities are the key components of the implementation plan. The implementation plan varies from project to project and is not captured in the framework. Since D2.5 focuses on quantifying MPC impact, not much is discussed here as regards to implementation plan.

3 A Framework for Quantifying MPC Business Impact

Assessing the economic impact of technology is not a straightforward task since a technology's value can be affected by many factors. Accordingly, broad categories of factors likely to capture the economic impact of MPC are used. The categories are drawn from the literature and broadly cover revenue, costs, and risks. Relevant benefits, costs, and risks associated with MPC are drawn from literature searches using academic databases such as Scopus, Google Scholar, Researchgate. Insights from related D2.2 were also explored. The TU Delft repository is also used as a resource that provides multiple studies on MPC. These were read through in full, and their references were checked for potential reference articles. Three report studies were deemed useful and used within this report. Each report provided around 10-15 papers from their references that were read more in detail. About 3 to 5 references per report ultimately found their way into this report.

To create the framework keywords used included: \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 Shar-ing 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 reading through all of the articles, their abstract was read. To reduce the volume of the articles and make the search more refined, add additional keywords were used. Most of the time, there were 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 were much relevant. The next step was to focus on relevant and scientifically impactful papers. 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 beneficial. These often-cited papers were mostly comprehensive and not about a niche subject. This made them often useful and exactly what this report needed. About 20 papers were found using this method that made it into this report. These papers were reread in full. The aspects that they described were noted and, in a broad sense and categorized. 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 reread in full 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.

3.1 The Revenue

This chapter aims to create a general overview of the different categories that have an economic impact on companies. Generating revenue is what interests most companies in considering the implementation of technology. Where can they get additional revenue with MPC implementation? How can they capture

additional value? A rationale is provided why selected revenue categories are relevant when considering the MPC business impact for an organization. The found revenue categories are later verified and expanded through expert reviews.

3.1.1 Consumer Interactions

The first category is consumer interaction. Consumer interactions simply refer to marketing-orientated benefits resulting from the additional insights a customer gains from closers interactions and awareness of the needs of consumers of its products and services. Consumer interaction is an essential aspect for companies[38]. Consumers are not only consumers of products; they can equally shape how companies refine their products or services through their feedback. For example, through anonymous responses and reviews on platforms, valuable feedback can be leveraged to refine a company's products. Such anonymous feedback is difficult to get when consumers feel personal data or identity might be revealed. MPC makes it possible to share more data, and consumer data can also be shared. Privacy-enhancing technologies support the interaction of consumers within research and development, manufacturing, price formulation, channel arrangement, consumer service management marketing management construction, and communication program execution" [39](p.4). She stated that these aspects could improve a consumer's sensory, emotional, social, and intellectual experiences, leading to a larger brand value. The sharing of data using MPC could allow companies to attain these benefits. For example, sharing unrestricted data reduce market distortions and even increases social welfare, including the consumers[40]. Consumers may even suffer privacy costs when there is less personal information shared with third parties. Consumers might want to share their data to receive discounts and recommendations for products. These examples show the importance of data sharing for the consumer. Accordingly, MPC implementation should positively lead to more consumer interaction with companies. Additional value is generated from the usage of consumer data which are discussed subsequently.

3.1.1.1 More Personalized Services

The use of MPC results in companies having more consumer data. The use of additional consumer data will lead to more enhanced personalized service, which is positive for the consumer[41] . Additional data has a beneficial effect on a company's profits when used to enhance personalized services[42]. This results in a win-win scenario wherein consumers get improved services, and the companies have profits. More personalized services also create customer loyalty to the ' 'company's brand [19]. This reduces the risk of

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[38] S. Tsai. Integrated marketing as management of holistic consumer expierence. Business Horizons, 48(5):431{441, 2005. doi: https://doi.org/10.1016/j.bushor.2005. 02.005.

[39] S. Tsai. Integrated marketing as management of holistic consumer expierence. Business Horizons, 48(5):431{441, 2005. doi: https://doi.org/10.1016/j.bushor.2005. 02.005.

[40] G. Clazolari and A. Pavan. On the optimality of privacy in sequential contracting. Journal ofEconomic Theory, 130(1):168{204, 2006.

[41] A. Acquisti and H. R. Varian. Conditioning prices on purchase history. Marketing Science, 24(3):1{15, 2005.

[42] A. Acquisti and H. R. Varian. Conditioning prices on purchase history. Marketing Science, 24(3):1{15, 2005

customers switching to a different brand and service, which goes a long way to increase potential revenue for a company.

3.1.1.2 Increase Revenues Obtained per Person

The revenues a company can obtain per single person are 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[43]. Additional data is valuable in inferring the individual consumer's preferences which can be leveraged 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. For example, Acquisti and Varian[44] 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 provided consumers with enhanced personalized services. Thus, the data must be able to enhance personalized services in general.

3.1.1.3 Boosting Ability to Address Specific Target Markets/Consumers

Firms can significantly benefit from learning about their past, current, and potential customers. Rich datasets provide such information that improves the marketing capabilities of a company. It boosts the ability to target markets or customers[45]. Targeted advertisements are less intrusive compared to old-fashioned non-targeted advertisements[46]. MPC can provide companies with rich datasets. Companies can then increase revenues through new coupon strategies and targeted offers. An example of such a new initiative is the success of Groupon[47]. 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[48].

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[43] C. R. Taylor. Consumer privacy and the market for customer information. RAND Journal of Economics, 35(4):631{651, 2004.

[44] A. Acquisti and H. R. Varian. Conditioning prices on purchase history. Marketing Science, 24(3):1{15, 2005.

[45] R. C. Blattberg and J. Deighton. Interactive marketing: Exploiting the age of addressability. Sloan Management Review, 33(1):5{14, 1991.

[46] A. Goldfarb and C. Tucker. Privacy regulation and online advertising. Working paper, 2010. URL SSRN:\http://ssrn.com/abstract=1600259.

[47] D. Pitta. Jump on the bandwagon{its the last one: New developments in online promotion. Journal of Consumer Marketing, 27(2), 2010.

[48] D. Ball, P. Coelho, and M. Vilares. Service personalization and loyalty. Journal of Services Marketing, 20(6):391{403, 2006.

3.1.2 Sales

The second category is sales. This category is interesting for the sales departments of companies for creating additional revenue. Sale teams are constantly selling as much as possible and jumping on new trends or ways to sell more. The following paragraphs explain the impact of MPC on sales.

3.1.2.1 Ability to Predict Trends

MPC makes it possible to gather an immense amount of consumer data. This makes it possible to predict better customer demand for specific products[49]. Inventory management also benefits 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 correctly. 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 will be, it can anticipate the demand. The sales team can prepare itself for this demand and provide the company with a sound strategy to play into this trend. Companies can make the product demanded the most and make a more significant profit compared to the laggards. The aggregation of the consumer's data is still of use to firms even if the data is not personally identified. Firms 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[50].

3.1.2.2 Selling Data

Organizations that gather and own data can directly sell this data to third parties using MPC without losing control over the data. They can state that they are willing to share their data for a specific price and only when using MPC. This creates an additional form of revenue for companies that are currently not selling their data. They can sell this data to marketers, data aggregators, advertisers, or consultants who want to know more about the markets[51].

