Utilising the Principles of Blockchain Technology for Managing Road Infrastructure Projects

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ABSTRACT

In spite of the amount of new tools and methodologies adopted in the road infrastructure sector, the performance of road infrastructure projects is not constantly improving. Considering that the volume of projects undertaken is forecasted to increase every year, this is a substantial issue for the road infrastructure sector. Hence this work focuses on the principles of Blockchain Technology, road infrastructure sector and the information exchange with the aim to use the advantages of the Blockchain Technology in supporting to overcome the various challenges along the life cycle of road infrastructure projects.

Within the scope of this paper, two studies were conducted. First, focus groups were used to explore where society (road infrastructure sector) stands in terms of industry 4.0 and to get a better understanding if and where the principles of Blockchain Technology can be used when managing projects in the road infrastructure sector. Second, semi-structured interviews were administrated with experts of the road infrastructure sector and experts of Blockchain Technology to better understand the interrelation between these two areas. Based on the outcome of the two studies, technology barriers and enablers were explored for the purpose of improved information exchange within the road infrastructure sector.

The two studies revealed that there are significant and strong interrelations between the principles of the Blockchain Technology, project management within the road infrastructure sector and information exchange. These interrelations are complex and diverse, but overall it can be concluded that the adoption of the principles of Blockchain Technology into the field of information exchange improves the management of road infrastructure projects. Based on the two studies a theoretical framework was developed.

In summary this research showed that trust is an important factor and builds the foundation for communication and to ensure a proper information exchange. Within the scope of this thesis, it was demonstrated that the principles of the Blockchain Technology can be used to increase

transparency, traceability and immutability during the life cycle of road infrastructure projects in the area of information exchange.

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I would like to dedicate this thesis to my beloved mother.

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Figure 1-1: Overview of chapter 1 – introduction to the research

1.1 Research background

Blockchain Technology (BT) is more than just the technology behind the currency bitcoin. The technology is a real innovation, which has the potential to change many areas of society.

The main advantages of the technology are highlighted with the help of principles. To simplify the technology with the help of the principles of the BT, it is expressed, that the BT is a digital journal for transactions between two or more computers. Every change within a process is recorded and stored in all involved systems decentral. Based on this decentralisation an increased trust within the process is given. The BT is also known as a distributed ledger technology and it is the foundation of Bitcoin and Ethereum. But the possibilities of the technology go far beyond that. A Blockchain is immutable, transparent, traceable and because of that, it enables trust (Underwood, 2016).

In the meantime, this technology goes far beyond the field of digital currencies. At least, because of its many possible applications, it is increasingly becoming the focus of public attention. In the past years, the BT has worked flawlessly in a wide range of applications in different aspects, in both the financial world and the non-financial world. The idea behind this thesis is to generate a study with the topic of the principles of BT in the field of Managing Road Infrastructure Projects. This research will investigate whether doors are open to optimise the process of error reduction in projects in the Road Infrastructure field, and simplify the transactions between different parties efficiently and in a verifiable and permanent way.

It is a fact that 7.9% of every pound is wasted due to poor project performance, which is for every GBP 0.79 billion invested around GBP 75.63 million. In the Brightline Initiative it is written that around GBP 7.9 million is wasted every 20 seconds, which is GBP 1.5 trillion every year; this refers to the global capital investment (Pulse of the Profession, 2018).

As we are in the middle of the fourth industrial revolution, for which the term Industry 4.0 has become very influential. The first 3 revolutions took almost 200 years to develop. The first industry was driven by steam engines, waterpower and mechanisation. Henry Ford was responsible for the assembly lines in the second industrial revolution where the mass production has been introduced. The third industrial revolution was driven by the use of computer and automation in manufacturing processes (Ghobakhloo, 2018). Industry 4.0 was introduced by the Germans in Hannover at the Hannover Fair. The interpretation of industry 4.0 is the application of the cyber physical systems (Posada et al., 2015). Analysing the term Industry 4.0 shows that a lot of organisations have put BT at the centre of their strategic agenda. Because cryptocurrencies allow countless smart devices to perform transparent, secure, fast and frictionless transactions, Scientifics believe that BT is critical to industry 4.0 (Devezas and Sarygulov, 2017M Sikorski et al., 2017).

With regards to the field of project management, it needs to be observed whether the advantages of Industry 4.0 can help with the known problems in the area of road infrastructure

projects. Road infrastructure projects are also known as mega projects. Whenever mega projects are mentioned in the thesis, the research is talking about road infrastructure projects.

In correlation with the challenges of mega projects, it is often said that these projects do fail, because they finish late or the budget is overspent (Turner, 2018).

In the context of a US research the performance of mega projects was analysed and a number of complexity criteria were identified. The challenges that are leading to the poor performance in road infrastructure projects are:

> ➢ The significant number of stakeholders;

> ➢ A large number of interfaces between the different areas of the stakeholders;

> ➢ Challenging project locations;

> ➢ Poor supply of resources;

> ➢ Unfamiliar technologies;

> ➢ Significant political, economic, environmental and social influence (Caldas and Gupta, 2016).

Many tools and models have been used in the implementation of projects (Sommer, 2016). The idea in the study is that the principles of the BT might help in the performance of road infrastructure projects as it can bring the challenges of these projects together. The purpose of this research is to elaborate on whether the new digital innovation, called BT, can optimise the process of road infrastructure project management. It is said that, with the help of the principles of BT, processes can be more transparent, all steps within a project can be made traceable and the data will be stored in a decentralised way. On the one hand with the help of these principles, the current research will investigate why road infrastructure projects are not completed on time and why a high number of these projects are overspent. On the other hand, this thesis will explore the importance of trust between the different stakeholders involved along the life cycle of road infrastructure projects. The involvement of different stakeholders shows

the complexity of a project and the different perspectives the different stakeholders have. Within the scope of this thesis, it will also be demonstrated where the road infrastructure sector stands in terms of new technologies and it will be shown why new technologies – in the current case the principles of the Blockchain Technology – should be used and what advantages they can bring.

One of the oldest industrial sectors is the construction industry. Our life has been changed by digital technologies. Innovations and new developments never come to a standstill; and they constantly change the rules of the game. However, the digital transformation is not taking hold in all economic sectors. The construction industry is not just one of the oldest industries, it is also one of the most inefficient industrial sectors. Historically, the construction industry has never been quick to implement innovations. A study conducted in 2004 at the Centre for Integrated Facility Engineering at Stanford University indicated that productivity in the construction industry fell by approximately 20% between 1964 and 2004 Figure 1-2, while all other industries experienced more than 100% productivity growth in the same period. A similar study was conducted in Germany. An evaluation period of 24 years (1991-2015) supported the proposition that the productivity in the construction sector had stagnated, while the productivity in other industries had increased by around 70% (Balwin, 2019). For the further steps and the further work, the Road Infrastructure needs to be considered as part of the construction sector.

The figure below describes how productivity in the building industry (blue line) has proceeded since 1964 compared to all other industries (green line), excluding construction and agriculture.
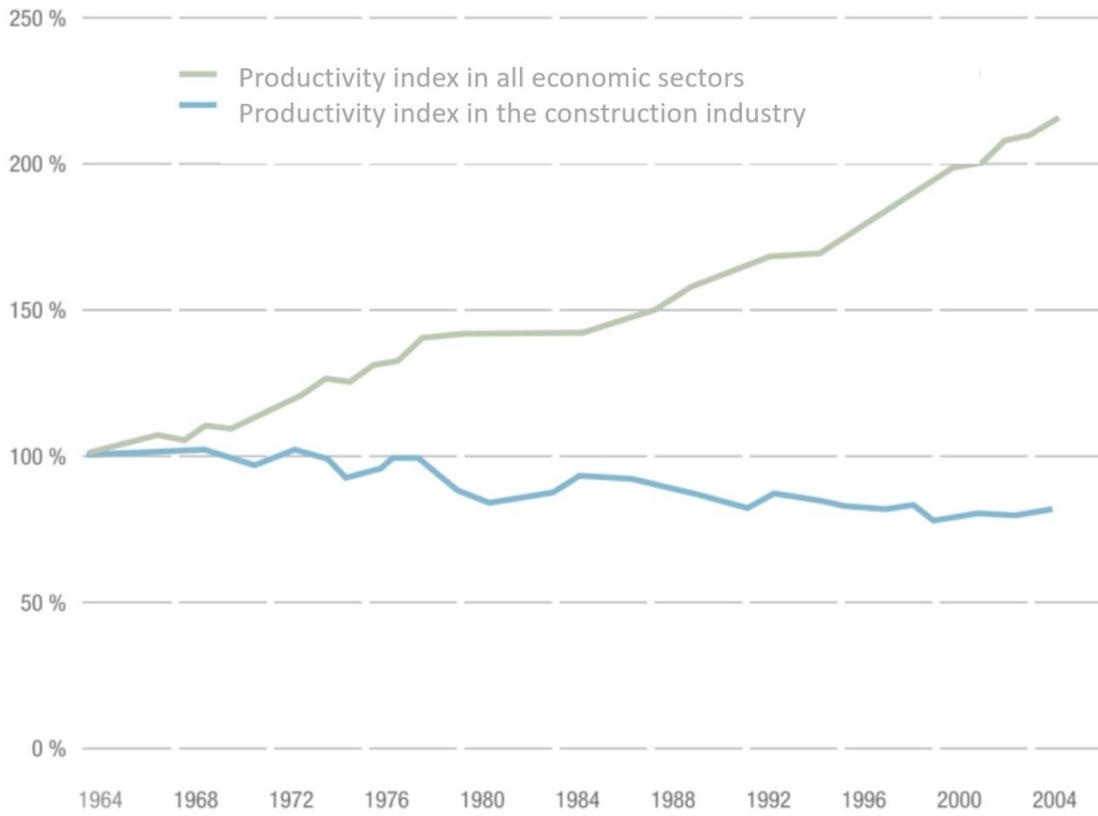
Figure 1-2: The building industry in the digital transformation age compared to other industries (Balwin, 2019)
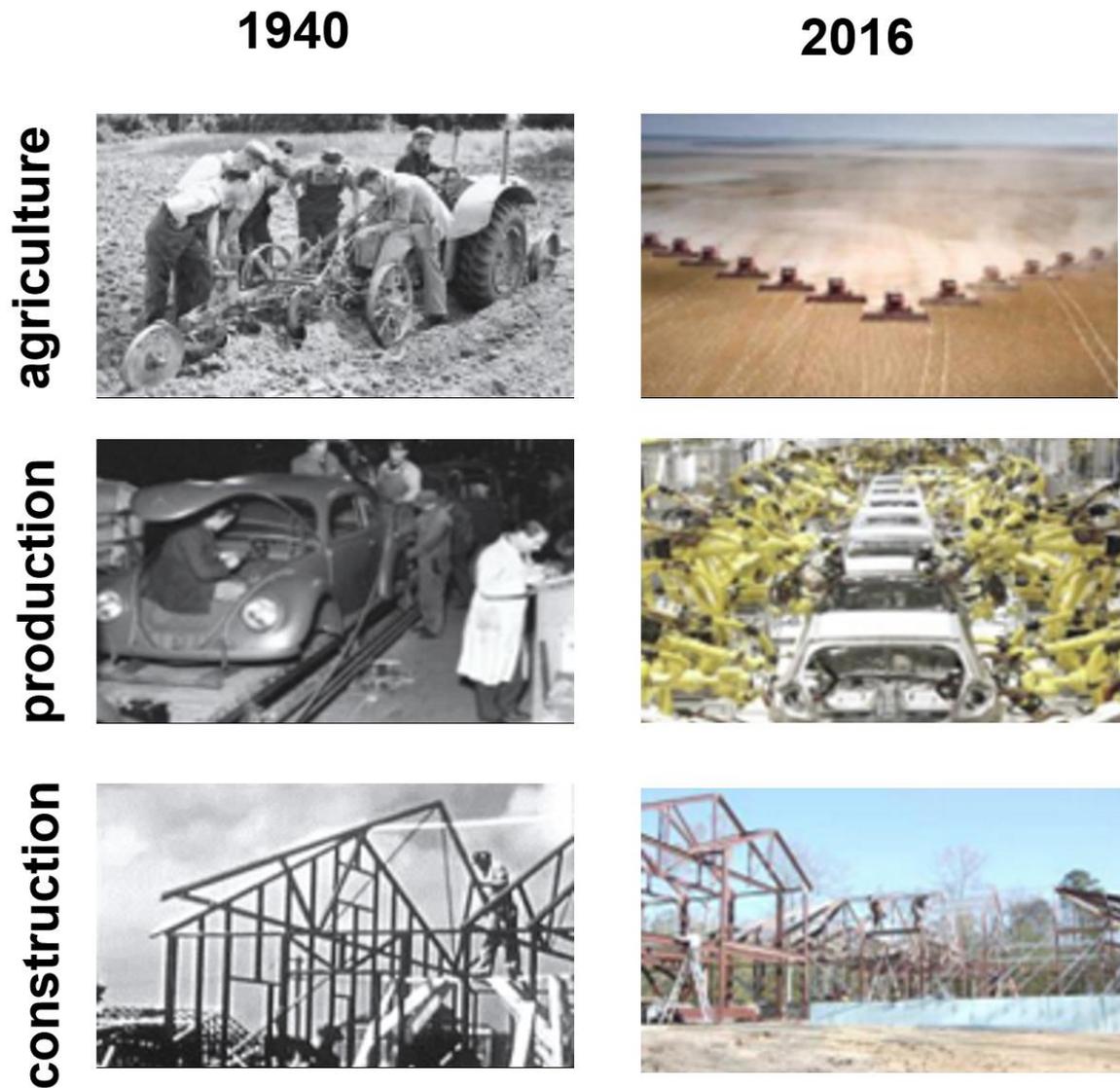
Figure 1-3: Development of the different industries between 1940 and 2016 (Gernot Strube, 2021)

As shown in Figure 1-3 , Gernot Strube (2021) demonstrated the differences between two other industries and the construction industry. In the first example, the great achievement in agriculture is visualised. The progress that was made in here was in automation in terms of machines with highly developed bioengineering. In the field of manufacturing, totally new assembly line concepts were developed. In retail, the progress was in the development of logistics for providing affordable mass-produced goods. Comparing the progress in these

industries with the construction industry, it can be seen that there has been virtually no change in the latter in the period studied.

1.2 Research question

The research question which has been developed and should be met in this doctoral thesis is the following:

> *"How can the principles of Blockchain Technology be utilised for Managing Road Infrastructure Projects?"*

1.3 Research aim and objectives

The three main parts that will be investigated in the research are road infrastructure projects in the context of road infrastructure project management, the principles of BT and the information exchange. In the new global economy, communication and information exchange has become a central issue for processes with a project. The information exchange is important for a wide range of scientific and industrial processes. In order to implement information exchange the factor trust is required.

So that the research question can be investigated in a structured way, the following three research objectives (ROs) and the research aim (RA) have been synthesised. With the help of these objectives and the aim, a defined approach is predetermined. The research aim of the study is "to develop a framework for the utilisation of Blockchain Technology to support the management of road infrastructure projects." In order that this aim can be achieved, three research objectives will be answered. The three research objectives and the research aim are listed in the following:

1. To identify in which aspects of managing projects the principles of Blockchain Technology can be effectively utilised. (RO 1)

2. To explore the interrelation between the principles of Blockchain Technology and the performance of Managing Road Infrastructure Projects. (RO 2)

3. To appraise the barriers and the enablers to the utilisation of Blockchain Technology in the context of Road Infrastructure Projects. (RO 3)

4. To develop a framework for the utilisation of Blockchain Technology to support the management of Road Infrastructure Projects. (RA)

1.4 Intended contribution to knowledge

The present thesis will provide a contribution to knowledge by developing a framework that will help to enable the applied principles of BT for managing road infrastructure projects. It will also help in understanding how new technologies, especially BT, will be used in the future and what the advantage of this technology is. The principles of BT and the parameters of road infrastructure project management will be brought together. These two areas are an important component and play a key role in the area of complexity in projects that are appearing in road infrastructure project management. One of the reasons why the road infrastructure industry is complex is because a lot of different stakeholders from different areas are involved in one project. Based on this investigation, this research will help to enhance the knowledge and the understanding of road infrastructure project managers in the field of BT and information exchange. Accordingly, the themes of road infrastructure project management, information exchange and BT will be brought together. As a result, project managers will understand how the principles of this technology will support managing road infrastructure projects. The thesis will bring the principles of BT into the field of road infrastructure projects and will generate a holistic framework for integrating the areas of road infrastructure, the principles of BT and the information exchange. The research will investigate which role the information exchange and the communication plays in road infrastructure projects between different groups and stakeholders. It will also examine what tools are used in terms of new technologies and if there

is an opportunity to find a way to combine the information exchange, the road infrastructure sector and the principles of BT.