3.1.2.3 New Opportunities

New business opportunities may arise because of the new data gathered by MPC and the trends unveiled because of data sharing. The improved targeting of advertisements makes it possible to develop and sell

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[49] G. Linden, B. Smith, and J. York. Amazon. com recommendations: Item-to-item collaborative _ltering. IEEE Internet computing, 7(1):76{89, 2003.

[50] A. Acquisti. The economics of personal data and the economics of privacy. commissioned by the OECD, for the OECD Roundtable on the Economics of Privacy and Personal Data, Paris, 2010.

[51] A. Acquisti. The economics of personal data and the economics of privacy. commissioned by the OECD, for the OECD Roundtable on the Economics of Privacy and Personal Data, Paris, 2010.

more niche products[52]. 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. New markets and buyers can be identified[53].

3.1.3 The Cost

Costs are a crucial aspect of a business case. This section examines the impact on costs with the implementation of MPC. The costs give an insight into the needed investments for the project once the technology is implemented. The investment costs are the costs needed to implement the project. The variable costs are the costs needed once the technology is implemented; both are important. The investment costs are needed to know how many financial resources should be acquired to implement it. It becomes a bigger obstacle to implementing 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. However, they cannot use it because the implementation costs depleted the whole budget. Therefore, the coming paragraphs will discuss costs for the development of the framework on the economic impact of MPC.

3.1.3.1 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.

3.1.3.2 Costs of Acquiring Data

Businesses might want to gather more data because they can now trade or sell it when MPC is implemented. The additional gathering of data costs money; think about cookies, purchase history, and consumer satisfaction. The data needs to be stored as well. 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 in 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 specific price.

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[52] A. Acquisti. The economics of personal data and the economics of privacy. commissioned by the OECD, for the OECD Roundtable on the Economics of Privacy and Personal Data, Paris, 2010.

[53] R. C. Blattberg and J. Deighton. Interactive marketing: Exploiting the age of addressability. Sloan Management Review, 33(1):5{14, 1991

An example could be that 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 considered[54].

3.1.3.3   Costs of Storing Data

Additional data brings benefits as well as costs. The more data a company owns, the more storage space it needs to save that data. Storage costs have fortunately been decreasing because of the evolution and increasing capacity of smart and computing devices[55]. However, the amount of data gathered also increases unprecedentedly, implying that organizations need more processing and storage capacities and infrastructure. MPC makes it possible to analyze more data given its computing capabilities. This makes it potentially profitable to start gathering more data to sell or use with the help of MPC. More data means higher storage costs. Fortunately, each company only needs to provide their data when using MPC. Furthermore, as the need for data grows, companies will equally need data, which adds further to the cost of data storage. The costs of storing data can be described in six parts[56].

The first cost associated with storing data is the *Initial costs of storing data:* These are the costs related to setting up the infrastructure to store data. Almost all businesses have already made these costs, but this is still added to the framework's completeness. The costs related to the initial costs are networking equipment such as routers, server racks, cooling fans, and disks.

The second cost associated with storing data is floor rent: The servers need to be placed somewhere, which takes space and thus money. The price for the rent can alter from place to place so that different companies can have different strategies for it. Smaller companies normally hire some office space within a city for their services. The more prominent 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 associated with storing data is *Energy costs*. Energy or power is needed to keep the networks, servers, and disks continuously running. This is an inevitable cost, and the more data needs to be stored, the more power is consumed.

The fourth is the *service cost*. 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 the

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[54] G. A. De Reuver, W. Aghari, G. Breitfuss, D. Decreane, A. Bruni, and Y. Markopoulous. Business models for use cases and generic business models. Project from the European Union's Horizon 2020 research and innovation program under grant agreement No 825225., 2020.

[55] D. M. Byrne and C. A. Corrado. Ict services and their prices: What do they tell us about productivity and technology? FEEDS Working Paper, 15(2017), 2017.

[56] A. K. Dutta and R. Hasan. How much does storage really cost? towards a full cost accounting model for data storage. Economics of Grids, Clouds, Systems, and Services, pages 29{43, 2013.

experience of the employees also influences this. The more experienced, the better and cheaper they can maintain it.

The second to final 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 disposal 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 has become a hot topic in 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 backup systems also create additional emissions. The back-ups are heavy diesel generators that still emit exhaust[57]. The energy and the emissions come at a price that should be accounted for.

3.2 Legal Costs

Companies have to comply with different rules and regulations. For example, in MPC implementation, legal experts are needed to advise the company on legal and regulatory measures, implications of implementing MPC, and any future legal events arising from MPC use. This impacts the costs for the legal departments. The influence of MPC on legal costs is discussed subsequently.

3.2.1 Sensitive Information

Encryption is a vital 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[58]. 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[59] (p. 6). The legal department should address the handling of sensitive information with third parties and within their internal processes. The handling of sensitive information gives more work to the legal department and should therefore be considered.

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[57] A. K. Dutta and R. Hasan. How much does storage really cost? towards a full cost accounting model for data storage. Economics of Grids, Clouds, Systems, and Services, pages 29{43, 2013.

[58] A. Al Mamun, K. Salah, S. Al-maadeed, and T. R. Sheltami. Bigcrypt for big data encryption. 2017 Fourth International Conference on Software De_ned Systems (SDS), pages 93{99, 2017. doi: 10.1109/SDS.2017.7939147.

[59] S. A. Fricker and Y. V. Maksimov. Pricing of data products in data marketplaces. Lecture Notes in Business Information Processing, pages 49{66, 2017. doi: https://doi.org/10.1007/978-3-319-69191-6 4.

Rules and Regulations for MPC: Several laws and regulations exist for data usage and data sharing. The main one is GDPR. The EU Charter of Fundamental Rights stipulates that it is impossible to share all data because of the right to protect personal data for all EU citizens[60]. Companies have to comply with the GDPR; otherwise, they get fined. The legal department should check compliance with legal requirements, an ongoing process considered in implementing MPC. The Safe-DEED deliverables D3.1, D3.2, and D3.3 have identified the legal requirements necessary for implementing MPC.

3.3 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 mentions the costs of the technology so that this framework is robust for multiple possible implementations. It might even be the case that there will be multiple options for MPC.

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 correctly. 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 more prominent companies. They can more easily pay these costs and profit from the advantage the smaller companies do not have. This might lead to a market with 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 profit from doing the computations. 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. The implementation itself can begin when a deployment alternative is chosen. Implementation is always a process that takes time and the work of people within a company. These costs will now be described.

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[60] EU European Comission. Data protection in the eu, 2020. URL https://ec.europa.eu/info/law/law-topic/data-protection/data-protection-eu_en.

Cost of Employees: There are two ways employees have an effect during the implementation. There are employees whose job is to implement the technology. These employees make decisions and plan on how new technology should be implemented. In more complex projects such as implementing privacy technologies, employees are needed in the legal and technical domains to ensure the alignment of technical and legal requirements. This translates to more work for employees and costs for an organization. Internal staff might require training on how to use the new technology, which costs money. Also, with encryption, each employee might need an account for the platform, which brings additional IT with it.

Operation Costs: Operational costs are costs incurred in maintaining the day-to-day operations of MPC once it has been implemented. These are the costs that include but are not limited to support contracts, warranties, license costs, and upgrade costs. These costs are recurrent and need to be forecasted and included in the costs. The use of MPC benefits from having additional data. However, it also costs more time to compute, and there might be more computations.