1.5   Core themes of the study

The literature review chapter in the thesis gives an overall understanding of the core themes of the study. As already exemplified in the sections on research background (1.1) and contribution to knowledge (1.4), a detailed level of understanding needs to be reached in the areas of road infrastructure projects, information exchange and BT. The relevant statements made in the research need to be recognised in the existing literature. In the literature review, the core themes are project management, road infrastructure projects, BT and information exchange. These four themes can be seen as core literature, which will be sub-classified into further sub-themes within every core theme.

In the first core theme, *project management*, the meaning and understanding of projects and project management is defined. This is relevant for the whole background of the research. This will support the characteristics and the environmental backgrounds for every conducted project. The second core theme in the research focuses on *road infrastructure projects.* On the one hand, it will be discussed why these projects are different to other construction projects and, on the other hand, successful and unsuccessful road infrastructure projects will be analysed. Based on this analysis, the researcher is able to use the key components of a successful road infrastructure project for the development of the holistic framework.

The third section, *BT*, underpins what the state of the art of the technology is and what the understanding of the principles of BT is. It also discusses the advantages and the disadvantages, and in which fields it is already used.

The last core theme "Information Exchange" covers what information exchange is and why this topic is important.

The below figure provides an overview of the core literature themes and the sub-themes.
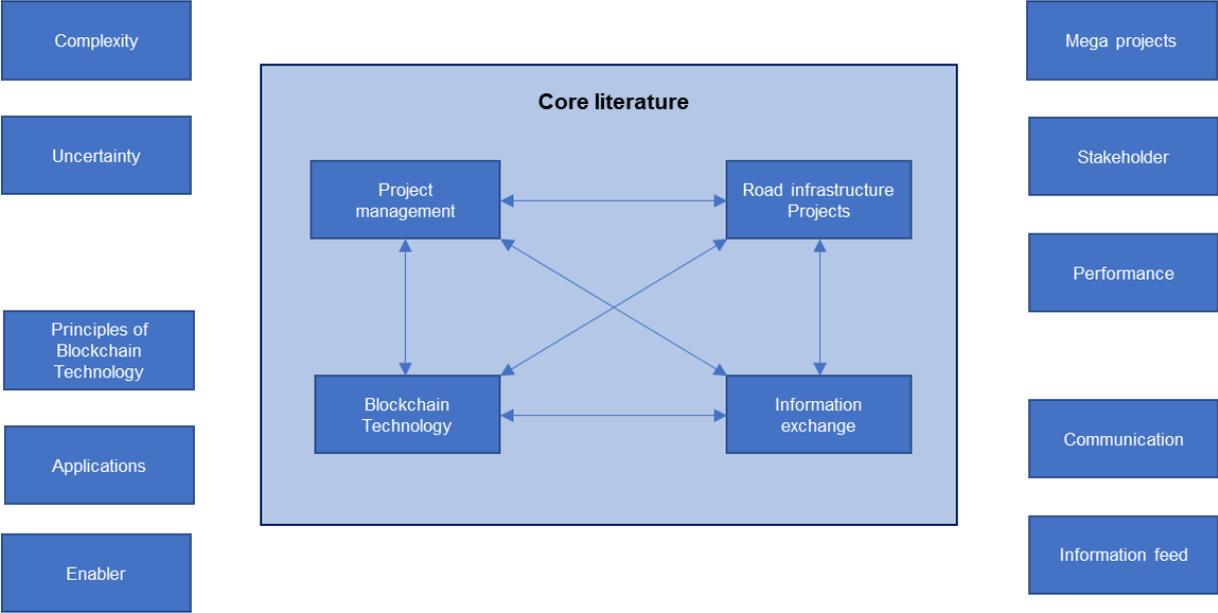
Figure 1-4: Core literature and sub-themes

1.6 Thesis structure

An overview of the structure of the thesis is shown in Figure 1-5. In this figure, the research process is represented and the relationship between the research objectives, the literature research and the findings of each are demonstrated.
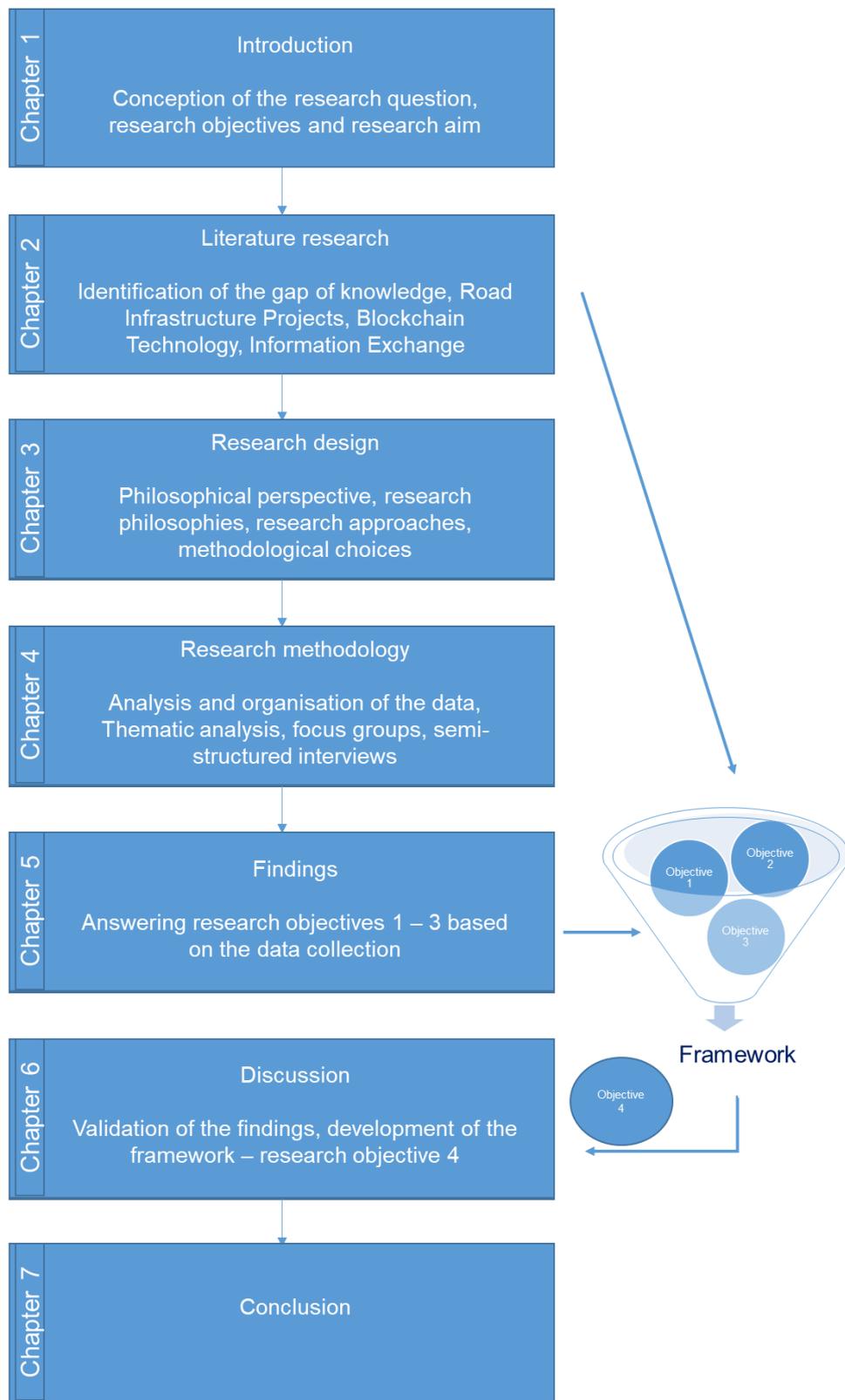
Figure 1-5: Holistic overview of the structure of the thesis

CHAPTER 1: Introduction to the Research

In the first chapter of the thesis, the research background and the challenges of the defined topic are presented. Consequently, the research question is stated, with its research objectives and the research aim. The first chapter also discusses the structure of the whole thesis.

CHAPTER 2: Literature Review

Subsequently, in the chapter on the literature research, the relevant literature is reviewed critically. The aim of the literature research is to generate the current stage of knowledge and to identify the gaps that need to be investigated in the present study. In order to obtain a comprehensive understanding, journals, books and previously conducted studies were reviewed. With the help of this chapter, the theoretical foundation for the research and the data collection is laid out. The chapter starts with a literature review in the field of project management. Next, a literature review is conducted in the area of road infrastructure projects. This part of the research covers the challenges faced in these large projects. Examples of successful and unsuccessful road infrastructure projects are given, and what can be learned from these is discussed. In the next phase, a review is identified related to industry 4.0 and new technologies. The focus in the current research into new technologies is the principles of BT. Hence, it is demonstrated in which sectors the technology is already used and which particular advantages, the technology is providing, are leading this technology to such a special technology. Finally, a literature review regarding information exchange is presented.

CHAPTER 3: Research Methodology

This chapter involves topics such as philosophical perspectives, research philosophies, research approaches and methodological choices. It is important to investigate these topics here, because it needs be to understood which research journey the researcher has chosen and it allows the reader to understand which position the researcher is taking in terms of other researchers and society. This is mandatory for the criteria the researcher is utilising in the

interpretations of the data collection and the comparison of the data collection and the literature review.

CHAPTER 4: Research Method

On the basis of the research design chapter, the chapter on the research methodology is established. Different methods are identified and the chosen research methods in the present study are discussed. The chapter elaborates on why different methods for the research were chosen. It describes in detail how the data collection, the organisation of the data collection, the analysis and the validation of the data were carried out. In the last section, the ethical compliance is indicated.

CHAPTER 5: Findings

In this chapter, the data collection from the focus groups and the semi-structured individual interviews is presented. The procedure for the conduction of the data collection in the current research is also presented and explained in detail. On the basis of this, the chapter provides details on how the analysis of the data was elaborated. The findings include the summary of the results of the focus groups and the semi-structured interviews. The meanings of the findings are also investigated. The reader needs to keep in mind that the comparison of the findings with the literature research will be made in the discussion chapter. The goal in this chapter is to answer the first, second and third research objectives, based on the data collection only. To ensure that the focus groups and the semi-structured individual interviews produced proper results, a pilot focus group and a pilot individual interview were tested, prior to conducting the whole data collection. To gather rich and useful data, only a selected group of participants were able to take part in that research.

CHAPTER 6: Discussion and Framework Development

The aim of the discussion chapter is to introduce the framework and to give a response to the research aim and to answer the research question. In this chapter, the results of the literature review chapter and the results of the findings chapter are brought together. The findings are compared to the literature review and the literature is able to support the findings of the data collection. On the basis of these results, the development of the framework is provided. This is given an important role and the chapter elaborates, step by step, how the framework is composed. With the help of the framework, the research aim will be answered. In generating the framework, the areas of road infrastructure project management, the principles of BT and information exchange are the foundation.

CHAPTER 7: Conclusion and Recommendations

In this last chapter, a summary of the findings and the insights is provided. It will be demonstrated how the research objectives and the research aim have been achieved in the research. In one of the last sections, the contribution of knowledge (practically and theoretically) is answered. This information can be used to develop targeted interventions aimed at the field of road infrastructure project management. The limitations of the study will also be mentioned in this chapter. As the findings and the discussion have a number of important implications for the future practice, lastly, recommendations for further research, based on the generated findings and the framework of the present research, are made.

1.7 Summary of chapter

In the "introduction to the research" chapter the context of the research is presented. This chapter provides a collocation of the problems of poor performance in road infrastructure project management and an explanation what the BT is and at the same time why this technology might help in the field of road infrastructure project management. The development of the industrial revolution was explained and that it is necessary to observe whether the

advantages of the BT can support in the known challenges in the road infrastructure. Based on these considerations the research question was developed. That the research question can be answered the research objectives were generated. With research objectives aim it will be investigated how the principles of the BT support the management of road infrastructure project management.

In the second part of the chapter an overview of the literature review was given and the structure of the thesis was introduced. The thesis will be divided into seven chapters, i.e. introduction to the research, literature review, research methodology, research method, findings, discussion and framework development and conclusion and recommendations.

2 Literature review
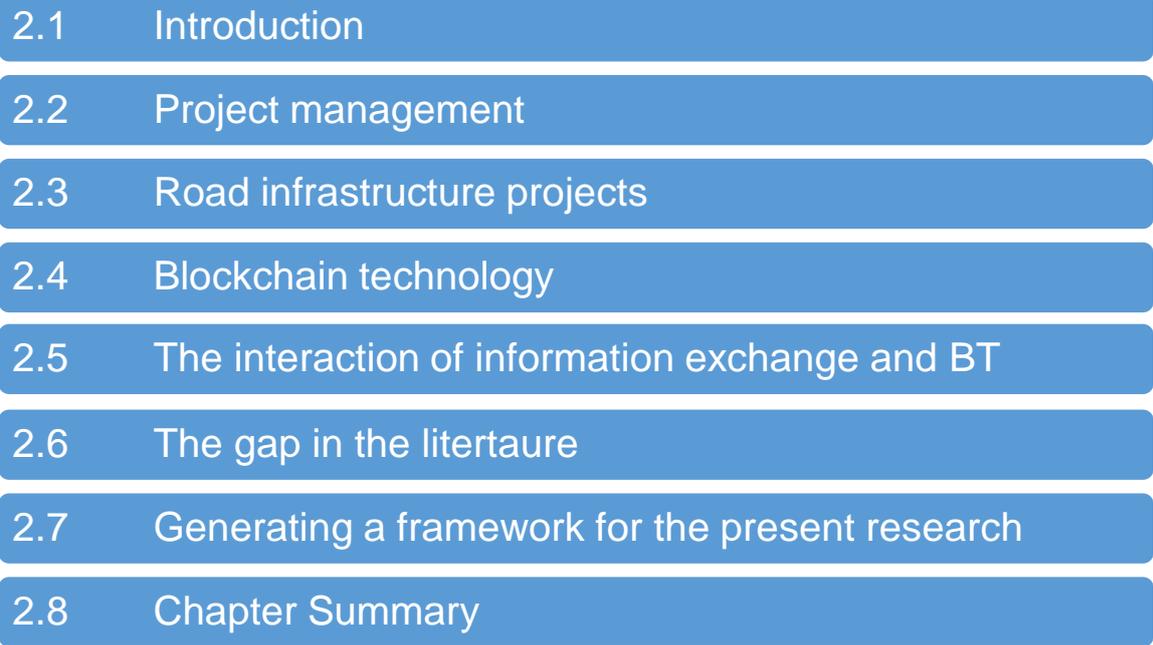
2.1	Introduction
2.2	Project management
2.3	Road infrastructure projects
2.4	Blockchain technology
2.5	The interaction of information exchange and BT
2.6	The gap in the litertaure
2.7	Generating a framework for the present research
2.8	Chapter Summary

Figure 2-1: Overview of chapter 2 - literature review

2.1 Introduction

In the following chapter, the literature review and thus the basis of the research will be discussed. At the end of the chapter, the researcher will have a wide understanding of the current stage of knowledge, in themes like project management, road infrastructure projects, BT and information exchange, which is relevant and the foundation to this research. Basically, the literature review will identify the gaps at this point in time, to be able to link up to the further research. The first part of the chapter identifies the themes of project management and road infrastructure projects. Project management is getting such an important focus, because the construction of roads, such as planning and building, has been carried out in the form of projects since time immemorial (Spang, 2016). Based on experiences, the perception is developing more and more that a production process and holistic project success related to the end product is only possible with a holistic view and treatment of the project, from the idea

to the use. Transport projects are usually not only of considerable financial proportions, but also of considerable magnitude in terms of the area affected and the people and organisations involved (Hertogh et al., 2008). In correlation with road infrastructure projects, complex projects are also discussed. The understanding of complexity entails different areas, such as different stakeholder expectations, complexity regarding cultural complexity, socio-political complexity and emergent complexity. This is only one of the reasons why road infrastructure projects can be defined as complex projects. The meaning of complexity will be explained in one of the following sub-chapters in more detail. Secondly, BT will be introduced and critically reviewed. As road infrastructure projects involve a lot of different stakeholders, trust, transparency, traceability and information exchange are big themes in this area. As BT is known to be used in areas in which trust is an issue, this technology is chosen for the present research (Lemieux, 2016). The third section represents the aspects of the information exchange management and the decision-making methods. Spang (2016) argues that the communication between the different stakeholder in road infrastructure projects is an important parameter. Accordingly, a literature review in the field of information exchange is conducted. Finally, the need for these different topics in this research will be highlighted and they will be brought together in a coherent manner.