3.4 Risks

Risks are not direct costs or revenue loss, but they generally render organizations to financial losses[61]. If certain risks are too high, a company might need to consider insurance, an alternate approach, or accept the risk. Most technologies are associated with unforeseen consequences, so too is the case with MPC implementation. The cost of risk is estimated by multiplying the risk probability and the costs or exposure to the risk. For example, if there is a 10 percent chance of losing 100.000 dollars, the costs could be expressed as 10.000. This is an example of why risks are essential for estimating or quantifying the business impact of MPC.

3.4.1 Data Leaks

Data leak or breach is a risk that companies are involved in collecting data. A data breach is a "security violation in which sensitive, protected or confidential data is copied, transmitted, viewed, stolen or used by an unauthorized individual"[62] (p. 1). Data leaks are accidental or a result of a hack. A consequence of data leaks is legal costs. Legal costs include settlements for affected parties, regulation compliance, loss of reputation, restoring the affected systems, productivity, and intellectual property[63]. Executives

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[61] Ofe, H., & Okah, P. (2011). Value at Risk: A Standard Tool in Measuring Risk: A Quantitative Study on Stock Portfolio.

[62] Privacy Rights Clearinghouse. What to do when you receive a data breach notice. Available at https://www.privacyrights.org/consumer-guides/what-do-when-you-receive-data-breach-notice, 2019.

[63] V. Richardson, M. Watson, and R. Smith. Much ado about nothing: The (lack of) economic impact of data privacy breaches. Journal of Information Systems, 33, 02 2019. doi: 10.2308/isys-52379.

ranked cybersecurity and leaks as their most severe concerns[64]. Businesses globally pay an estimated 2.9 trillion dollars by 2019 for cyber security and related data leaks problems[65]. For example, the hack of Target in 2013 led to over 70 million personal data of customers and 40 million credit cards being stolen. The damages were over 200 million dollars for reissuing credit cards with over 90 lawsuits. The CEO and other executives lose their job because of the breach[66], resulting in massive investment in cybersecurity on the part of Target to gain back confidence in their privacy reassurance. A problem with cybersecurity is that it is expensive.

Thus risks are an essential concern in the implementation of technologies that handle sensitive data. Richardson et al.[67] even doubt the economic impact of privacy data breaches. However, this might be a bit short-sighted if there are solutions to prevent them. Multiple sources indicate the severity and impact of breaches, so data leaks and breaches should be considered as relevant for valuing the business impact of MPC. MPC could be valuable for companies. For example, through encryption, potential accidental leaks by employees or if data is transmitted or obtained by the wrong parties is minimized. Then again, the potential costs of data leaks and breaches should be higher than MPC costs if the angle is purely economic. Otherwise, it might not be worth it.

3.4.2 Competitor Entry to the Market

Competitor entry costs are barriers companies face in entry to new markets. This includes but is not limited to fixed investments new entrants need to make before joining the market[68]. In general, when initial investment/costs are high, it poses barriers for new or smaller companies to join the market. The risk of new competitors is generally lower for market-leading companies with the resources and capabilities to overcome barriers. Accordingly, large multinationals with large resource bases might have the capital to afford MPC if the initial investments are high. For smaller business owners, if MPC costs are high, this might hinder consideration for implementing MPC. The small company might not have enough data at first to do data analysis. The additional data from MPC might let smaller companies do data analysis and compete on that level with more prominent companies and gain market share. This eventually all depends on the affordability of MPC.

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[64] A. Provity. Executive perspectives on top risks for 2016. Available at: https://erm.ncsu.edu/az/erm/i/chan/library/NC-State-ProtivitiSurvey-Top- Risks-2016.pdf, 2016.

[65] S. Morgan. Cybercrime to 6 trillion dollar by 2021. Available at: https://cybersecurityventures.com/hackerpocalypse-cybercrime-report- 2016/, 2017.

[66] J. Gonsalves. Target top security o_cer reporting to cio seen as a mistake. Available at: https://www.csoonline.com/article/2363210/data-protection/target- top-security-o_cer-reporting-to-cio-seen-as-a-mistake.html, 2014.

[67] V. Richardson, M. Watson, and R. Smith. Much ado about nothing: The (lack of) economic impact of data privacy breaches. Journal of Information Systems, 33, 02 2019. doi: 10.2308/isys-52379.

[68] R. P. McAfee, H. M. Mialon, and M. A. Williams. What is a barrier to entry? The American Economic Review, 94(2):461{465, 2004. ISSN 00028282. URL http://www.jstor.org/stable/3592928.

3.4.3 Trust in each Implementation

When doing computations with other parties, companies need to trust the other party. The different structures cover different areas of whom to trust. The trust that data providers within the peer-to-peer structure require lies with the MPC software. The parties involved have their 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 not to collude with the opposing party and 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 trust the single server to not reveal the input data compared to multiple servers. Safe-DEED D3.6 and D3.7 have further assessed this issue of trust.

3.5 Miscellaneous

Cost of Advertisement: Currently, some companies might be over-investing in acquiring personal data[69]. 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. Suppose they can analyze and target the right customers. In that case, they can reduce the costs spent on communicating with consumers. Consumers can reduce the effort to obtain helpful information. The information and targeted advertisements might create new business models, services, or low-cost products[70].

Inventory Costs: Trend prediction can help create additional revenue. The additional data can also predict the demand for raw material suppliers, retail managers, and manufacturers. It can be used to optimize the whole supply chain and decrease costs. Inventory costs are one of these costs that could be lowered. 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 needed, and how long they need to store them. 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 combines all the knowledge found above seen in figure 14. The developed framework is composed out of categories, and aspects are drawn from the literature.

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[69] C. R. Taylor. Privacy in competitive markets. Duke University Economics Working Paper, pages 3{10, 2003.

[70] A. Goldfarb and C. Tucker. Privacy regulation and online advertising. Working paper, 2010. URL SSRN:\http://ssrn.com/abstract=1600259.
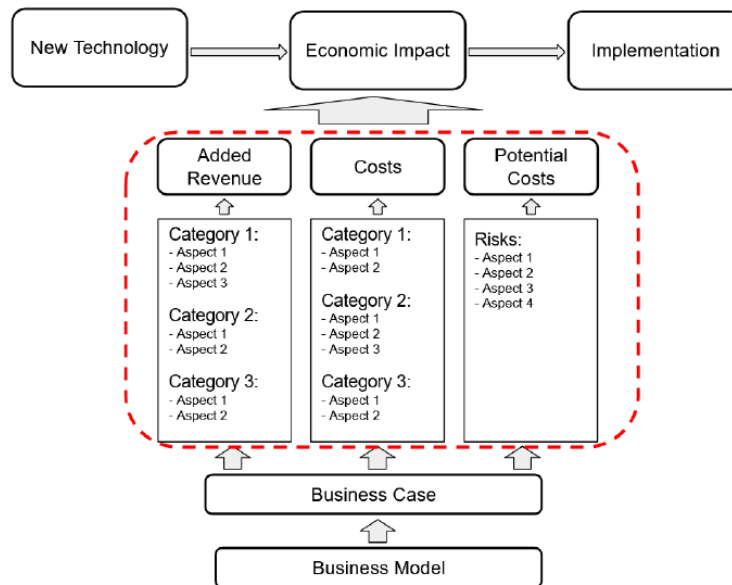
Figure 8: Conceptual model