2.2 Project management

2.2.1 Definition of the term project

Prior to elaborating on the term project management, the term 'project' will be defined and how projects come about will be analysed. The Project Management Institute (PMI) divides a project into two key characteristics:

> "A project is temporary and undertaken to create a product, a project is a
> service or a result that is unique." (PMI, 2017, p.4)

The given definition is explained by PMI (2017) as the following. Projects are executed to achieve objectives through the production of deliverables. An objective is defined as the result towards which the work is directed, a strategic position that is achieved, a purpose that is fulfilled, a result that is achieved, a product that is produced or a service that is provided. A deliverable is defined as a distinct and verifiable product, result or capability that must be produced or provided in order to complete a process, phase or project. Deliverables can be tangible or intangible.

2.2.2 Complexity in projects

Complexity in project management starts with the construction project team. The project team can differ in every project. The only reason why a project team is set up, is because of the development of the construction, a building or a road for example. According to Cherns and Bryant (1984), the project team or the different stakeholders differ on the one hand in their different roles and positions and on the other hand also in their belonging to different organisations. The key parameters for a complex project setting are the quantity of custom-made components, the sub-components of a system and a big part is the degree of technological novelty (Hobday, 1998). Hence, many large construction projects, such as road infrastructure projects, are categorised as complex products and systems. For this reason, Geraldi et al. (2011) suggested classifying these types of large projects as complex projects. Complexity is supported by five dimensions, structural complexity, uncertainty, dynamic, pace and socio-political complexity. The different parameters of complexity will be explained in more detail later in the chapter.

From the perspective of Engwall (2003), the whole environment of a project can be called complex. This is explained as a project environment is a crucial factor that can influence behaviours, knowledge and even the project goal. This is related to the pre-project, to past

experiences, disruptive events during the life cycle phase, and values during the whole organisation and vision of a project, after it is completed.

As was defined at the beginning of the sub-chapter, the organisation of large projects or mega projects, such as road infrastructure projects, is a complex construct, as the number of stakeholders is growing and the distribution of their tasks has become more complex (Spang, 2016). Given these themes, it is clear that the term complexity is becoming an increasingly important factor regarding the challenges within such project environments.

McIntosh (2013) explained that complexity means, that a lot of different components are involved and it is hard to recognise all the parameters that influence the outcome or to find good solutions for the challenges that are arising together with the complexity along the whole life cycle of a project. When it is spoken about different components all different kinds of challenges that can occur within the scope of the project environment are meant which means for example, social complexity, environmental complexity or also factors like the socio-political environment.

Atkinson (1999) explored how to improve the efficiency of project management, looking at the impact of complexity in mega construction project success. In this study, a relationship was demonstrated between project complexity and project success in mega construction projects. The understanding of project success will be explained in more detail in section 2.3.7.2. From a general understanding, the meaning of a successful project is one that is completed on time, on budget and to the required quality.

To get a better understanding of complexity in mega projects, this complexity is merged into five aspects in the Chinese paper; the technological complexity (TC), organisational complexity (OC), goal complexity (GC), environmental complexity (EC) and cultural complexity (CC). Regarding project success, the five dimensions are: schedule (SC), cost (CO), quality (QU), stakeholder satisfaction (SS) and sustainability (SU). The following example refers to the study of Ma conducted in 2020.

The following figure reveals the influencing mechanism of project complexity on project success.
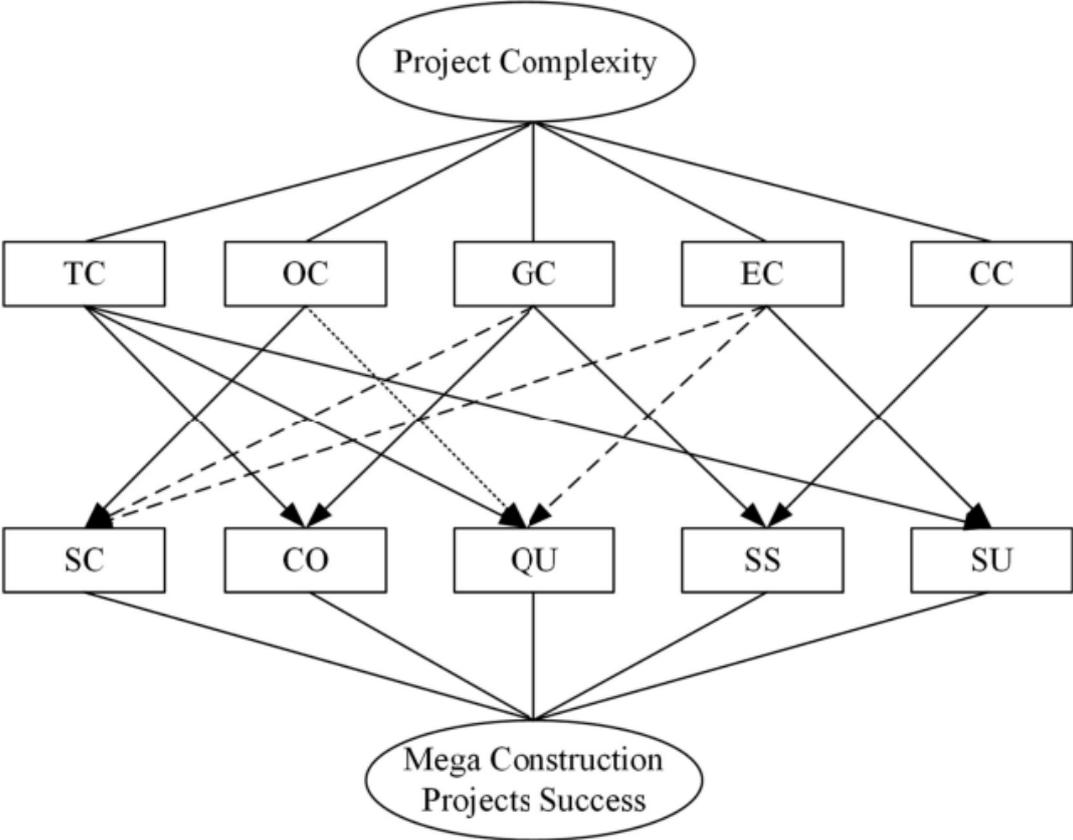
Figure 2-2: Influencing mechanism of project complexity on project success (based on Ma, 2020)

In principle, the study confirmed that a high TC, GC, EC or CC has a negative effect on variable dimensions of project success. It is obvious that a distinct low or high OC negatively affects the construction of a project.

The result of the study presented that a project has serious delays (SC) if the OC factor is high or there is a combination of a high EC and GC. This is a reasonable result, as the construction of mega projects needs the attendance of different organisations that have to participate with each other and a permanent information exchange with each other is required (Senescu et al., 2012). As the construction of a road infrastructure project takes longer and is more complex

than a common project, a higher uncertainty from the environment perspective is also expected (Jia et al., 2011).

Having a look at the parameter cost (CO), the two parameters technological complexity (TC) and goal complexity (GC) influence it. This relates to the fact that, in a road infrastructure project, the participants need to manage a lot of unpredictable risks. In order to achieve the project goals, the participants need to communicate at the same time with partners (Ma, 2020). On the other hand, it needs to be considered that, in every road infrastructure project, scores of unique and complex technologies are required. The procurement of these technologies normally takes more time than planned (Puddicombe, 2012). Wu et al. (2017) found that a high goal complexity (GC) also results in costs overrunning.

Ma (2020) found that the quality (QU) of a project is affected by high technological complexity (TC) or a combination of high environmental complexity (EC) and low organisational complexity (OC). In a study in 2013, it was found that it is possible that errors in a road infrastructure project occur because of the multiple and complex technologies that need to be used (Fast- Berglund et al., 2013). In terms of the EC and OC, it needs to be understood that the implementation of a road infrastructure project is influenced by the project's natural environment. With the help of the organisational complexity, this environment can be managed. This leads to the fact that the cooperation of many organisations is able to reduce the effects of environmental factors. Thus, it is obvious that the quality of a road infrastructure project is affected even if only a small group of the organisational level is included in the vast environmental challenges (Luo et al., 2017).

The stakeholder satisfaction (SS) is affected by goal complexity (GC) and cultural complexity (CC). The diversity of the goals of a project affects the implementation of the project in all its different phases that can be directly related to the key stakeholders. On the other hand, organisations from all over the world, with different cultural understandings, are involved in

such projects, which makes the cooperation and conversations more difficult. These parameters lead to the fact that the stakeholder satisfaction is affected (Luo et al., 2017).

Lastly, sustainability (SU) needs to be considered. Ma (2020) found that sustainability is affected by technological complexity (TC) and environmental complexity (EC). This can be explained easily, with the above statements, that a high TC can affect the quality of a project. It is obvious that changes in the environment influence the sustainability (Agostini et al., 2017). Finally, Ma (2020, p.24) stated: "Although a mega construction project operates continuously and maintains its functional stability in a period of time, the rapid social and economic development make it may not fully meet the new needs of the people and lead to reduction in its SU performance evaluation, which is an essential factor that should be considered when designing a mega construction project in the early stage".

As it was introduced at the beginning of this section on complexity, a paper by Geraldi et al. (2011) provides an overview about complexity in the field of project management. According to this paper, complexity is split into five different types: structural complexity, uncertainty, dynamic complexity, pace complexity and socio-political complexity. As complexity was developed further over the next couple of years, Maylor et al. (2013) provided further detail of the five types. Here, the complexity of structural complexity and socio-political complexity is highlighted and a third dimension is added to them, emergent complexity. This in turn is split into uncertainty and change, as shown in Figure 2-3.
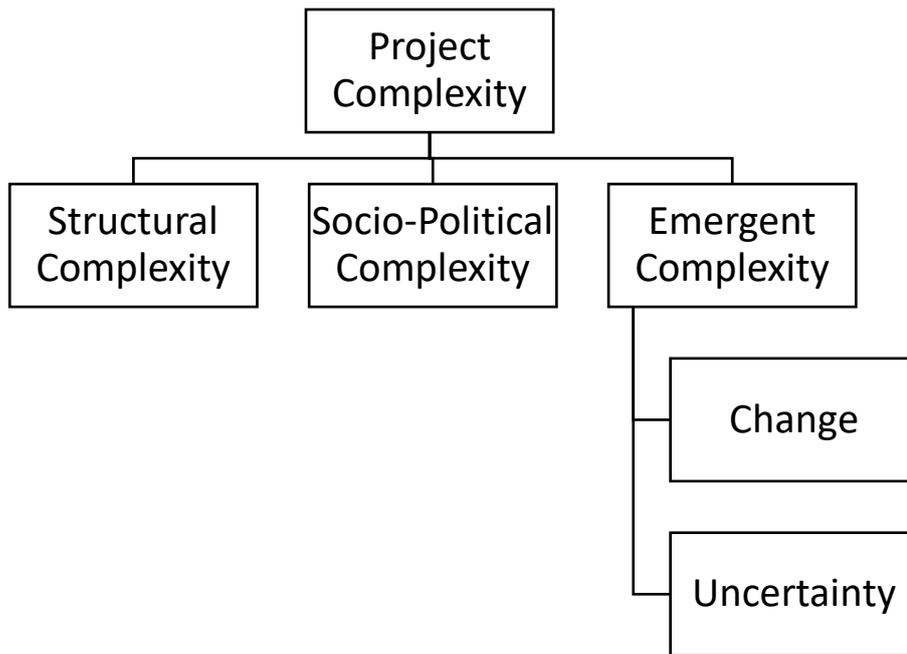
Figure 2-3: The three dimensions of complexity (adapted from Maylor et al., 2013)

Referring to the above figure, the meaning of structural complexity means the complicated tasks which are faced in a road infrastructure project. The socio-political complexity is related to the large number of stakeholders and external parties in road infrastructure projects (Maylor et al., 2013). The area of emergent complexity is focusing on the core of the topic complexity, which is uncertainty. As Maylor et al. (2013) mentioned, uncertainty is one of the core problems of complexity in road infrastructure projects. The second level of emergent complexity is 'change'; this refers to changes in the organisations, in technologies and in the group of stakeholders.

A known issue in the field of socio-political complexity is that the stakeholders and establishments are locked out from each area, but they need to be connected. Behind all these differently named factors, different stakeholders are involved. There are other sub-factors as well, which are called community tolerance, political administration and institutional response. Gharehbaghi (2019) proved that, if all authorities are involved to the same degree, projects are more manageable. As Gharehbaghi (2019) demonstrated with regard to mega rail projects, the known complexity is based on future challenges and in not balancing the sustainable

factors. In projects three are sustainable factors, environmental, economic and social factors. A fourth factor was added here, which is the engineering one. The advantage of adding an engineering factor is that uncertainties and predicaments can be managed better (Gharehbaghi, 2019).

Various factors, such as numerous stakeholders, for example the public, the politicians, the building owner and the different construction organisations (Spang, 2016), complex engineering and changing environmental factors, are responsible for the challenge of managing complex projects such as road infrastructure projects. The environmental factors are affected by parameters like nature protection, bird sanctuary or historic monuments, for example. Natural disasters that cannot be planned must be taken into account as well. In every project, the management function interacts with and exhibits a level of dependency (Bible and Bivins, 2019). Flyvbjerg (2007) stated that major projects are congenitally risky due to the long execution timelines and a complex interface between project participants during the different phases. A road infrastructure project lasts around 30 years, which does mean that a lot of different generations and cultures are involved (Spang, 2016).

2.2.3 Uncertainty of complex projects

As mentioned in the previous section, uncertainty does play an essential role in the field of project management such as in the field of road infrastructure. Therefore, uncertainty is explained to get a better understanding of this.

Due to the complexity of construction projects, a series of cost overruns can be encountered over the years. The reason for this is that complexity and uncertainty appear in road infrastructure projects (Afzal, 2019). It is said that road infrastructure projects face a lot of different problems, compared to other projects, such as uncertainties, predicaments, immense complexity and probable risks. Uncertainties are spoken about a lot, but what is the meaning of 'uncertainties'?

Maylor et al. (2013, p.47) defined uncertainty as: "Uncertainty is typically the result of novelty of technology or process, a lock of experience, a lock of availability of information, or some combination of these".

Uncertainties need to be managed within all projects. The way to manage uncertainty in a project is to achieve the project objectives with the help of the process of risk management. The Project Management Institute defines risk as "an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives" (PMI, 2017, p.397).