Figure 8 provides a general overview of the conceptual framework that provides a basis for developing a framework that is specific to MPC. Figure 9 is informed by the insights from the literature discussed in the section related to revenue, cost, and risk.
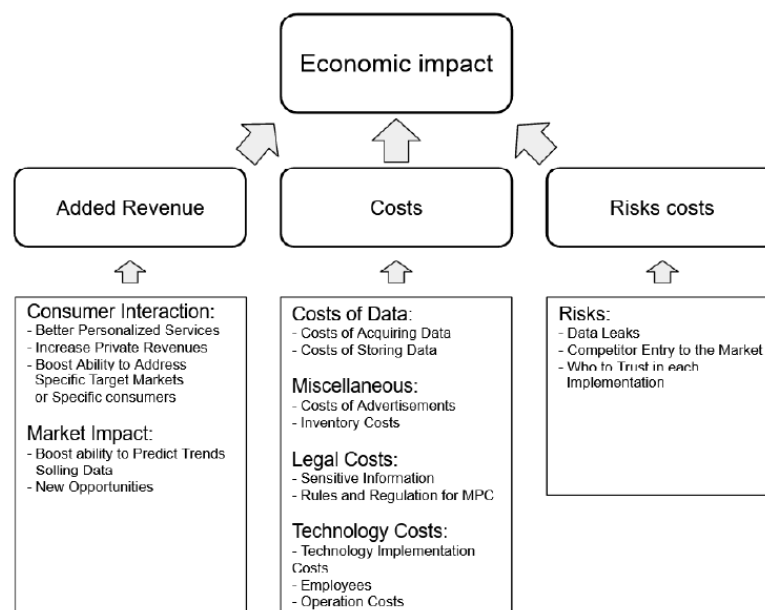

Figure 9: Derived Framework

4 MPC Business Opportunities and Business Case

4.1 Business Model

Business models (BMs) have evolved and are widely researched in several disciplines, e.g., information systems[71], strategic development[72], and technology and innovation [73]. There is no consensus on a generally accepted definition for business models[74]. Nevertheless, there are certain aspects that almost all BMs mention, such as value creation, value capture. In this report, BMs refers to the logic of how organizations create, deliver value to customers, and capture value[75]. Business models help companies capture and create value[76] and, as such, provide business opportunities that a business can consider. Figure 10 below shows an example of a business Model Canvas original proposed from the works of [77].
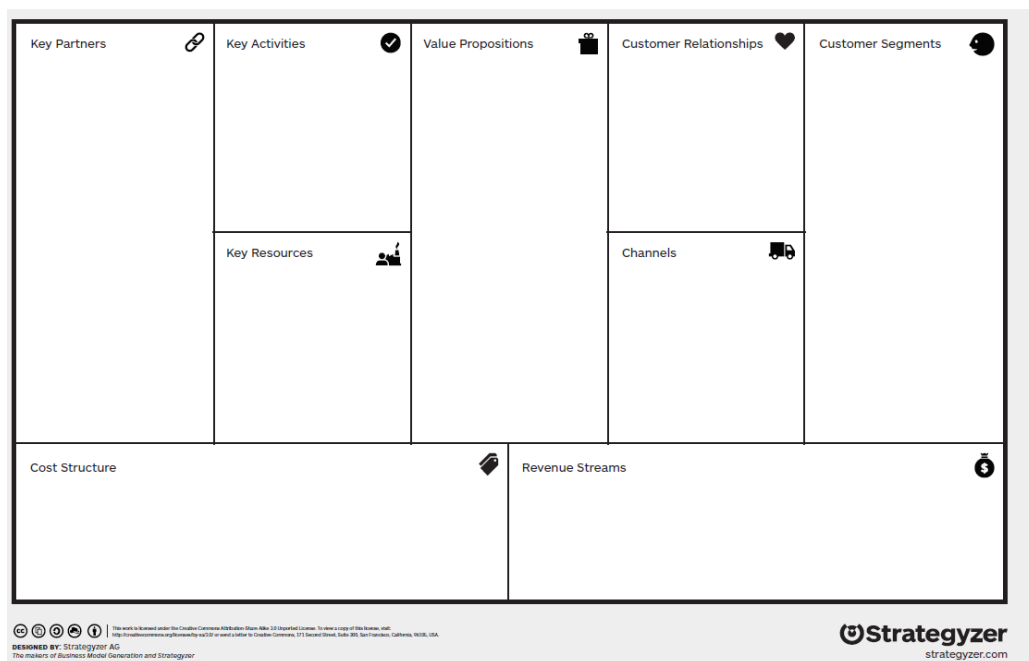

Figure 10: Business Model Canvas

[71] Al-Debei, M. M., & Avison, D. (2010). Developing a unified framework of the business model concept. European Journal of Information Systems, 19(3), 359–376.

[72] Wirtz, B. W., Schilke, O., & Ullrich, S. (2010). Strategic development of business models: implications of the Web 2.0 for creating value on the internet. Long Range Planning, 43(2–3), 272–290.

[73] Chesbrough, H. (2010). Business model innovation: opportunities and barriers. Long Range Planning, 43(2–3), 354–363.

[74] Zott, C., Amit, R., & Massa, L. (2011). The business model: recent developments and future research. Journal of Management, 37(4), 1019–1042.

[75] Teece, D. J. (2010). Business models, business strategy and innovation. Long Range Planning, 43(2–3), 172–194.

[76] H. Bouwman, H. de Vos, and T. Haaker. Mobile service innovation and business models. Springer Science And Business Media, 2008.

[77] A. Osterwalder, Y. Pigneur, T. Clark, and A. Smith. Business model generation: A handbook for visionaries, game changers, and challengers. Kluwer, 2010.

The Safe-DEED project made its own Business (Model) Canvas to identify data-driven business opportunities or use cases. The model focuses on data sources, analytics, product, customer benefit, and financial implications. Companies can fill in the boxes by answering the provided questions to make a data-driven business canvas applicable to their company. An example of this canvas is given in figure 2.6. This model is used in the framework because of its applicability for enabling technologies such as MPC and generalizability to other companies.

The Safe-DEED project was the only research that made general business models for MPC within an explorative study[78]. De Reuver et al.[79] also stated that there was not much qualitative research about implementing 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 business opportunity was identified in De Reuver et al.[80] and included data sharing between departments (see figure 11). 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 behavior. These data usually are 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 potential added revenues. 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.

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[78] G. A. De Reuver, W. Aghari, G. Breitfuss, D. Decreane, A. Bruni, and Y. Markopoulous. Business models for use cases and generic business models. Project from the European Union's Horizon 2020 research and innovation program under grant agreement No 825225., 2020.

[79] G. A. De Reuver, W. Aghari, G. Breitfuss, D. Decreane, A. Bruni, and Y. Markopoulous. Business models for use cases and generic business models. Project from the European Union's Horizon 2020 research and innovation program under grant agreement No 825225., 2020.