The idea behind risk management is that it does not only confront unexpected problems but also investigates the opportunities for improvement. Thus, it can be said that uncertainty can also have a positive effect. Thereby, risk does have a negative impact on project outcomes and opportunities do have a beneficial impact on project performance. To summarise it, the objective of risk management is to increase the probability of known risk and to decrease the probability of negative risks with the result that project success can be optimised. To identify and assess conflicting incentives and perceptions in the risk management process, it could be useful to involve different stakeholders into the process (Qazi, 2020; PMI BoK, 2017).

Brink (2016) investigated the way in which the management of uncertainty can enable the sustainability of complex projects. The mentioned research was conducted through focus group interviews with 11 companies, 20 interviews and a seminar with 60 participants. One of the findings of the research was that it needs to be considered that risk and uncertainty are not the same. The definition of uncertainty was: "do not know that you do not know" (Brink, 2016, p.316). And the description of risk is that something is known about the event and in the best case it is possible to calculate outcomes through the best and worst scenarios. It is mandatory to manage uncertainties through different paths in a project. One main task is in the field of project management. Important issues from a project need to be thought from the end of a project. And then it needs to be thought to the beginning. This means that resources need to

be used much earlier than noted. The other path is that every organisation needs the capacity to explore and exploit important issues (Brink, 2016).

Up to now in the literature review, an understanding has been generated in terms of the field of project management, complexity and uncertainty. As the research is in the field of road infrastructure, corresponding explanations have been roughly made in the specific topics. To obtain a better understanding about the specialities of road infrastructure projects and to understand why complexity and uncertainty are playing such an important role in these areas, a deeper literature review of the field of road infrastructure was conducted and will be explained in the next sub-chapter.

2.3 Road infrastructure projects

As the focus in this research is road infrastructure projects and it is well known that these projects are in the public eye, the content of the road infrastructure literature review provides a clear definition of road Infrastructure, why road infrastructure projects are that important and how these projects differ compared to other civil engineering projects.

In the context of road infrastructure projects, the performance and the success of a project are often discussed. Hence, the terms performance and success will be discussed in more detail in the following section, to provide a clear understanding of the challenges of a road infrastructure project and what is meant by the term successful.

At the end of the sub-chapter, examples of successful projects are listed as well as examples of well-known unsuccessful projects. As a result, it is concluded what can be learned from the so far conducted successful and unsuccessful projects. Based on this, the research will define the existing similarities between road infrastructure projects and BT regarding the potential role of the principles of BT in terms of maximising performance and success.

2.3.1 Definition of road infrastructure and road infrastructure project management

2.3.1.1 Definition of road infrastructure

Road Infrastructure consists of fixed assets including surface roads, railways, terminals such as bus stops, trucking terminals and railway stations (Chandra Das, 2016). A road infrastructure network includes more than just vehicles and roads. Aviation, bridges, ports, waterways, rail and transit are also part of the transportation infrastructure (Tonn et al., 2019).

A clearer definition, as it is found in other countries as well (e.g. Victorian Road Management, 2004), is listed in the below figure.

Road Traffic Facilities	Surface of the Road	Carriageway, Others (footpaths, cycle paths, parking spaces)
	Others	Drainage, earth body, substructure, planting, culverts, equipment, accessories
	Structures	bridges, traffic sign bridges, tunnel/trough structures, supporting structures, noise protection structures
Others	Service Area of the planning department	
	Building Constructions of the planning department	

Figure 2-4 : Road infrastructure accessories (Zander, 2015)

With the help of the above figure, it is highlighted that the road infrastructure is separated into a lot of different sections. Behind the term road infrastructure are more than just highways – bridges, tunnels and airports are also involved in the huge field of road infrastructure project management.

2.3.1.2 Definition of project management in road infrastructure projects

Spang (2016) outlines the following project management steps needed to complete a project in the road infrastructure sector. Road infrastructure project management is the planning, organisation, implementation, control and management of a self-contained unique process.

This process is geared to a clearly substantive goal; it is described by a clear task and limited by a defined cost framework as well as essential deadlines.

Figure 2-5 shows the main phases of road infrastructure project management. The whole process starts with Phase I, in which the project idea is generated, and first analysis of the project is made, and it is finished with a feasibility study. The core element of the whole procedure is Phase II, which includes the design and planning tasks. It depends on the project, but this phase can last for several years. The planning engineer, #RI-13, interviewed for this study mentioned that, in their existing project, it is estimated that the planning phase will last around 10 years. After Phase II is finished, Phase III starts, which is the part of the tenders and the orders. After this, Phase IV, the building phase, starts. When this phase is finished, the project itself can be used and it is handed over (Phase V).

Figure 2-5: Main phases of an infrastructure project (own representation based on Spang, 2016)

The road infrastructure projects which are focused on in this research are mainly in the fields of highways, roads and paths. In the current study, everything will be included that fits into that topic like bridges, tunnels, public-private partnership projects (ppp-projects), etc.

2.3.2 Megaprojects

When road infrastructure projects are discussed, they are often associated with mega-projects. Hence, in the next sub-chapter the term megaprojects will be explained in more detail.

In the literature, there is no accepted definition for the term megaproject. Gellert and Lynch (2003, p.16) stated that: "Mega-projects can be divided analytically into four types: 1. infrastructure (e.g., ports, railroads, urban water and sewer systems); 2. extraction (e.g. minerals, oil, and gas); 3. production (e.g. industrial tree plantations, export processing zones, and manufacturing parks); and 4. consumption (e.g. massive tourist installations, malls, theme parks, and real estate developments)".

Megaprojects are strategic-aligned projects which deliver key strategic assets in large projects (Eweje, 2012). A more detailed definition is given by Bruzelius et al. (2002), who define a mega project with the help of five parameters. These parameters must be fulfilled independently:

- Investment volume > 1 billion US dollars,

- Life time > 50 years,

- High degree of uncertainty regarding demand and cost forecasts,

- Characteristics of a club property where exclusion of use is possible – e.g. by charging tolls and where there is at least partial rivalry in consumption,

- Indirect benefits that cannot be internalised by the operator.

Road infrastructure projects are one type of mega project. These projects are of utmost importance for any state or national government. Road infrastructure projects help in improving the quality of our lives. (Aziz, Riaz and Arslan, 2017). And, as is mentioned above, the focus in this study is on road infrastructure projects.

The main challenges of megaprojects are the poor, unreliable and spurious information that is exchanged. Because of that, a detailed literature review will be conducted in the last sub-section of this literature review chapter.

The other challenge that is faced is the conflicts between the decision-making parties, the policy, the planning and the public (Flyvberg, 2007). Project managers working in megaprojects are used to adopting the traditional methods of project delivery. In this way of

working, everything is focused on time and costs; what is getting lost, is paying attention to how to get the best overall results (Asrilhant et al., 2007).

Because of the diversity of the objectives of megaprojects, a number of diverse stakeholders are involved. The theme here is that all the different stakeholders use different systems and represent other interests. This obviously leads to high socioeconomic, political interest and to high industrial and public attention (Turner et al., 2009). With these key parameters, the significance of the complexity in a road infrastructure project (mega projects) is highlighted again.

If one takes into account that the planning and construction of megaprojects will play an important role in the future, it must be realised that design and delivery are becoming increasingly important regarding the effective and efficient performance of a life cycle.

2.3.3 Stakeholder

Freeman (1994) investigated the meaning of the term stakeholder. Freeman and Maitchnik (2013) explained that a stakeholder is a person or group that has a legitimate interest in the course or outcome of a process or project.

Based on Freeman (1994), two questions need to be thought of in general:

1. What is the purpose of a particular company/project?
2. What responsibilities do managers have towards stakeholders?

What Freeman is focusing on is that the goal of a project should not only lie in the financial aspect; he mentioned that it is important that different groups of interests are involved. Freeman's general idea of the stakeholder is as follows:

The project is in the middle and the stakeholders are put around the project in a simple radial.

Figure 2-6: Freeman's understanding of stakeholder management (Freeman, 1994)

According to this model, there is no connection between the stakeholders. This refers to the idea that every group is acting in its silo. As Freeman mentioned, every stakeholder is working in its silo, so the idea in this study came up with was that the information exchange between the different stakeholders needs to be increased.

2.3.4   Road infrastructure projects

Since time immemorial people have used roads and paths to overcome spaces. With the invention of motorised vehicles and the development of the first modern traffic networks, the foundation of our current road network was laid. Due to the technological and cultural development, the demands on the infrastructure grew. Above all, the growing volume of traffic and transport of goods and the greater distances between home and work led to increasing traffic volumes. This was associated with progressive demand on the road infrastructure.

Regular investments in the road network are now necessary to meet the increased demands (Tonn et al., 2019).

A study in 2019 observed that now is the first time that majority of the population is living in cities and this trend continues to grow. Provision of transportation is concentrated into the cities and into the conjunction between cities. This means that a comprehensive infrastructure is needed to maintain appropriate living standards (Wojewnik-Filipkowska et al., 2019).

The quality of public transportation is crucial to life and society. Furthermore, transportation must be focused on a green, low-carbon, energy efficient and sustainable environment (Narayanaswami, 2017).

2.3.5 Characteristics and challenges

Why are road infrastructure projects so different from other projects and what are their specific features and challenges?

In building a road infrastructure project, there is a huge interference with the environment and with the living environment of humans, animals and society. When a road infrastructure project is planned, it is clear that there will be massive disturbances due to construction sites and logistics over a long period. Large projects also have high costs and, in a lot of projects, the funding is supported with the help of the taxpayers' money. Another relevant topic in terms of infrastructure projects is that it is hard to do a detailed planning in terms of the time schedule, because materials such as soil, rock and the weather are only partially predictable. Thus, it is unavoidable that changes will be made in the planning and the time schedule (Samset, 2014).

The field of road infrastructure projects is huge and can be split into a lot of different fields. One is to define road infrastructure projects as large Transport Infrastructure Projects (TIPs), which are associated with mega projects – see section 2.3.2 – in the transportation sector. The challenges that occur in these TIPs are mainly that they are delivered late, they are over budget and their benefit is less than expected. To overcome these challenges, the early engagement

of external and internal stakeholders is necessary and also the financial support of the government (Locatelli et al., 2017). Within road infrastructure projects, the expectation is high that they will deliver value to their stakeholders and users long after their completion (Martinsuo and Vuorinen, 2018).

The challenge of large infrastructure projects is that these projects are difficult to undertake and an abundant time for conception and development is required. What needs to be considered, is that a diversity of parameters needs to be managed. These parameters are time, planning, human resources, costs, risk prevention, change requirements and quality control. Metro development projects demonstrate how important transportation projects are, because they are spread out globally (Mohan, 2011). They are found in developed countries and in developing countries. Even for urban supply chain management, public transportation is an important component. Narayanaswami (2017) stated that a balance between planning and managing is necessary if the focus in a project is on project management, technology and quality.

It can be said that road infrastructure projects are different to non-infrastructure projects because other key stakeholders, as for example the public, are included as well and these projects do have a value to society. This includes the government, the general-public, pressure groups, media and the firm involved in delivering the infrastructure (Bryde, 2020).

Common problems that arise from stakeholders in large infrastructure projects are repair and restoring work, cost overruns, poor communication and failure of the supply chain (Barlow, 2000; Yang et al., 2011). Road infrastructure projects are in the public eye: communication, transparency and participation are becoming increasingly important (Spang, 2016). These are just some of the topics which appear in road infrastructure projects, but they do highlight how demanding and complex these projects are.

Another huge demanding topic, is the theme of trust. In the literature several aspects of trust are specified (Schoorman et al., 2007). According to scientist, trust is a one-dimensional entity, trust in business relationships is different, but practically inseparable (Zhang et al., 2011).

2.3.6 Complexity in road infrastructure projects

As complexity like structural complexity, socio-political complexity and emergent complexity are discussed in section 2.2.4, Figure 2-7 visualises the term complexity in terms of the different stakeholders. The below figure gives a holistic understanding of what the environment of a road infrastructure project looks like. In the middle of the figure, the project itself is visualised. Around the project, the different groups that are affecting the project are visualised. Firstly, a deep investigation of fauna and flora needs to be made. This is the first possibility that unforeseen issues can affect the project. All decisions, from the planning phase onwards, need to be discussed with the authorisation agency. During the whole lifetime of the project, there is a constant exchange with the building owner, the media, the society, the authorisation agencies and the politicians. The red arrows show that all the stakeholders do affect the project itself. And it is becoming visible that all stakeholders support different interests (Spang, 2016).
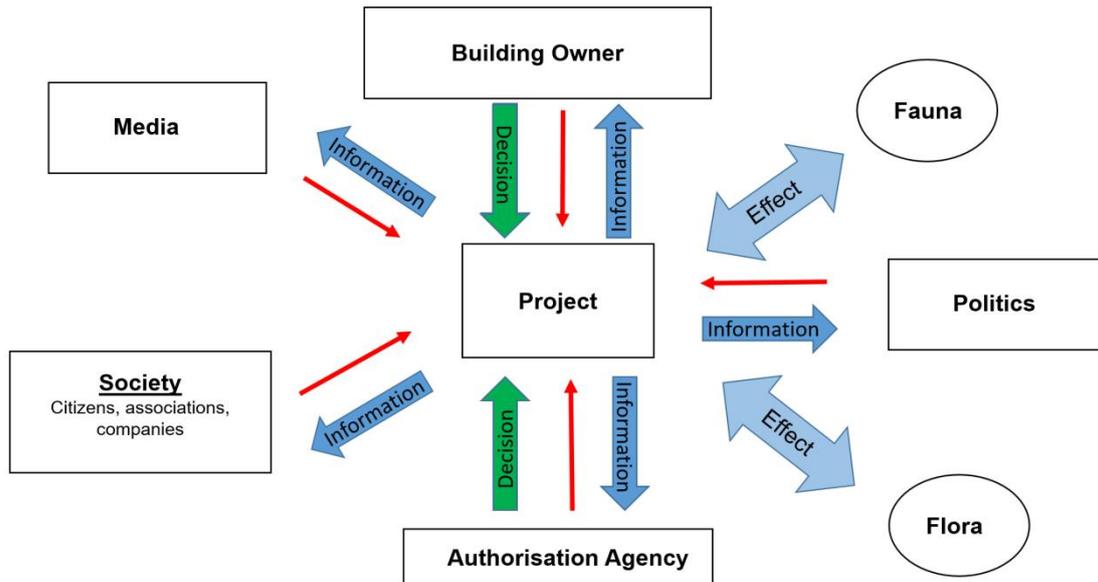
Figure 2-7: The environment of a road infrastructure project and who is affecting the project (Spang, 2016)

2.3.7   Performance and success of road infrastructure projects

Prior to undertaking an investigation into the meaning of performance and success, the general difference between the two needs to be understood. In principle, these two are known as CSFs (critical success factors) and KPIs (key performance indicators).

The CSFs are the factors that need to be delivered to achieve success in a project. These are the factors that cause the success. Differently, however, are the KPIs: these are the indicators that measure if a project is successful or not. The KPIs are the indicators that affect the actions in a project (Marr, 2011).

Both are combined, because without having a positive action in a project, the project cannot be delivered successfully, and without using the CSF, a project cannot deliver successfully either (Ionescu, 2015).

2.3.7.1 Performance

The golden triangle has already been mentioned several times in the current study. According to Jha and Iyer (2007), the performance of a project is normally measured with the three criteria of cost, time and quality. Measuring cost and time is different than measuring the quality of a project. The performance of quality is usually measured by technical standards or by agreements that were made in the contracts (Tabish and Jha, 2012). In contrast, the time and the budget are measured against the deviation from the time schedule or the budget planning that was made at the beginning of the project. In this context, the topic in terms of the complexity, regarding the different stakeholders in a road infrastructure project, arises again. As different stakeholders often have different interests in a road infrastructure project, this leads to that the fact that the different stakeholders sometimes also have different performance criteria as well (Winch, 2010). This circumstance has the consequence that the limitation of project performance to the parameters of cost, budget and quality is inappropriate. Therefore, a supplementary parameter for the measurement of project performance should be included. According to Lehtiranta et al. (2012), this additional parameter should be the satisfaction of the client.

2.3.7.2 Success of road infrastructure projects

Before we start talking about the success in road infrastructure projects, we need to distinguish between the success of projects and the success of project management. As Pinot and Slevin (1988) mentioned, there is no agreed knowledge when project management is discussed together with project success. The authors stated that "articles, cases, and other studies of 'successful' project management will remain of lesser impact simply because of our inability to fully define a concept which can mean so much to so many different people" (Pinot and Slevon, 1988, p.1). The current literature review found no opposing argument. This is different to the

definition of project success. The criterion of project success is explained by three components: cost, time and quality.

With all the information gathered so far, it is worth thinking about the performance of road infrastructure projects. Discussing performance is not simple. The understanding behind the meaning of performance is success and efficiency. But to describe the meaning of success again, Cooke-Davies (2002) mentioned that this needs to be separated into three different explanations. First, the factors that help in achieving successful project management need to be elaborated on. Second, the factors for a successful project need to be analysed. Third, the factors for a constantly successful project need to be identified. In the context of this, the understanding of project success is that a project achieves its general goals. And, if a project is finished in time, in cost and to the required quality or performance, this is said to be project management success. De Wit (1988) also differentiates between success criteria and success factors. The success criteria are the ones which are used when the success or failure of a project is judged. And the success factors are the ones which are used in judging the success of a project. In this context, the needs of the different project stakeholders need to be considered, who are the ones who established the project, and what the benefits of the project are need to be analysed and what it is expected to achieve (Cooke-Davies, 2002). Based on this, it was found that the benefits of a project are not delivered through a single manager or a team; they depend on the whole operation's management. This leads to the conclusion that it is more difficult to deliver a successful project, because it involves goals and the different methods.

Eray (2017) mentioned that a variety of factors are involved to deliver a project successfully. On the one hand, highly effective coordination and communication among project stakeholders is needed. And, on the other hand, delivering a project successfully also relies on real-time tracking, measurement of the project, progress and performance, risk detection and minimising but rapidly adapting to imperative change. The authors of a Chinese paper (Turner and Zolin,

2007) identified four dimensions of project success. The first dimension is if an output is produced that makes it valuable in a special time and with appropriate costs. Secondly, if a desired outcome is achieved on time and with appropriate costs. Thirdly, if a positive net present value is delivered, and lastly if a business or public need is delivered at time and cost. These four dimensions are all related to time and cost. As a basis for this study, a study by Turner and Zolin from 2007 was used. In this paper, they identified the following three dimensions of a successful project, efficiency, customer and the business. Whether or not a project is efficient can only be concluded at the end of the project. In order to be efficient, the project needs to be completed in time, in cost, with high functionality and performance. After the project is completed, the customer evaluates if it is successful with parameters such as requirements, specification, benefit, use, availability, reliability, maintainability and satisfaction. Turner and Zolin (2007) stated that the second level of success is achieved in the following years, after a project is completed. Hence, the parameter business is mentioned, which is measured in sales, profits, market share, return on investment, cash, cycle time, organisation and approval. What was also found in the study by Turner (2018) is that sometimes success cannot be measured from a financial perspective.

In the current study, the goal is to focus on the delivery of project success and the delivery of successful project management.

Using success as an indicator for a road infrastructure project is very complex. Success can be interpreted differently by different individuals and different stakeholders. Depending on the individuals' preferences, the understanding of success is different. An example of this is that the understanding of success for a project manager is that the project is in time and in budget. In contrast, the investor, for instance, is more concerned about the long-term economic viability (Samset, 2014). This alone demonstrates the difficulty when several stakeholders are involved in a project.

It is also stated that road infrastructure projects impact people's quality of life. The infrastructure of a country is a value, with which the economic growth of a nation and its international competitiveness can be measured (Maghsoudi et al., 2016). It is important to highlight that a project is not only successful because of the goals that have to be achieved during it. More important is to achieve the benefits and values the TIPs should deliver (Ahola et al., 2008; Sehnar, 2001). A study in Australia found why in major road infrastructure projects innovation is so rarely used for the basis of the objectives in these projects. It is known that it is a challenge and very complex to implement and manage innovation itself. But, because of the risk-averse culture, benefits and great opportunities are being lost. The reason for that is that in road infrastructure projects innovation is not used like it is used in other projects. However, there needs to be consideration of how innovation can appear in road infrastructure projects and how it can be captured and produced (Maghsoudi et al., 2016). This study reflects the challenges in terms of new technologies, which is the reason why research in the field of industry 4.0, in this study in BT, is conducted.

2.3.8 Examples of existing projects (successful and unsuccessful projects)

Road infrastructure projects are well known and affect the whole society. As has been examined so far during the literature review, road infrastructure projects have been discussed in the context of successful and unsuccessful projects. In the following section, examples of successful and unsuccessful projects will be given. In the present study, the understanding of successful projects is based on the traditional iron triangle shown in Figure 2-8. The iron triangle identifies three components that are related to a successful project. These components are cost, time and quality (Barnes, 1988).
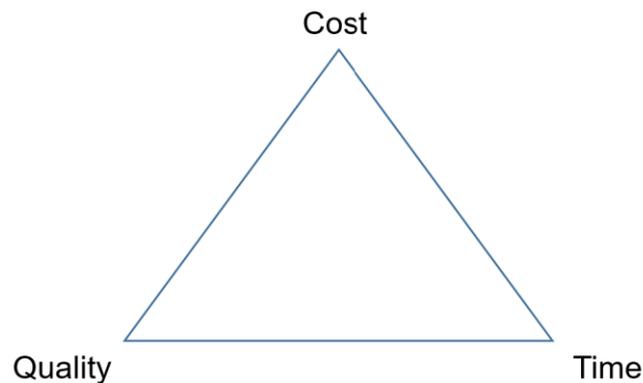
Figure 2-8: The iron triangle (Atkinson, 1999, p. 338)

Many road infrastructure projects are successful. Thus, it needs to be identified what can be learned from them. A successful and well-known road infrastructure project is the Gotthard Base Tunnel in Switzerland. This project was completed in budget and in time. The Gotthard Base Tunnel is the longest railway tunnel in the world. It takes 40 minutes to travel through it in the Alps and it is a great success for travel and transport between the south and north of Europe. One of the reasons that this project was successful was that all stakeholders were included in the organisation of the project. The advantage of this was that it was possible to simplify contacts and links, because of control a better management, transparency was feasible and, with the help of a lean organisation, the project had better governance and efficiency (Fabbri, 2019).

The Gotthard Tunnel is 57 km long, the largest construction project in project management history in Switzerland. In total it took 17 years to build and was finished on the 1st of June 2017. This project is a showcase for excellent project management and highlights the importance of road infrastructure projects. Such a tunnel brings people and economies together (Bluepm; Accessed, August 10th, 2020). What makes this tunnel so special and popular is that this

mammoth project was built in time, in cost and with high quality (Spiegel, Accessed, August 10th, 2020).

Another well-known road infrastructure project is the Morandi Bridge in Genoa. Although the reason for rebuilding this bridge is a story with a really sad background, it is a good example of how to deal with a road infrastructure project and what needs to be optimised. And the new bridge is a good example of a successful road infrastructure project. On 14th August 2018, the old bridge construction collapsed. To this day, the reason for the collapse has not really been clarified. Apparently, it was known that the bridge was ramshackle but the necessary treatments were not implemented.

The reconstruction of the new bridge started in 2019 and was finished one year later. Normally, it would take three years to build such a bridge, but all the stakeholders involved in this project had only one goal. The reason for reconstructing this bridge as soon as possible was because the bridge is an important arterial highway for the seaport of Genoa. It is also one of the most important conjunctions from the northern to the southern part of France, Tuscany, Piedmont and Lombardy (Zeit, Accessed April 20th, 2021).

The reasons for the success of both of these projects are well-managed quality management, huge transparency in every construction phase and strict public controls (Tagesschau, Accessed April 20th, 2021)

As well as the successful road infrastructure projects, there are also a number of unsuccessful projects. The inefficient projects are especially found in the large and complex projects in the field of road infrastructure. The inefficiency is due to the large numbers of stakeholders included in such a mega project. When large numbers of stakeholders are included, various interests appear. The larger the project, the more difficult the authorisation procedure (Bryde, 2020).

An up-to-date and well-known mega project is the new airport in Berlin (BER) in Germany. It took 30 years to get it finished and it cost three times more than expected. At the beginning of 2007, a Danish man, Bent Flyvbjerg, published a major essay with the title: "Policy and planning of large infrastructure projects: Problems, identification of a cause, solutions". This essay was published in the same time as the master builder of Berlin and Brandenburg started to get bogged down. In the essay, Flyvbjerg stated that the explosion of costs, incorrect forecasts and botch-ups of all kinds are worldwide phenomena, which are found in a lot of road infrastructure projects. He also mentioned the insufficient transparency between the different stakeholders in such mega projects, for example between the project managers and the politicians. What he proposed in the essay was that all the different stakeholders need to be involved in the whole planning, of a project, from the first step on (Flyvbjerg, 2007).

2.3.9 Learnings from the literature review of road infrastructure project management

Within the literature review of successful road infrastructure projects, the Gotthard Tunnel and the Morandi Bridge were mentioned. Both projects were successful in terms of timing, budget and quality. The mentioned reasons for why they worked were because of the transparent processes, all the stakeholders had the same goal, the stakeholders trusted each other and they had a good working information exchange. On the one hand, the information exchange and proper communication were mentioned several times, so this supports the researcher's investigation of a proper literature review in terms of the information exchange. This needs to be done to get an understanding what an information exchange system is and why it can support the current study. It was mentioned so far that different stakeholders are involved in these large projects and normally they do not work in a transparent way, because of the missing trust. As the BT can be used if groups do not trust each other a literature review will be conducted in this field as well.

During the literature review of road infrastructure projects, the characteristics and challenges of these projects were named. In correlation with these characteristics, the literature review of BT and information exchange will be described in more detail. The idea came up that a thorough information management is needed in projects which involve so many different stakeholders. How the information exchange is working in these projects needs to be investigated. Prior to conducting the literature review of information exchange, the literature review of BT will be presented. As it has been stated that the BT is a decentralised system and many different stakeholders can be involved, it needs to be proven in the next sections if it does make sense to use this technology in this research.

2.4 Blockchain technology

BT was initially introduced in 2008 by Satoshi Nakamoto. In the last years in a lot of businesses areas the technology has become the focus. The reason why it has become the focus is because of the role in the transformation of operational processes (Hamed, 2022). When BT is discussed, it is important to know that this technology initially was created to support the currency bitcoin (Nakamoto, 2008).

The technology was created in 2008 and, based on the number of searches for 'Blockchain Technology', in Google Trends, since then the technology has become more and more popular, with a peak in the year 2017.
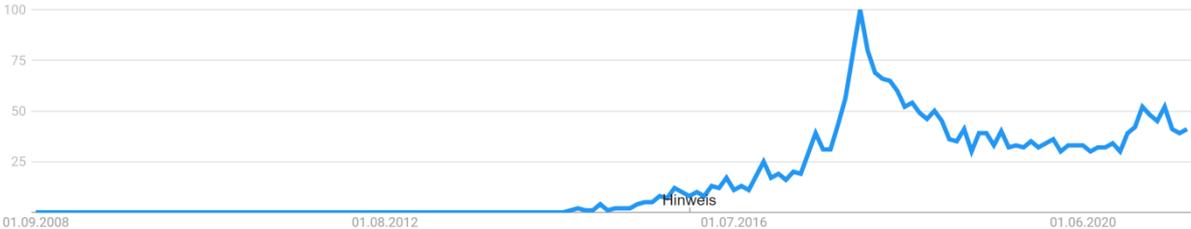
Figure 2-9: Number of searches for 'Blockchain Technology' worldwide, according to Google Trends, 2020

The system of BT is working as followed. The structure of every block in a BT is made of transactions. All transactions that are made are recorded through distributed databases and contributing nodes. The nodes in a BT are known as miners. As these systems bring security to transactions it is used when different parties do not trust each other (Loukil et al., 2021).

BT is probably a technology that can lower the costs of institutional entrepreneurship along industrial dynamics, technological change and innovation. It is uncontroversial in the experimental phase of development regarding technological, economic and political uncertainties, but it is certainly the core component of the future generation of the internet. BT is an internet-based decentralised economy. It provides a digital platform for digital assets, digital currencies, digital identity and smart contracts. Different to other platforms or systems, which are governed centrally, BT is managed, distributed or decentralised through a tremendous number of token holders, block validators or developers. Since 2008, there has been a lot of development around that technology (Allen et al., 2020).

In recent years, BT has become more and more important and well known. The author who introduced the crypto currency bitcoin in a whitepaper, called "Bitcoin: A Peer-to-Peer Electronic Cash System", in 2008 is called Satoshi Nakamoto. So far, it is not known if Satoshi Nakamoto is a person or a group of different people. Nakamoto developed a special payment system, with which the token can be transferred directly between two parties, without using an intermediary. The famous application of BT is the digital cryptocurrency bitcoin. Nakamoto's aim was to develop a technology to close the gap of trust. (Laurence, 2017). But what is behind that technology, becoming more and more popular, is called BT. It is called BT because this technology is a distributed transaction ledger with a decentralised database in which different computers – the different computers are also known as nodes – cooperate as a system (Lemieux, 2016). So far, 80% of the total blockchain asset market capitalisation is comprised of bitcoin (Yeoh, 2017). According to the World Economic Forum, by 2025, 10% of the world´s GDP may be on BT (Zalan, 2018). The idea of the current research is, because of this important

technology for the future and the issues that are faced in the field of road infrastructure projects, to see if there is a way to combine it with the information exchange and the road infrastructure projects.

BT can be used to address issues associated with information integrity in the present and near term, assuming proper security architecture and infrastructure management controls (Lemieux, 2016). This analysis from the year 2017 is also a reason why the idea is to develop a framework for the utilisation in managing road infrastructure projects with the help of the principles of BT.

Studies have shown that BT is at the heart of the latest attempt to improve transparency, efficiency and security across a wide range of value transactions. It has been found that BT is having its first disruptive effects in different industries (Frizzo-Barker et al., 2019).

BT is worthwhile if you want to share information with parties you do not fully trust, if your data needs to be verified or if there is a risk of your data being manipulated internally or externally. None of these issues are easy to solve and it can get very complicated to find the right solutions (Laurence, 2017).

What was happening within institutions and companies, and still keeps going on, is that people do not trust each other or have lost the trust to their institutions (Lemieux, 2016). This was also one of the reasons why the BT was developed, to create digital trust within people working together and in institutions. The advantage of this technology is that, with its help, an agreement is achieved which can be used between parties who do not trust each other. "Together, we are entering the trust age" (Mazzella et al., 2016, p. 31). The BT system allocates an interface, a technical infrastructure, a process guidance and a service such as insurance for establishing trust between the different parties (Katz, 2015). It also provides transparency of the processes without giving the information about who/what is behind the receiver. This works with the help of a code. For somebody who is using Airbnb, one of the most important issues is that the participants trust each other and behave in a thoughtful and respectful manner. On the other hand, it is important that, in terms of the booking and payment,

these processes need to run smoothly. For the user themselves, who is behind the transaction this is not the most important thing; the most important thing is that the transaction and process itself is transparent (Hawlitschek et al., 2016a). And this procedure can be supported by BT, as it is possible to use different kinds of BT. These will be explained later on in the thesis.

The blockchain database works because of a clever mathematical algorithm. Another advantage of this technology is that it can be used through large networks on many different computers located in places all over the world by many people (Shrier, 2020).

The terms bitcoin and blockchain are often used interchangeably, but they do not mean the same thing. Bitcoin has a blockchain. The Bitcoin Blockchain is the protocol that enables the secure transfer of bitcoins. The term bitcoin is the name of the cryptocurrency on which the bitcoin network is based. The blockchain itself is software; bitcoin is a specific cryptocurrency (Laurence, 2017).