[80] G. A. De Reuver, W. Aghari, G. Breitfuss, D. Decreane, A. Bruni, and Y. Markopoulous. Business models for use cases and generic business models. Project from the European Union's Horizon 2020 research and innovation program under grant agreement No 825225., 2020.
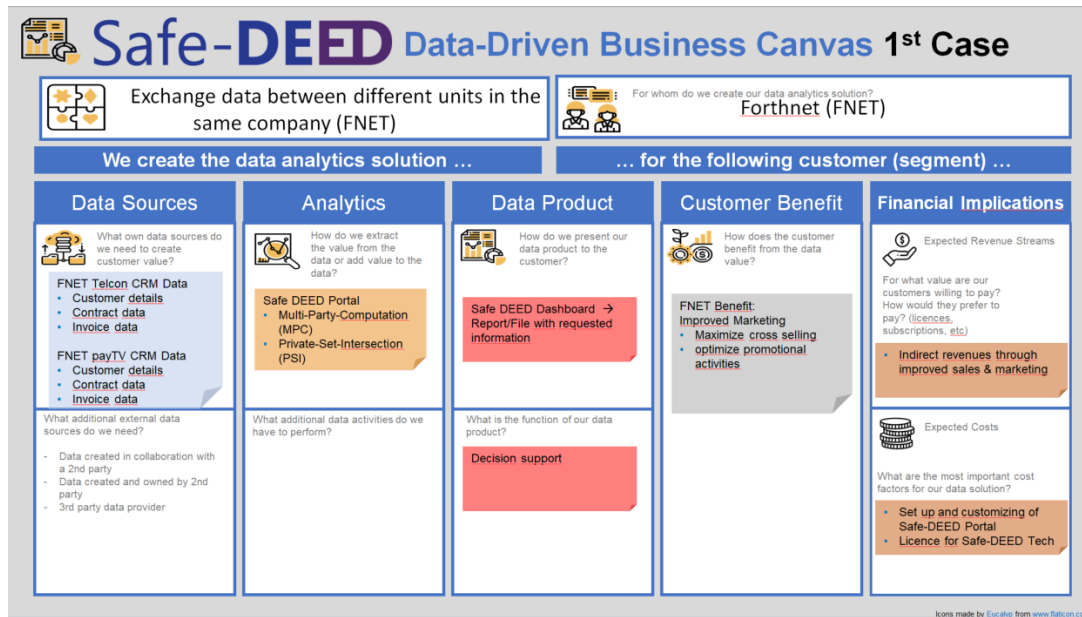
Figure 11: Data Sharing between departments

The second business opportunity is about sharing data between two firms that have a joint interest (see figure 12). 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[81] .
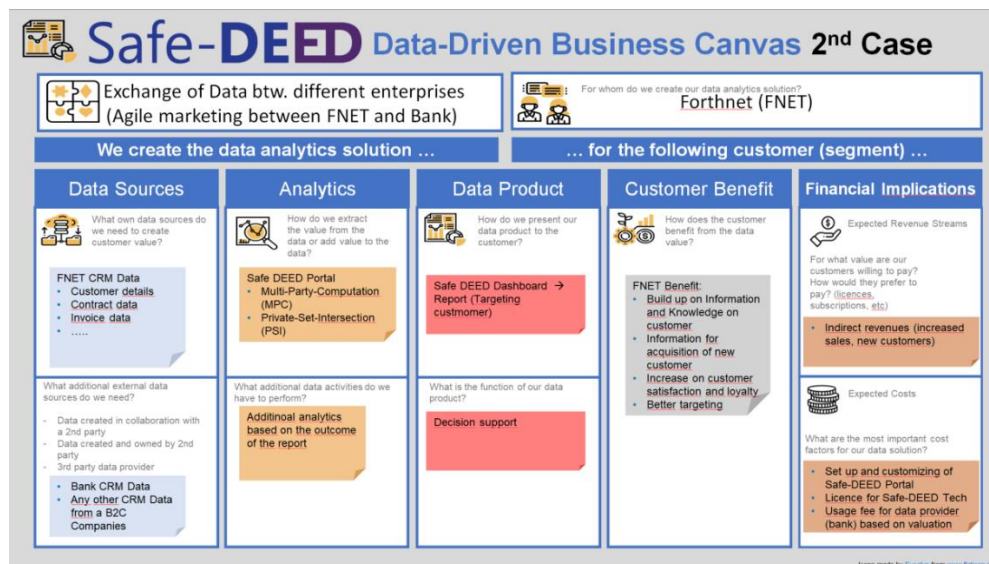

Figure 12: Data Sharing between firms

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[81] G. A. De Reuver, W. Aghari, G. Breitfuss, D. Decreane, A. Bruni, and Y. Markopoulous. Business models for use cases and generic business models. Project from the European Union's Horizon 2020 research and innovation program under grant agreement No 825225., 2020.

The third business opportunity is that of selling data to firms in other industries (see figure 13). The data that a company owns has value. Companies in different sectors could potentially want data such as customer details. This data could potentially be sold. This comes close to a data marketplace and could be a source of income[82]. These business models indicate how companies can create value using MPC. The business case will be about the implementation of MPC.
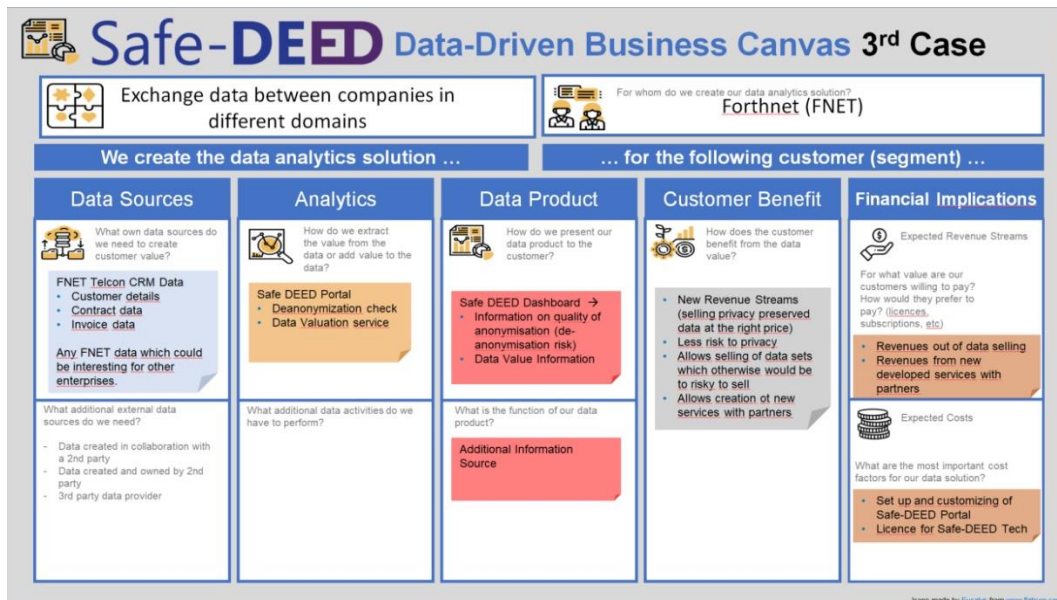

Figure 13: Selling data to other industries.

5 Research Design

5.1 Research Context

The framework is applied to the real-life context of a telecommunication company. Telecommunication companies have large amounts of data which makes the potential benefit of using the technology larger than a small bakery. Telecommunication companies are data-heavy, meaning they have data that could be analyzed and sold. However, they could also share their data between their departments. Telecom companies are also already in the data provider business. They already have the infrastructure in place for handling data which is helpful for MPC implementation. Telecom companies are large firms that could potentially finance higher implementation costs. A smaller company might not have the resources to set up and implement the technology. Therefore, telecom companies are thus selected since they are potential big players interested in implementing the technology. Therefore, they are chosen to apply the framework. 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. In this way, the telecommunication industry context allows discussion of all three scenarios of applying MPC for data sharing, as identified in this deliverable.

The option to use data could motivate them to investigate new technologies that enable the potential of the data. The data collection will come from multiple sources and include the interviews done for the research[83, 84]. 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 contributes to the study's reliability[85].

5.2 Participants

The experts were chosen based on judgment sampling to see if they fit the objective of obtaining the necessary expert knowledge. Judgment sampling is a variant of purposive sampling. It can be used to gather specific information which is not easily accessible[86]. This information can be obtained by interviewing specific experts who do know and have insights into these subjects. They needed to know 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. He would provide more in-depth answers to the business-related aspects of the framework. The contacted experts had either a business role, knowledge about data and data security, legal, or worked at a telecom company. This ensured that all

[83] G. A. De Reuver, W. Aghari, G. Breitfuss, D. Decreane, A. Bruni, and Y. Markopoulous. Business models for use cases and generic business models. Project from the European Union's Horizon 2020 research and innovation program under grant agreement No 825225., 2020.

[84] R. Dolci. Realizing platform control in data marketplaces through secure multiparty computation: A qualitative study exploring the use of secure multi-party computation (mpc) as an instrument for realizing platform control in data markets. Master thesis at TU Delft, 2020.

[85] R. Yin. Case study research: Design and methods. United States of America: SAGE., 2013.

[86] U. Sekaran and R. Bougie. Research Methods For Business A Skill Building Approach. Wiley, 2016.

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 1.

Table 1: Expert interview numbers, expertise and background, and relevance		
Expert 1=E1	Lead innovation manager on data exchange and privacy in a telecom company	Possessed expert knowledge about MPC, which is helpful in implementing the developed framework on telecom companies.
Expert 2=E2	The second expert is a senior manager at the Cybersecurity and Privacy team.	She could help with explaining legal requirements and costs and could provide additional insights into the risks of using MPC with her knowledge of data security
Expert 3=E3	E3 is a strategist, leader, and business developer at a large telephone company with expertise in technology implementation	He could provide insight into the process and costs of implementing new technologies, share his vision of how MPC would affect a telecom company, and know much about data.
Expert 4=E4	E4 is the head of an Innovation Center with 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 innovation and how he would identify the opportunities it had.

5.3 Interview Questions

The interviews were set up as follows. First, experts are asked if they are familiar with MPC technology. After that, MPC is defined and explained to the expert. If understood correctly, the first question is asked. The following questions were asked to experts:

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 where not been discussed yet?

Question 1 and 2 seek to explore the benefits and costs of MPC. Before presenting the framework, the questions are asked not to direct experts to categories of cost and revenues in the framework. The expert 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. The second question is asked if the expert did not explain why MPC would affect their domain as 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. Suppose the expert has a different opinion of the effect of a factor. The effect is re-evaluated within the literature and other interviews.

The purpose of questions 3 and 4 is to find what is essential within companies looking at implementing MPC. The answers are compared to insights from the literature. The questions should provide clear answers on what is essential and the impact of the mentioned aspect in implementing MPC. Discussing the most important aspect and why it is essential 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 let the expert develop their interpretations. The intention was to let them first come up with all the impact MPC might have. 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 found within their domain in the literature and the effects on the economic impact will be presented.

Questions 6-8 are asked to find out what their opinion is of the produced framework. Questions 6 looks similar to question 1; however, presenting the framework might let them think of other aspects that they did not think about before. Otherwise, they answer no, and the framework can be considered complete according to the expert. The purpose of questions 9-11 is to find the specific benefits of the different deployment alternatives. Question 9 refers to the different implementations structures, e.g., peer-to-peer structure or intermediaries with single computing servers or with multiple and independent computing servers. They might discuss aspects that were not yet mentioned in the framework. The findings can also be helpful for future research. If all the respondents answer that they prefer the peer-to-peer structure, it might be best to start their research. Question 10 is whether they would prefer a time-based subscription, pay per use, or a different form of payment. The final question will be an open question. The expert is asked if they have opinions or other matters, they would like to share about this topic that was not discussed yet to ensure they have shared all their insights.

5.4 Data Analysis

Data analysis was undertaken in four iterative steps. First, all interviews were transcribed. The text was kept as close as possible to the original transcription. Grammar was only improved a little, or some

words were left out to enhance the readability. Other errors that did not affect the readability of the interviews were not adjusted. The full transcribed interviews were read back-and-forth while listening to the recordings. The research strategy for the analysis is the Middle-Ground Approach[87]. The Middle-Ground approach was taken for creating the codes. The initial code list consisted of concepts identified from the literature. Codes were changed or refined during the research process as new codes and categories emerged inductively.

The second step was to code the fully transcribed interviews using atlas.ti. for open, axial, and selective coding[88]. Coding simply means that a portion of text is assigned a code. An example of the coding is the following. "Big companies always store data either in-house or in cloud services, so I do not think that MPC influences data storage cost. " This quotation is coded as an influence on data storage cost." There were codes such as 'Implementation costs into systems' and 'implementation costs of the technology' merged into one code 'Implementation costs of technology. Multiple codes contained a single quote and were not merged because of the uniqueness of the quote addressing a specific aspect. Some codes were renamed to a different quote because they would fit better. Codes deemed not essential for the framework or provided additional insights were discarded. 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 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. 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 deciding what to put. A few days later, this process was done to have a fresh look at the created groups and have a new view of what goes where.

The outcome of this step was second-order concepts. The fourth and final step was to identify aggregate dimensions that the second-order concept influences by selective coding. The core categories and interrelations were found this way. Figure 15 shows the first-order concepts, second-order concepts, and aggregate dimension.

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[87] U. Sekaran and R. Bougie. Research Methods For Business A Skill Building Approach. Wiley, 2016.

[88] Charmaz, Kathy, and Liska Belgrave. "Qualitative interviewing and grounded theory analysis." *The SAGE handbook of interview research: The complexity of the craft* 2 (2012): 347-365.
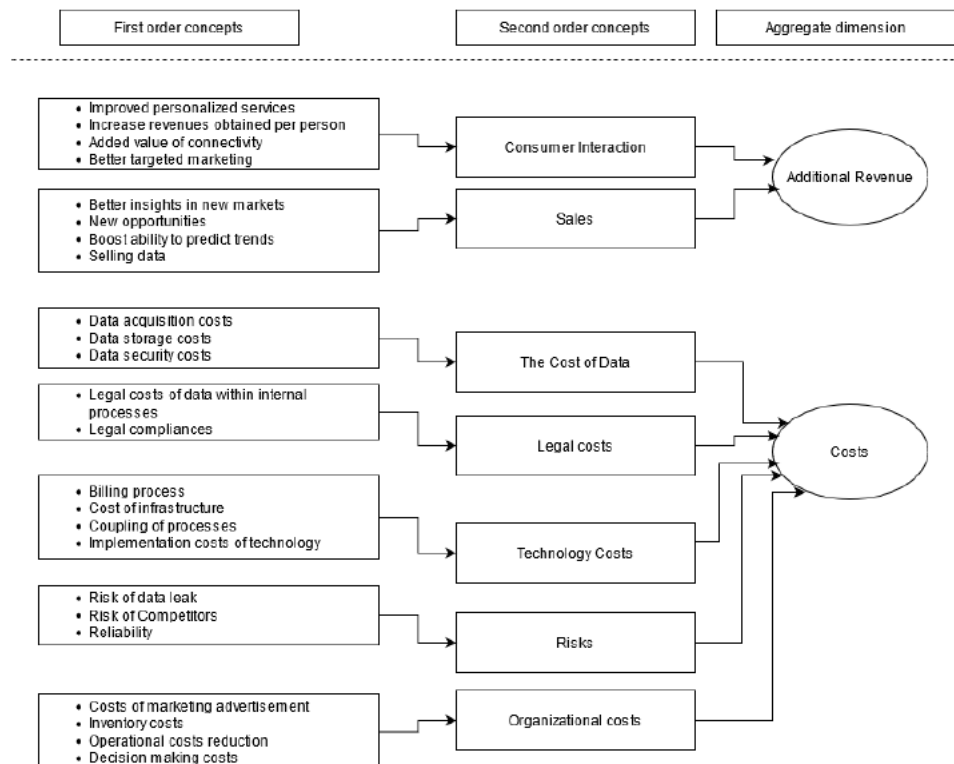
Figure 14: Outcome of the interviews