This is the same as a road and a car, which are not the same but are mentioned in a similar context. A car needs a road to move effectively from A to B. But a road can also be used for buses or bicycles, for example.

2.4.1   The bitcoin blockchain – an illustrative example

Terms which are used when discussing the BT are distributed ledger, blocks and mining. To provide a better understanding of the BT system, it is described in the following with the help of a Bitcoin Blockchain.

DISTRIBUTED LEDGER

The common centralised systems we are used to working with are vulnerable to hacking or other breaches. It is sufficient to have access to only one system and a lot of accounts, processes or records can be changed. And there is no copy of it which can prove that a process was changed. In the present time, this is becoming a major issue, when something is managed

centrally by a government and when in the worst case you do not trust the government. The advantage of a distributed ledger is that there is a record or a ledger available that has many identical copies. The system of a distributed ledger ensures that the copies can talk to each other, automatically update themselves and that, if one record is hacked or changed deliberately, the other copies will fix the problem and show what really was changed. This gives the advantage of providing transparency of a whole system, from the beginning on, and can make processes traceable and immutable (Shrier, 2020; Laurence, 2017; Zamani, 2018). A distributed system is a system which is spread across different severs, saving the copies and spreading them out again across different servers (Gordon, 2018).

BLOCKS

In the context of BT, immutability is mentioned. Blockchain does help in terms of trust and immutability. But how can this be guaranteed? The understanding of a process that can be trusted is a system in which every transaction can be seen and a ledger can be altered. To create such a system, a mathematical solution was developed. With the help of Merkle trees it is possible to create an immutable history of transactions. An example of a Merkle tree can be seen in the figure below. The system of a Merkle tree works like this: one block in such a tree is set at a number of calculations. The output of the first block is used for creating the calculation for the second block. For the calculation of the next block, the output of the second block is used, and so on. As a result, it can be said that it is not possible to change something in the second block without affecting the output of the first and second blocks. The figure demonstrates how this system works. What makes a blockchain so special, is that every block is encoded with the help of hash-functions. This gives another level of security that a process cannot be hacked or breached (Shrier, 2020); (Laurence, 2017); (Zamani, 2018).
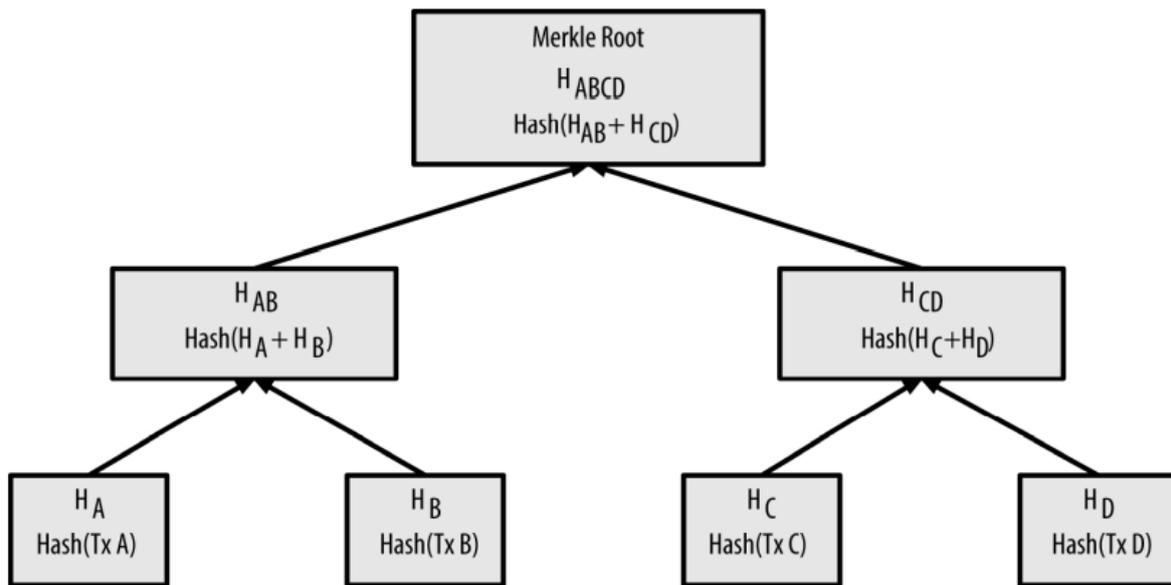
Figure 2-10: Merkle tree of a blockchain (Shrier, 2020)

MINING

Mining in a blockchain can be compared with a mystery. There are different ways of earning a bitcoin. In the process of bitcoin mining, you earn bitcoins as you are getting part of the network. For this, there are special mining software packages around (Laurence, 2017); (Easley, O'Hara and Basu, 2019). A lot of different miners are behind creating a code for one block. Whoever creates the code first, gains an incentive. In the Bitcoin Blockchain, the prize a miner gets is a bitcoin.

CHAIN

A hash key links the blocks, mathematically concatenating them. This is one of the most sophisticated blockchain concepts and not very easy to understand. But it is precisely this seemingly magical mechanism that binds blockchains tightly together and enables mathematically-based trust. The hash key in blockchains is generated from the data of the previous block in each case. It is a fingerprint of this data that immutably fixes its rhine sequence and time (Laurence, 2017);

2.4.2 Principles of blockchain technology

First of all, the term BT has to be understood. "*A Blockchain is a decentralized transaction and data management technology developed first for Blockchain cryptocurrency*" (Yli-Huumo, 2016 p.16)

As in the study, the focus is on the principles of BT; they will be summarised in this sub-section, based on the knowledge the research obtained through the reading. BT is a technology based on a decentralised procedure. This leads to the conclusion that the principles of the technology are that transparency can be generated during a process or a project. With the help of the technology, it is possible that the process itself can be transparent, but the group/stakeholder behind that process can be made non-transparent. Because of the transparent parameter, processes in a project are traceable and immutable. This means that, if a term needs to be changed, it needs to be understood why it was necessary to change it. A good way of using the principles of BT is when discussing projects in which a lot of different stakeholders and groups are involved. The system of a BT is working as the following. A blockchain is parted into a lot of different blocks, whenever a new set of transactions is generated a new block in the structure of a blockchain is made. All these blocks are performed by nodes and these are known as miners. Based on this system, transactions can be used in a distributed way that is not related to a central party. The quality of the decentralisation of the BT brings the feature of trust, traceability, transparency and immutability (Hames, 2022).

Distributed Ledger Technologies (DLTs) as Blockchain Technologies promise to create an information system that is transparent and does make processes immutable.

2.4.2.1 Explanation of the principles of the blockchain technology based on an example

To get a better understanding of the BT and to be able to bring the BT into the context to industry 4.0, as an introduction, the different industries will be explained and, based on this, the origin of BT was generated. The path of the industries is visualised in Figure 2-11.
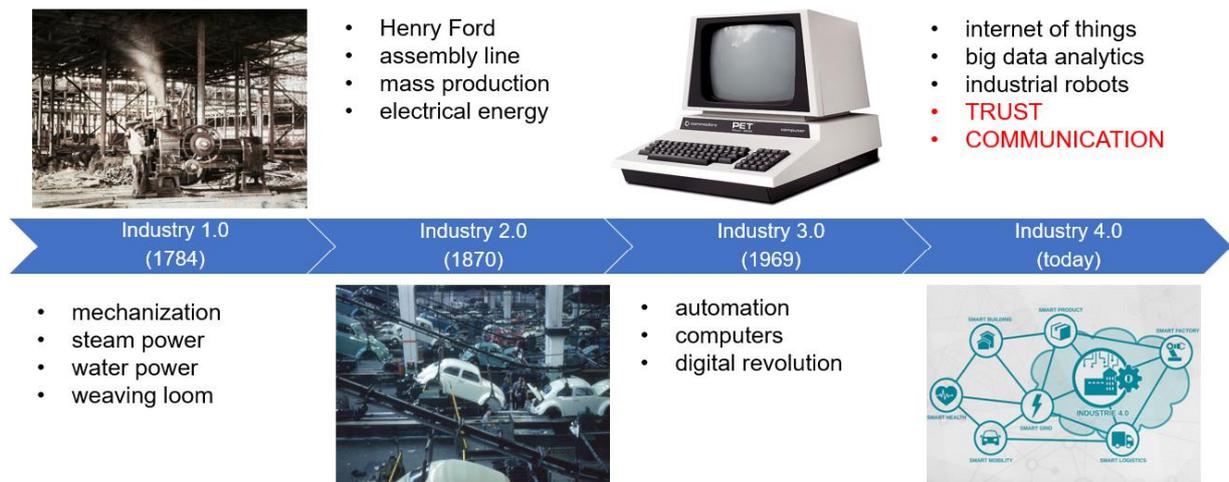
Figure 2-11: The path of industry 1.0 to industry 4.0 (own representation)

Whenever the topic of digitisation arises for the first time, sometimes it is not clear what the meaning of this big term "digitisation" exactly is. To define the scope of this, normally the term is related to industry 4.0. The term industry 4.0 is explicitly based on digital innovations (Kleemann, 2020). Bauernhansel (2014) noted that industry 4.0 can be traced back to the revolutionary phase of development. Each of these eras changed the industry in terms of an increase in productivity.

Industrialisation started in the year 1784 with the creation of, for example, steam power and water power. With the help of these, production, with regard to mechanisation was possible. In industry 2.0 (1870), electrical energy was used and Henry Ford implemented the assembly line; mass production was launched. The digital revolution started with industry 3.0 in 1969 with automation and optimisation of production processes. The first computers and the use of

electronic and information technology were a great development for this industry. After this, industry 4.0 was achieved. Topics in this industry are the internet of things, big data analysis and industrial robots. This industry is also known in terms of autonomisation and intelligent predictive optimisation of entire production systems (Kleemann, 2020). One of the technologies in this digital age is the decentralised BT.

Figure 2.13 shows in which state BT stood in the year 2018 in the Hype Cycle for Emerging Technologies. The year 2018 was chosen as this was start of the present study.

The Hype Cycle is one of the most well-known tools for assessing the potentially transformative technologies across different industries. Traditionally, it has been assessed by measuring strategic planning, innovation and emerging technology that will have a huge impact across different businesses. As Panetta (2018) mentioned, Gantner assumes that every newly developed technology succeeds through a pattern of maturity and adoption. As can be seen in Figure 2.13, every technology follows a special way through different ups and downs. In principle, the hype cycle is grouped into five categories: the innovation trigger, the peak of inflated expectations, trough of disillusionment, slope of enlightenment and the plateau of productivity. Another description for this is: on the rise, at the peak, sliding into the through, climbing the slope and entering the plateau.

Simon Sinek (2015) explained that this curve can be compared with the diffusion theory. The first 2.5% of our population are our innovators, they are in the category "innovation trigger". In the category "peak of inflated expectation" are the next 13%, the early adopters. The next 34% are the early majority, 34% are the late majority. What the curve is saying, is that if a technology is to become successful it needs to turn over the tipping point of 15% to 18% market penetration. When this explanation is compared to the below figure, it can be seen that BT is almost one step before the tipping point. That was also one of the reasons why this technology has been chosen in the research. To obtain a better understanding of the technology, its principles of are explained in the following.
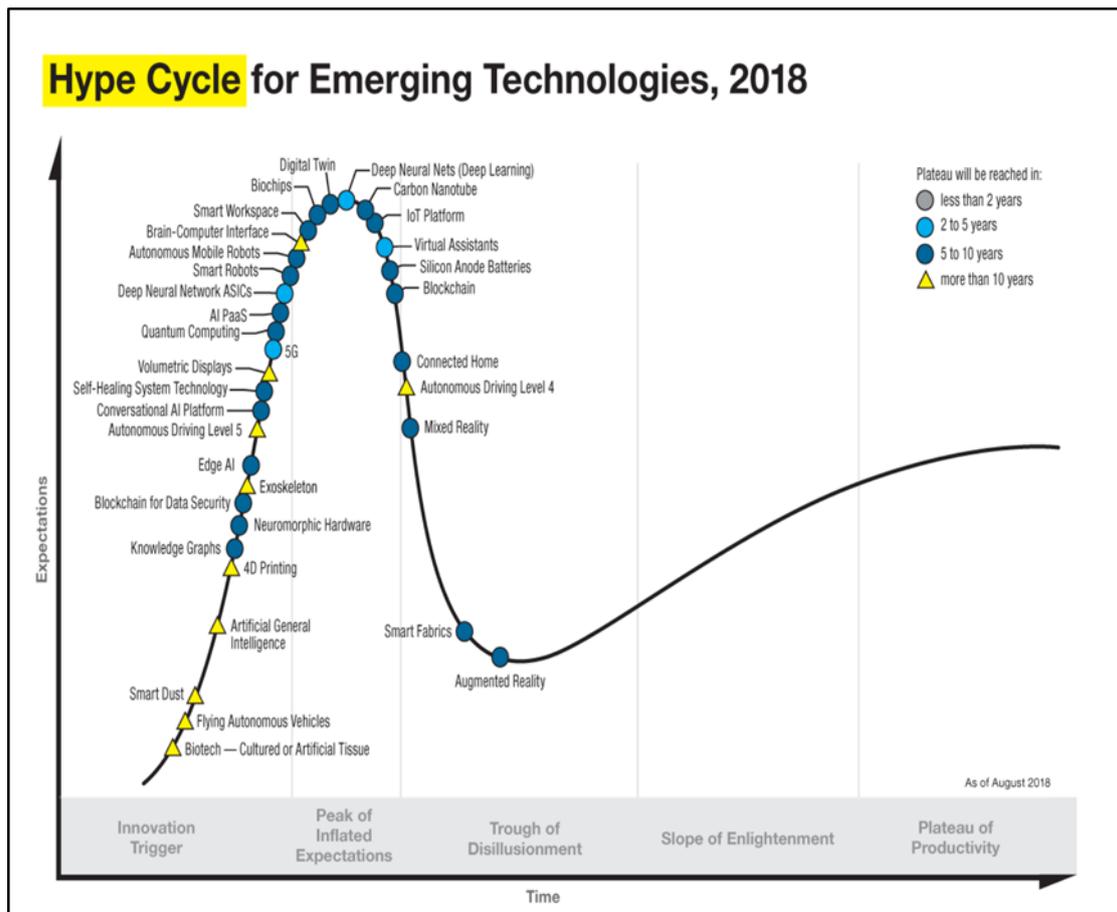
Source: gartner.com/smartwithgartner

Figure 2-12: Hype cycle for emerging technologies, 2018

To explain the principles of BT, the idea of Satoshi Nakamoto (2009) was picked up. The question Nakamoto is asking with the idea of BT is: "How can digital transactions be carried out efficiently and securely in complex networks"?

Figure 2-13: Centralised system – bank (financial institution)

An explanation that supports the idea of the central system is the banking system (financial institutions); see Figure 2-13: Centralised system – bank (financial institution). Basically, the system works like this: the money is stored at the bank and if A wants to transfer money to B, A gives the order to the bank. After the bank receives the order, it makes the cash transfer to B. Because this is a service provided by the bank, A is dependent on the bank and A needs to trust the bank, that the bank will make the transfer. Normally, a fee has to be paid for the transfer. In case the system of the bank is hacked, the money is not stored safely in a central system.

The system of a decentralised system, as for example a BT, works differently; this will be explained with the help of Figure 2.15.

Basically, three requirements need to be fulfilled so that a Blockchain can work:

1. An *open ledger* is available.
2. A *decentralised system* exists.
3. As an incentive, mining is used.

For example in Figure 2-14 four participants are involved in that blockchain. What the blockchain is known for is that all the information and processes are transparent for everybody involved in the blockchain. It needs to be highlighted that only the processes and the nodes are transparent; it is not known who is behind A, B, C or D; this information is anonymised. In the existing case, A, B and C all have a specific amount of money available. This information is stored in the ledger in the middle of the figure. This is the so-called *open ledger*. The difference to a centralised system is that this ledger is not stored centrally; whenever new information is added into the ledger, a lot of duplicates are made of this ledger and all the duplicates are encrypted with a special code that nobody knows. The duplicates are stored on several servers and are linked to each other; this means that it is not possible to hack one. This is known as a *decentralised* system.