6   Results

This section discusses the results of experts' interviews. Insights from the experts have been explained as well as any opinions that differ from the literature. Additional insights given by the experts are used to enrich the framework. The groundedness table is found in appendix A.

6.1 Revenue

Experts indicated that better-personalized services and increased revenues per person would improve, as mentioned in the framework from the literature. For example, additional information on the consumer allows this. The ability to address specific target markets and specific consumers was marked as crucial. For example, when asked about an essential factor for a telecommunication company considering implementing MPC, E1 stated that 'Well, it is always the higher revenue that comes from the new markets that you can target.' Multiple sources indicated that exploring new markets was a real benefit for them. The sources also indicated the addressing of specific customers as necessary. They gave the example of handing out flyers or coupons within a specific area as examples that MPC could improve. 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'. These aspects as thus included within the framework.

The interviewed experts agreed that MPC enhances the prediction of market trends and improves the ability to try new opportunities. For example, E4, when asked about how they can benefit from MPC, stated that '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 complementary parties. 'Well, in terms of banks, I don't see them ever selling their data. Not ever. In terms of sharing anonymized data, yes. They may share data with some specific organizations, mostly public sectors. But I can see smaller companies doing so.' -E4. This category was easily validated, and no discussions arose.

6.2 Added Revenue

Experts stated that they would not share data with competitors but only with companies that provide complementary services. Sharing data with complementary organizations provides information that allows telecom companies to boost their ability to target new markets. New and specific markets could be targeted, and customers could be targeted more precisely. 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 obtained 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 significant 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 that rely on their reliable reputation and 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 significant factors for telecom companies. They are continuously searching for the following 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 specific areas and discover where they should implement the technology first. Trends could also be essential to identify. It is not so much for their product because they do not need to maintain a large inventory. However, it helps predict which bundles they should sell. Telecom companies could benefit differently by becoming an intermediary. This is not implemented within the framework because it is only possible for so few companies not generalizable. It will be briefly explained now because it is of importance for telecom companies. Telecom companies already have a data-sharing infrastructure and a trustworthy reputation. Therefore, they could fill in the role as a data marketplace. They would implement a subscription model, the same for the internet and phone subscriptions 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 need to invest 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 little or no existing customer base. Big telecom companies, on the other hand, already have an extensive client database. Overall, telecom companies might be intermediaries in the future.

6.3 Costs

Most costs were deemed insignificant by multiple sources. They are still important because they show an impact and no change for a telecom company. The experts agreed that the costs for acquiring data as

relevant. E1 mentioned transaction costs as an aspect stating, 'telecom companies buy data and find a correlation.' The payment structure was discussed with the experts. E1 stated that '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, meaning that the costs of acquiring data should be a fixed amount. 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.

Costs of storing data were found not to have a significant impact for organizations implementing MPC. For example, E3 said: 'I don't think MPC affects the cost of storing data. Big companies have always stored data either in-house or in cloud services. So, I don't think MPC implementation influences data storage costs. Companies will not save huge amounts of additional data.' Also, the companies already have data storage in place, so not much additional storage space is needed. However, small businesses such as bars that do not have a place to store their data need to consider storage costs if they consider implementing MPC. MPC implementation has minimal impact on the costs of storing data. This is because companies already have their data storage in order. MPC does not change the amount of data that is stored drastically.

The total costs of advertisements will go down because they can analyze and target the right customers. Suppose they can analyze and target the right customers. In that case, they can reduce the costs spent on communicating with consumers. Consumers can reduce the effort to obtain helpful information. This leads to lesser investments made in advertisements and thus lower advertisements costs. The inventory costs remain unchanged because it is not applicable for telecom companies.

The legal costs are interesting. For a large telecom company, it is stated that legal costs will not matter that much. The full-time employed legal staff can easily oversee the additional work. They have to ensure that data is used according to GDPR standards. The most important category to investigate is 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 vital 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 a lease contract to cover all the operational costs, or the operational costs could come separately.

The experts said data sharing would be done mostly with complementary parties. E4 stated: 'Yeah, for us, that is not relevant, but I can see how other companies could benefit from MPC with their inventory.' Inventory can be an excellent 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. However, it surely has an economic impact and is therefore mentioned in the framework. The costs of advertisements were identified to drop as predicted by the framework and validated and still included. E1 stated: 'It could be that they would have to spend less on marketing advertisements.'

Experts had varied opinions on legal costs. E1 stated, for instance, that the costs would not be high based on the massive size of their company. The legal costs are relevant according to E3. There are two ways the legal costs are influenced. The first is making the data GDPR compliant. The second is making sure all the internal processes are done legally. E3 stated: 'The internal process also needs to be within the requirements of GDPR, and that can be pretty 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, they are included in the framework.

The experts indicated that technology implementation, employee, and operational costs were essential for MPC implementation. For example, E1 stated that 'it gets costly because it has to be implemented into your CRM (customer relationship management) systems and your provisioning systems and the whole machinery.'

6.4 Risks

The most mentioned risk was `data leaks.' Experts stated two different effects of data leaks. The first is reputational damage. E3 stated 'I think data leaks are a considerable risk. Your reputation is at risk even if you meet all the GDPR requirements." The second consequences are the fines that come from the leaks. The fines can, for instance, come from not complying with GDPR anymore. For instance, E4 stated that 'the companies may not have consent to share this data with another company." This results in a non-compliance of GDPR. This aspect is thus relevant when assessing the impact of MPC on businesses.

Competitors' entry into the market was discussed but is removed from the framework. E3 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 are less of a barrier to competition. Experts stated that the implementation should be with intermediaries. They also stated not to trust any party fully. 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. However, a company could take a risk and collaborate with a competitor if they estimate substantial gains. 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 more significant market share. Smaller companies should ask themselves how and if they want to work with more prominent companies.

6.4.1 Additional Risks

A new aspect uncovered from the interviews was the cost associated with the decision-making process. E3 described it as follows: 'So, we have an idea and what we do is we brainstorm with some people. We have some interviews with potential customers or other people involved. Then we usually set up a prototype or a proof of concept to see whether it works. When we see potential, we can then start developing a product'. Therefore, costs of the decision-making are a new category. The other new aspect uncovered from the interviews is that of reliability. The technology needs to be very reliable for the companies. E3 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. Alternatively, quality requirements that you have to fulfill. Reliability should be added to the framework.