For example, all the participants know that A has €10 and B has €5. It is also visible to all that A is transferring €4 to B. Just in case B says that A has not transferred the money, the system is visible so all the participants can see that B is wrong.

As in the system of the Bitcoin Blockchain, no central system or tool is available that is managing the system, so-called crypto miners are around, that are managing the system in a Bitcoin Blockchain. These *miners* do record, verify and book all transactions into that open ledger. As an incentive, they receive bitcoins.
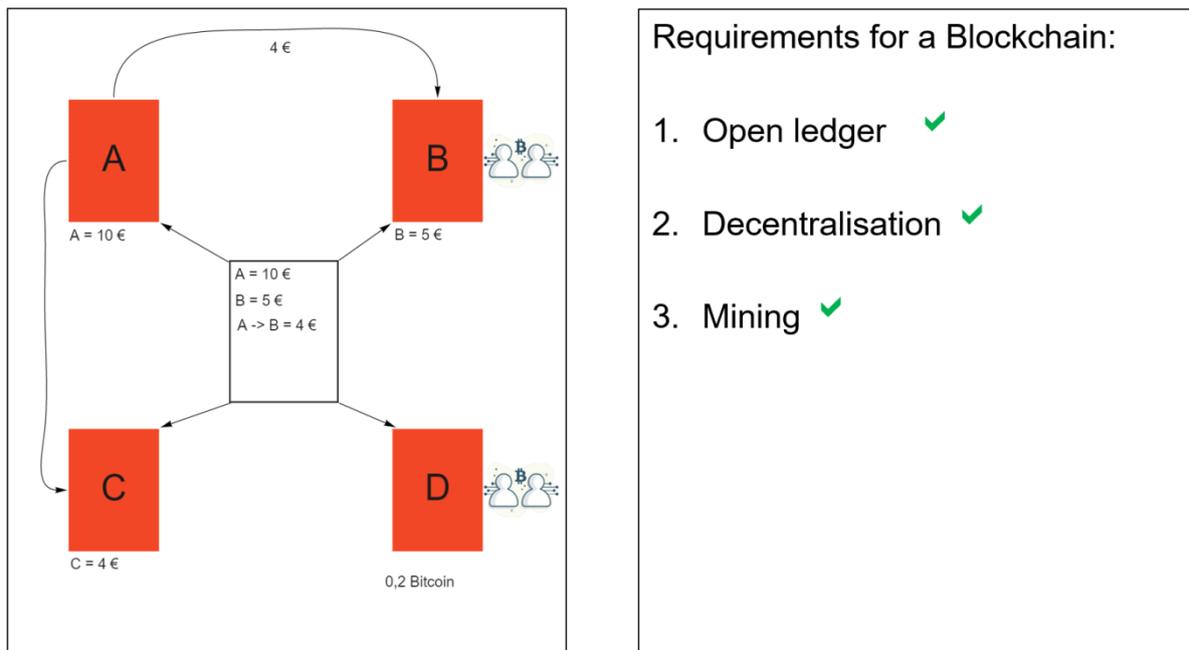
Figure 2-14: Decentralised system – Blockchain Technology

Figure 2.16 shows the themes of a complex network. And when it is talked about the BT, it is talked about a complex network. All potential participants do want, that their data and values are stored safely. This means, that it needs to be ensured, that these data cannot be hacked. The participants also expect that the transfer of information for example, will happen without high costs and time expenditure. And as it is expected, they are not be hacked, it is also expected that they are not manipulated by the participants. So it can be summarised, that the

receiver and the sender do want the same circumstances from different perspectives. The receiver wants to be sure that the sender also owns the good to be transmitted and the receiver wants to be able to prove with certainty that he also transferred it.
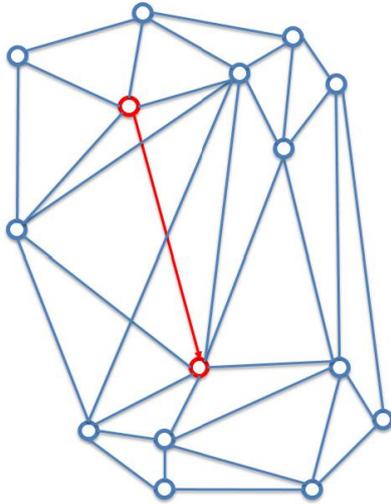
All participants in a complex network want:
- To store values safely
- To transfer values without high costs and time expenditure
- No manipulation of the transaction

Receiver wants:
- To be sure that the sender also owns the good to be transmitted

Sender wants:
- To be able to prove with certainty that he also transferred it

Figure 2-15: Complex networks

The principles that a BT provides, because of the distributed ledger or the decentralised system are the following:

- ➢ Transparency is given,

- ➢ Related to the transparency, process for example can be made traceable, so it can be talked about traceability,

- ➢ This traceability leads to an immutability of information, documents and processes,

- ➢ These three themes lead to the fact, that with the help of the principles of BT systems offer trust.

2.4.3   Advantages of blockchain technology

One of the big advantages of BT is the transparency which is given through it. This transparency leads to immutability, but what does this mean? What is written in the chapter in

the introduction to BT, is that one of the reasons why it was developed is because of the lost trust, people and institutions are facing. Another big advantage of BT is that it can help understanding where something comes from. This means that the provenance is known Talking about trust again: trust can be built in a way in which processes are visible and that a process or transaction cannot be changed. This is the main reason why BT was developed in the field of finance. People who are working in this sector do know that, with using this technology, although different flows of funds are needed, it can be trusted. The issue with trust is known in lots of different areas in our society. This is also an upcoming problem in the field of information sharing, for example through the internet. Thus, BT can help in decreasing the distrust of people (Gordon, 2018). Another interesting possibility for a blockchain is as an absolutely infallible data storage. A blockchain can create an unambiguous timeline that records who did what and when. Many industries and regulators have spent countless hours evaluating this problem. Blockchain-based records remove some of the difficulties in interpreting past events (Laurence, 2017).

2.4.4 Disadvantages and challenges of blockchain technology

As already mentioned, BT is a very complex technology which also has some disadvantages and is not useful in every part of the industry.

If the idea emerges to use a blockchain, the tremendous electric power consumption needs to be considered. In order to make this visible, it is worth comparing a bitcoin transaction with a VISA transaction. A bitcoin transaction takes 819 kWh whilst a VISA transaction takes 0.0082 kWh. This means that, in terms of the electric power, a bitcoin transaction takes 100.000 times more electronic power than a VISA transaction. A bitcoin transfer costs €200.00 for average German electricity consumption. It also can be said that for one bitcoin transaction you can use a refrigerator in Germany for eight months (Bund-rvso, accessed May 18th, 2020).

The other issue with this technology is that there have been few experiences with it and it is very complex to implement. There are a few pilot projects around, but companies are still afraid of implementing this new technology (van Hoek, 2019); (Leon, 2017).

Even though BT offers many advantages, it needs to be mentioned that there are still some challenges to overcome. The first challenge is the selection of time-resilient cryptographic hash-functions. The cryptographic hash-functions are essential to implement a distributed ledger system, which has the correct and secure design and implementation. The last one is the adequate selection and implementation of efficient, robust and trustworthy leader election algorithms (Leon, 2017). Lean (2017) also supports the fact that we need more research in the field of BT. Leon describes the first misconceptions which are possible in BT so is it true that BT is safe, secure and trustworthy? The finding of this paper shows, as well, that more research on BT will be needed to ensure that this technology is secure and that the developed systems are trustworthy, before its use becomes widespread.

2.4.5 Applications of blockchain technology

Due to the main properties of BT as traceability, transparency, immutability, smart contracts and security the technology is used in manifold areas including government elections and logistics (Pu, 2020). The innovation of BT is occurring in a lot of different industrial sectors, starting with the finance sector, including agriculture, healthcare, creative industries and government services (Allen et al., 2020).

As already mentioned, 80% of the successful implementations of BT have been in the finance sector (Yeoh, 2017). During the past few years, BT has also started to be implemented in different sectors. The first study of BT, next to the finance sector, was made in the food industry, which was released in the British Food Journal in 2018 (Sander, 2018). The purpose of this paper was to generate a holistic picture of various perspectives of the traceability and transparency of systems in the food supply chain. The issues in the food industry are that the

customers are overwhelmed by the current certification systems, and that labels are hard to understand and distinguish in terms of their relevance and credibility. Because of that, the BT could be a good solution to provide an overview (Wang et al., 2019).

The European Commission is also looking at BT. It is looking seriously at the potential of BT and the distributed ledger technology (Miseviciute, 2018). The issue at the moment is that too many people think that it is too early to implement this technology. Regarding this, it is important to have a lot of studies in a lot of different fields, to convince not just the EU to work with the BT (Leon, 2017).

There are several fields in which BT has been used so far. One big field is the sector of energy and food. The reason why it is used here is because, with the help of BT, the client is able to understand where something came from. In terms of the food sector, this can be useful in food safety and in improving the economies of the farmers. Looking to the energy sector, it can be seen that the production and the delivery of energy can be improved. The result of this is that the financial market in this sector is becoming more effective. In the health sector, the first experiments are starting regarding lower costs and improved care with the help of BT (Dave et al., 2019). Research is also being conducted regarding to what extent the technology is helping in clinical research and if there is a possibility to speed up the time to market for life-saving drugs. In the real estate sector, the technology is already successfully in use. It is traceable in terms of who bought, sold, developed and maintained the building, for instance. Other sectors where is starting to be used are the field of education and in governance itself (Shrier, 2020).

Another field in which it is attention is the supply chain field. A study executed by Vivaldi (2020) wanted to find out where the principles of BT are applicable and in which supply chain fields it can provide successful results. This study relates to the traceability of products and the transparency of operations within a process. It has been proved that an advantage of the technology is the given safety and speed of information. Challenges which are currently arising

concern the multiple platforms used in projects. Thus, it is valid that a vast level of connectivity for the multiple platforms is required. In this day and age, the society needs to deal with an increasing number of innovations and improvements. The question which is arising together with this is if the technology can have a positive influence in current processes in existing and upcoming projects (Vivaldini, 2020).Adoption of new technologies – blockchain technology

In the last few decades, the implementation and the understanding of new technologies have become increasingly important. The diffusion of new technologies restructured work spaces and is leading to new skills and capabilities (Bartel et al., 2003; Bresnahan et al., 2002). The challenge behind new technologies, especially behind the information technologies, is that, for firms and companies, new technologies still are kind of a black box (Antonietti, 2005). Antonietti (2005, p.3) mentioned that "adoption refers to the stage in which a technology is selected for use by an individual or an organization, namely the firm".

An analysis was conducted through the UCL Centre for BT about the adoption of BT in supply chains between 2010 and 2020. During this research, 271 blockchain projects were analysed based on parameters like inception date different types of blockchain and sectors applied to different organisations that founded a blockchain pilot project (Vadgama and Tasca, 2021). The characteristics of DLTs are that they are able to make processes transparent and immutable. These properties represent tremendous progress in the supply chain field. The field of supply chain management still requires a lot of manual procedures and a lot of paperwork. Normally, the undertaking of complex supply chain projects takes a lot of different interactions and communications. With the help of BT, the shipment of flowers between Africa and the Netherlands saved 20% of time and 15% of costs, compared to the years in which the technology was not used (Maersk, IBM, 2017).

2.4.6 Summary of the literature review on blockchain technology

Gathering the most important parameters of BT and summarising them into the principles of BT, it has been learned that this technology is based on a distributed ledger. As the distributed ledger can be used in a large network society, this leads to the fact that it can be used when a huge number of stakeholders are involved. The main reason for using a BT is to use it when little trust is available between the different groups of a project. What the distributed network delivers is to make processes transparent and secure and this combination of processes is traceable and immutable. And it needs to be investigated in the data collection, if is the principles of the BT also support the collaboration of people, processes and technologies.

2.5 The interaction of information exchange and blockchain technology

2.5.1 Introduction

To deliver a successful road infrastructure project, several parameters need to be analysed and investigated. In the thesis a research between information exchange and BT also will be undertaken. All the themes that are involved into information exchange will be explained in the following sub-chapters.

2.5.2 Communication management

To ensure that the information needs of a project and its stakeholders are met, proper communication management in a project is required. The communication management in a project consist of two parts. In the first part, a strategy is developed that will ensure that the stakeholders do have effective communication. In the second part, the operations that are necessary for the implementation of the communication strategy are carried out. The processes of the communication management in a project are:

- Planning of the communication management means the process of developing an appropriate approach and plan for project communication activities based on the information needs of individual stakeholders or groups and the resources available to the organisation and the requirements of the project. Managing the communication entails ensuring that project management information is collected, created, distributed, stored, retrieved, managed, monitored and submitted for final disposal in a timely and appropriate manner. Monitoring the communication is the process to ensure that the information needs of the project and the stakeholders are met.

- In the field of the fundamentals in communication management, various approaches are possible. The term communication can be traced back to the meaning of whether it is an intended or unintended exchange of information. In terms of the information exchange, it can be a matter of thoughts, instructions or feelings. The exchange of information takes place, for example, with the following mechanism:

- In written form; either in tangible or electronic form

- Communication describes the possible means by which information can be sent or received – either through communication processes such as meetings and presentations or through artefacts such as e-mails, social media, project reports or project documentation. Project managers spend the majority of their time communicating with team members and other project stakeholders both within, at all organisational levels, and outside the organisation. Effective communication bridges the gap between individual stakeholders who may have different cultural or organisational backgrounds, expertise, perspectives and interests (Röttger, 2013; Deekeling, 2017).

The processes of communication have many dimensions. The most important ones for the field of Blockchain Technology are listed in the following:

> ➢ Internally: alignment with the stakeholders in the project and in the organisation

> ➢ Externally: alignment with external stakeholders such as customers, suppliers, other project organisations, the state, the public and environmentalists

> ➢ Formal: reports, formal meetings, regular and spontaneous meetings, meeting agendas and minutes, stakeholder briefings and presentations

> ➢ Informal: general communications via e-mail, social media, websites and informal, spontaneous conversations

> ➢ Hierarchical orientation: general communications via e-mail, social media, websites and informal, spontaneous conversations

> ➢ Written and oral: verbal (words and tone of voice) and non-verbal (body language and actions) communication, social media and websites, press releases (PMI, 2017).

As the communication and the information exchange have been mentioned most in the literature review so far, a deeper investigation of the information exchange will be conducted in the next part.

2.5.3   Information exchange

In recent years, there has been an increasing interest in the data-driven information environment (Milne, 2015). In association with this, topics such as personal data ecosystems and technologies that enable the collection and dissemination of information are gaining

increasing importance in project environments. Information is basically used so that consumers and businesses are able to make better decisions in their marketplaces (Milne, 2015).

Although the information exchange is an important aspect regarding communication, coordination and problem solving that is widely used in distributed systems, unfortunately it is handled secondary and has not been the focus of the research in the past (Dodds, Watts and Sabel, 2003). Another upcoming problem is the unwillingness of sharing data. Studies that researched the unwillingness of sharing data have reported about problems with confidentiality (Zhang, 2008; Tan et al., 2016), competition (Ha and Tong, 2008; Huo et al., 2013) and lack of trust (Tran et al., 2016; Kembro at al., 2017). Nevertheless, a considerable amount of literature has been published on information exchange. This literature distinguishes information exchange as having an essential role in the performance in different areas, such as, for example, airline, infrastructure and transportation networks as well as file-sharing systems and communications networks (Faloutsos et al., 1999; Gerth et al., 1946 and Taylor, 1911). Taking this as a base, nowadays information assists in identifiying problems at their sources by accessing real–time information and improving transparency go hand in hand (Nakasumi, 2017).