Companies must consider the additional costs of protecting the data; E2 indicated that many investments are needed in the technical domains to ensure technical safeguards. Overall, this might not be the most significant impact on costs. However, it should be included within the framework because it is still significant, especially for smaller companies or companies who did not collect data before. Figure 6.3 shows the final version of the framework.
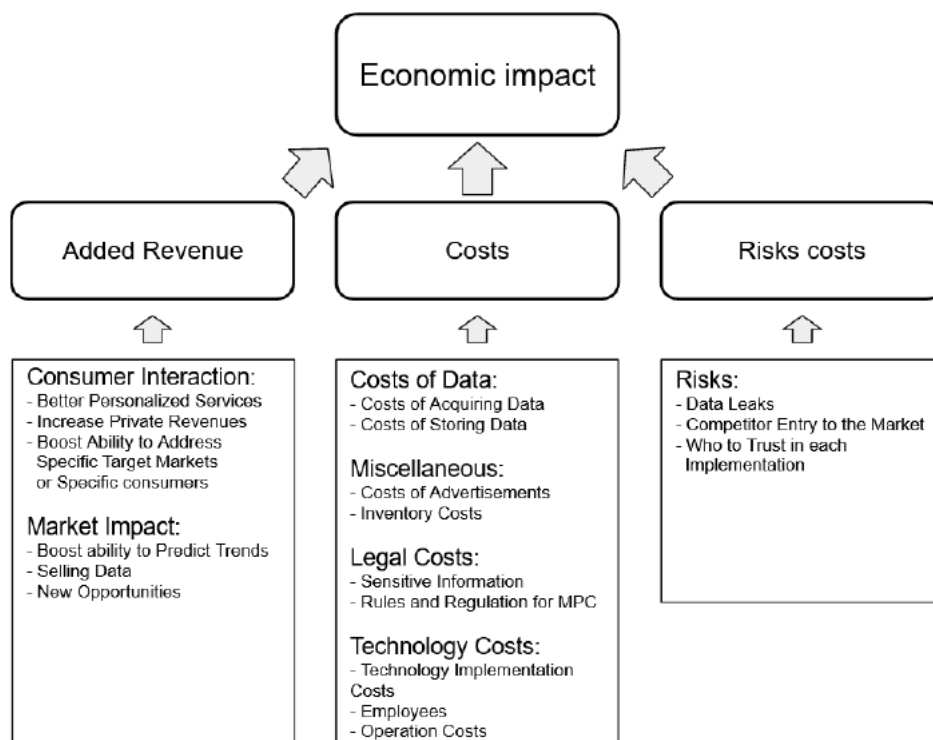

Figure 15: Final Framework

7 Discussion

7.1 Is there a viable business case for MPC implementation?

The business case analysis showed that implementing MPC has benefits for organizations. The objective of implementing MPC in a business is to enable data sharing with other companies. Enhanced data-sharing with the implementation of MPC will result in the availability of more data that can be leveraged to explore more new opportunities. Managers can see the positive effects and opportunities in these aspects found in the framework on which an implementation decision is considered. We discussed revenue, risks, and cost components associated with the implementation of MPC

7.1.1 Revenue

MPC implementation was identified to provide business opportunities for telecommunication companies to enhance their revenue. For example, more personalized services as a business impact of MPC arises because more data is assumed will be shared with organizations since customers will be less concerned about privacy concerns given data anonymization. Additional data for the company means more insights into customers' needs. Taken together, MPC is of value to businesses, particularly in marketing. Additional data could be leveraged to predict market trends, personalized services, and even opening more other revenues sources where companies can trade in data. The revenues provided in the framework should constitute a basis on which MPC impact can be quantified.

7.1.2 Costs

The implementation of MPC also comes with additional costs for companies. This cost was identified in broad areas of legal costs, technology cost, cost of data, and other miscellaneous costs. The specific cost is shown in the final framework in figure 16. Most especially companies have to consider legal costs as regulations addressing issues of privacy become important. For example, in the implementation of MPC, companies have to ensure constant, the MPC is interoperable with other technologies in the organization. Ensuring alignment with existing technologies creates technological implementation costs. For example, this includes the recruitment of employees to provide up-to-date knowledge on securing MPC. In addition, this contributes to operational costs to ensure that MPC is functioning all the time.

7.1.3 Risks

Data leaks are key risks that should be considered as critical factors that can affect the implementation decisions of MPC. The results of the study show that MPC may be susceptible to a data leak. Data leaks affect businesses through the reputation damage of the image of a company. As shown in the framework, another risk that needs to be considered in MPC implementation is trust among the participating organizations sharing data. Trust is important in data sharing since companies could exchange data for purposes that another organization or a customer stipulates.

7.2 Recommendations for MPC Implementation

The intermediary structure was consensually chosen to be the preferred implementation structure. Therefore, this report also recommends this structure. The advantages of this structure lie within two factors. The first factor is responsibility. For example, suppose Company A wants to use MPC and Company B and use an intermediary. In that case, 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 share data. They still put their respected names on the line, but most financial liabilities lay at the intermediary. The second factor is the costs of computation. It is cheaper to have an intermediary do many computations than having every company implement MPC and make their computations. 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 essential to implement a payment method that parties could use to acquire or sell data.

Identified payment structures were periodic payment, pay-per-use, and pay-per-data. Periodical payment structure was the most favored. 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 does not 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 operational at all times and must not exhibit any malfunctions. This would influence usability and decrease the use of MPC. The technology must be impeccable. The reputation of a company is at stake. They could risk fines for not complying with GDPR if the data is exposed by accident. Therefore, the technology must be implemented robustly.

7.3 Limitations

This report did not compare MPC with other privacy-preserving technologies. Other technologies could have different effects on companies not reflected in the framework. The framework is, therefore, only usable for the implementation of MPC. However, the framework can be used as a starting point for future studies on the economic impact of other privacy-preserving technologies similar to MPC. Furthermore, the cost of data was insignificant for telecom companies because they already have an extensive system for data processing. This is not the case for smaller businesses such as a local pub. Middle and smaller companies might also struggle with legal costs. This research does not provide quantitative results or real-life quantitative examples. The businesses should use the created framework and quantify the aspects themselves by doing a cost-benefit analysis. A final limitation is that the evaluation of the framework was based on a relatively small number of interviews and that additional interviews could lead to new insights.

7.4 CONCLUDING NOTE

This report provides a framework for understanding the potential economic impact of MPC. Implementation. It uses a business case analysis that provides steps to consider when assessing a technology's impact and economic viability. The framework constitutes essential cost, revenue, and risk categories drawn from existing literature on business models, privacy technologies, and business case analysis. Although MPC was the focus of this report, the categories of cost, revenue, and risk provided in the framework are helpful for other privacy-preserving technologies similar to MPC.

8 Appendix

Appendix A: Groundedness Table

The groundedness table shows 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.

First-order concepts	Representative quotations
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 most significant impact will be addressing specific target markets or specific consumers. It would be great to 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 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 regulations for MPC	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	For example, they usually run into something, an idea, or a capability in their networks 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 not have 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. However, a company could 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.