For the data transfer between construction organisations and their clients, there are different technologies around. The general name of these technologies is Information Exchange (IE) (Baldwin, Thorpe and Carter, 1999). Baldwin, Thorpe and Carter's (1999) study found the benefits in alliance projects. Using IE does help in the promised delivery of data; it supports in improving the quality of the data; the communication between the partners in an alliance is improved, which leads to the fact that the risk of project delay is reduced. These findings were facilitated by 67 surveys.

The Information Exchange Theory digs even more into the topic than just the data transfer. The theory aims at the study and modelling of information exchange processes among

interacting agents. The concepts of protocols, types of information systems, misinformation and information distortion, codification and information distance are introduced.

As was already discussed in the stakeholder section, there is a need to investigate information exchange.

As mentioned by Jia et al. (2011), because of the reduction of the pace and the quality of the information exchange in a project, the efficiency is also reduced. With this statement, a question arises concerning the meaning of information exchange and how this is related to road infrastructure projects. Based on this, how the principles of BT can help in the field of information exchange needs to be investigated.

The previous sections described that several parameters between the different stakeholders need to be managed through the project managers. In correlation with this knowledge, transfer and information exchange is a high priority.

A general meaning of the term information exchange is that people pass information from one to another. The understanding of this is that data are shared between a sender and a receiver (Milne, 2015). Jacob and Varghese (2018) categorise the importance of an information exchange in the design process. Through a structured approach, it is possible to forecast and manage an information exchange. In this research, it was also detected that special information exchange models can be used to improve the life cycle management. There are different methods of information exchange. It can be done electronically or through certain systems. Another method of information exchange is through telecommunication or protocols (Young-Ybarra, 1999).

2.5.4 Information exchange theory

When the question arises what information sharing supposes to do, it seems like it is a simple question. The focus is to share information (Chang, 1982). And from a general understanding an information exchange also supports a better security of people, data and processes (Jackson, 2022).

The Information Exchange Theory (IET) itself is the theory of modelling the information exchange process between interacting agents. As already mentioned, a lot of different stakeholders are involved in a road infrastructure project. Freeman (1995) mentioned that every stakeholder is working in its silo, which gives the impression that there is no proper communication between the silos. With the help of this research, it will be investigated if the information exchange based on the principles of the BT can provide support here.

One part of the present research is to obtain an understanding of where the society and the different companies are in the period of industry 4.0 in the field of implementing information exchange in the road infrastructure sector.

Talking in the construction industry about information management, the question arises whether information management is the same as document management or if document management is part of information management (Gyampoh-Vidogah, Moreton and Proverbs, 2003). Joia (1998) found that only a small part of the documentation is online and most of the information is on paper. Another issue with the communication is that the information an engineer is getting is often outdated, and engineers do spend more time in search of documents than using them. The challenge in looking through documents and finding the correct one is to find the most recent version. This ends up in a process where documents are created from scratch again and again.

Doney and Canon (1997) and Mayer et al., (1995) mentioned that trust normally has been embedded in social interactions. For instance, does the literature propose "*that trust*

development is conventionally associated with relational governance mechanism according to the information exchange theory" (Xu et al., 2022, p. 1879).

A well-known process which is helping in terms of information exchange is BIM (Building Information Modelling). Later text will describe how BIM is defined in detail and what other tools and processes are available. The question is whether these tools are efficient or if they can be optimised. This will be analysed with the help of this research, which is based on the information exchange literature review.

2.5.5 Method of information exchange

In the construction sector, known issues are in the fields of complexity, collaboration, concurrency and collocation (Jacob and Varghese, 2018). The question is whether a proper information exchange can help here.

To improve life cycle management of asset data and predictive analytics, certain platforms should be used for better management. Administration authorities are under tremendous pressure, because the effective management of highways does need appropriate processes. The road networks are aging and the number of users is increasing. From this, it can be concluded that maintenance and improvements of the highest standards are required. The vast growth in the last few years has led to different methods being used for handling all the information. A well-known method is Building Information Modelling (BIM) (Brodt, 2013). It is said that, with the help of BIM, the design and construction phase can be used to inform all the different assets and registers in a project from an early point. An existing problem is that, when a project is crossing over from planning and building to the operation stage, a lot of information does get lost. Using BIM offers huge advantages, because in the road infrastructure sector a lot of different stakeholders are involved, they have to collaborate with each other, and what is happening is that at the same time a tremendous amount of data is produced. This needs to

be managed and at the same time the goal needs to be that no information gets lost. To use BIM properly and become successful with it, the three parameters – people, process and technology – need to be combined (Aziz, Riaz and Arslan, 2017).

One of the reasons why road infrastructure projects are that complex is that, between a lot of different disciplines, different collaborations need to be involved. It is also a challenge to handle the pressure which arises in terms of performing in a concurrent mode. In mega projects, the different stakeholders who are involved are spread out globally and the team is not located at one specific place

This has led to the fact that the collaboration and the re-entrance of data in the handling of construction projects is becoming inefficient. Because of this, the idea is that a thorough information exchange can help. With regard to the information exchange, two questions need to be thought about: "Who needs to know what?" and "Should knowledge be shared between or after formal meetings?"

In road infrastructure projects, different stakeholders are involved, i.e. the project owner, the project manager and the steering group. The project owner is the key stakeholder and has the superior authority and responsibility for a successful project result. One of the project owner's many tasks is to identify requirements and objectives and to determine the overall budget. Another term for the steering group is the management committee. This group represents the project owner in large project, when several owners are involved. This group is authorised to make decisions and can provide resources (Terje Karlsen, 2010).

Knowing this, it is helpful to understand why information needs to be shared and how it can be shared. First of all, it is important to say that, to be successful in a project, the access to data and information is mandatory. Information sharing plays a significant role in improving performance. The requirements for improved performance are a clear information sharing policy and a proactive approach to sharing information. Based on this, the most important factor for the participants to share information is trust. The impact of commitment and the

reciprocity is also an important factor which needs to be mentioned here (Zaheer and Trkman, 2017).

It is worth mentioning that an information exchange process does bring a lot of advantages to projects. It does help in increasing the existing knowledge, because of the participants' past experiences. With such a process, upcoming challenges and issues in the existing project can be responded to more quickly. It also provides a simple way of sharing ideas and insights. In summary, it can be said that sharing information can avoid repeating mistakes and reinventing the wheel every time (Cyr and Wei Choo, 2010).

Many actors are involved in road infrastructure projects. This does mean that a lot of information needs to be shared. The challenges which arise are that information gets lost, that the interpretation of the data is wrong, and that the information which should be shared does not have a structure or is all stored in different locations. Another issue which is faced is that information and knowledge exchange is limited among life cycle phases. Where are we with the information exchange at the moment and what tools are used commonly? Although we are in the period of Industry 4.0, the information and knowledge exchange is mainly based on documents and 2D drawings. The literature research shows that that information management and the method of communication in the whole life cycle of a project is inefficient in a lot of projects so far (Hoeber and Alsem, 2016).

Problems which are faced in current projects are that several stakeholders use different tools and processes to proceed. The data which are delivered are often in an unstructured way and it is hard to analyse them. Looking at optimal information management, the strategy needs to start at an early stage in the whole process. It is also important to split the data into different categories (Aziz, Riaz and Arslan, 2017).

Together with this, a well-known term is the building information modelling (BIM). A study conducted in 2019 investigated the challenges between facility management and building information management with regard to the information exchange process. It was proved that

such a platform can enable an information exchange between different data sources and the facility management systems. A problem in all existing projects is that the employees spend a huge amount of time in searching, sorting, validating and recreating information (Matarneh et al., 2019).

The reason why BIM is becoming more and more popular is that a better design quality can be achieved. In a project, normally different disciplines are involved, for example, planners, architects, civil engineers, mechanical or operation managers. Every group normally has its own platform or system for the specific goals of the group. Because of that, problems arise in terms of data incompatibility or a lack of interoperability in the information or data exchange processes (Lai, Deng and Chang, 2019) .

Problems arising in the transportation infrastructure are not only associated with the finance. This means that attention needs to be paid to the public and to the engagement of the public. It is said that the early engagement of public stakeholders is significant to project success. How the involvement of the public affects the effectiveness, sustainability and the utility of every single road infrastructure project has been investigated in a study by Wojewnik-Filipkowska et al. (2019). They found that the impact of all stakeholders at an early stage can improve and determine the early development of trust-building processes.

Vivaldini (2020) wrote that the reason for new processes is to improve the communication and information exchange between the different stakeholders to contribute in the planning and the operation and to create an instrument for historical data and data analysis.

2.5.6 Information feed and decision framework

Large projects, such as road infrastructure projects, are infamous for deterioration in the execution phase. Due to the information feed within a project, decisions are made by the project managers. These decisions have a considerable effect on the project delivery.

Based on this proposition, in a study conducted by Eweje, Turner and Müller (2012), two research questions were proposed:

> ➢ "Which factors of information-feed supporting a project manager's decision impact the strategic value delivered by megaprojects for the sponsoring organization the most?"

> ➢ "How can the decision framework of the managers of megaprojects be enhanced?" (Eweje, 2012)

What was found in that study is that, if the relationship between the host communities is not good, thisnegatively impacts the overall performance. Another surprising result of the research was that the project manager's decision is not influenced by the tenure practising of the profession, but by their idea of what senior management want. What is confirmed and represented is that a risk management system enhances the decision-making process of the project manager in terms of the value-creating decision (Eweje, 2012).

Back in 1994, it was suggested that ways of manipulating data had been found, leading to the fact that a system is needed that is applying a procedure in which resources and information are treated effectively and more securely (Robson, 1994).

2.6 The gap in the literature

One of the gaps within the road infrastructure sector identified by the literature review is the fact that until now, digitisation is used little in the construction sector. This finding will be the base for all further research within the scope of this thesis. According to Yunfei (2019), the little use of digitisation leads to the situation, that not all information that are available are used effectively which s results in a gap of knowledge and a lack of available information. As there is little data regarding digitisation in general in the construction sector, there is also too little data in terms of the complexity of risks in construction projects. The little use of digitisation

results in having too little reliable data available and the main challenges of megaprojects are the poor, unreliable and spurious information that is exchanged. Another challenge which occurs are conflicts between the decision-making parties, the policy, the planning persons and the public (Flyvbjerg, 2007). Because of the challenge of unreliable information exchange, the method of information exchange management is used within the scope of this thesis. Because of the known issues regarding the little innovation in road infrastructure projects, the topic for this research was laid out with a focus on the industry 4.0 and the principles of BT.

It is known that it is a huge challenge and very complex to implement and manage innovation itself. But, because of this risk-averse culture that we are living in, benefits and great opportunities are lost on a constant basis. The reason for that is that in road infrastructure projects innovation is not used, like it is used in other projects. But it needs to be considered how innovation can appear in road infrastructure projects and how it can be captured and produced (Maghsoudi et al., 2016).

The question arises whether we do have the same issues in the area of the project management sector as well. Do we have the problem that companies and customers do not trust the existing models and forms? Do we also need a decentralised system here?

2.7 Generating a framework for the present research

To understand the meaning of a theoretical framework, the section will start with an explanation of different types of frameworks and models.

A model is the result of a process of representing a real-world object or phenomenon as a set of logical, mathematical and computational concepts and equations. Contemporary scientific practice employs at least three major categories of models: concrete models, mathematical models and computational models. Simulation of a system is the operation of a model in terms of time or space, which helps analyse the performance of an existing or a proposed system.

A framework is an abstraction (purposefully arranged and interrelated concepts) in which a system providing generic functionality can be selectively changed by additional, purposely developed constituents, thus providing application-specific features and services. In a pragmatic view, a framework (a piece of software, a system, or an environment) is a platform for developing specific applications. It supports logical, functional, computational, interaction and application aspects.
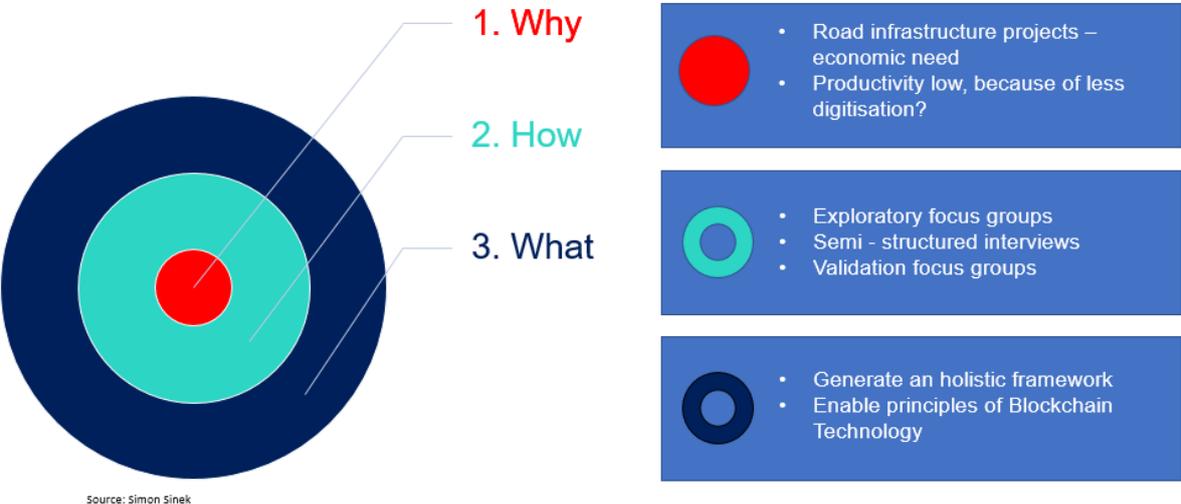
Figure 2-16: Understanding the why of the framework (own representation)

Simon Sinek (2014) mentioned in a speech that the most important is to understand the "why" of something and that it is important to understand "why" we are doing something before we can start thinking about the "how" and the "what". For generating the framework, it is important to get an understanding why the framework needs to be developed.

Trust and communication are the themes that emerged in the literature review. Based on these themes, the idea is to generate a framework.

For solving the trust issue, the idea is to use the principles of BT. And, for solving the communication issue, the method of the IET is used. But this is a result of the idea that

communication and trust are not about the tool, that they are more about the conversation, but tools are needed for communication and trust for having a good conversation. Thus, because of this, the idea is that a theoretical framework needs to be developed for this research.

Based on the literature review in this chapter, the motivation for the present research becomes clear. It is becoming visible that, from a medium and long-term perspective, a change in the communication within road infrastructure projects is required. One possible solution for this can be an appropriate system that helps in the fields of transparency, traceability, immutability and trust. Basically, it can be supposed that implementing the principles of BT do make sense if:

> ➤ Automation in a process is available

> ➤ A process is repeatable several times a year and not only every four years

> ➤ More than at least two stakeholders/different groups are involved

> ➤ A value transfer is existing (not just monetary, for example information)

> ➤ Information and documents need to be immutable (no manipulation)

> ➤ Transparent processes are required

> ➤ Trust is the foundation of a project/process (Shrier, 2020; Laurence, 2018; Lemieux, 2016; Clohessy and Acton, 2019)

Utilising the principles of BT for road infrastructure projects is essential and does need appropriate elaboration. The elaboration is based on the lack of information exchange management and the decision-making methods in the society and field of road infrastructure projects (Kahneman, 2012; Gyampoh-Vidogah, Moreton and Proverbs, 2003). Although we have arrived in the age of digitisation, most of the documentation is still made on paper. This does make it hard for the exchange of information and documentation. The contribution of generating a holistic framework for bringing road infrastructure projects and the principles of BT together, will require a lot of applications; nevertheless, it can provide benefits for the

industry. The BT is a breakthrough technology, that is used in the meantime in a wide range of areas such as industries, banking and healthcare. Because of the special features of the technology it is essential to adopt it (Hames, 2022).

The relationship between the above exemplified aspects is illustrated in the conceptual framework for project management, road infrastructure projects, information exchange and principles of Blockchain Technology in Figure 2-17. With the help of the arrows the relationship between the different areas can be understood.
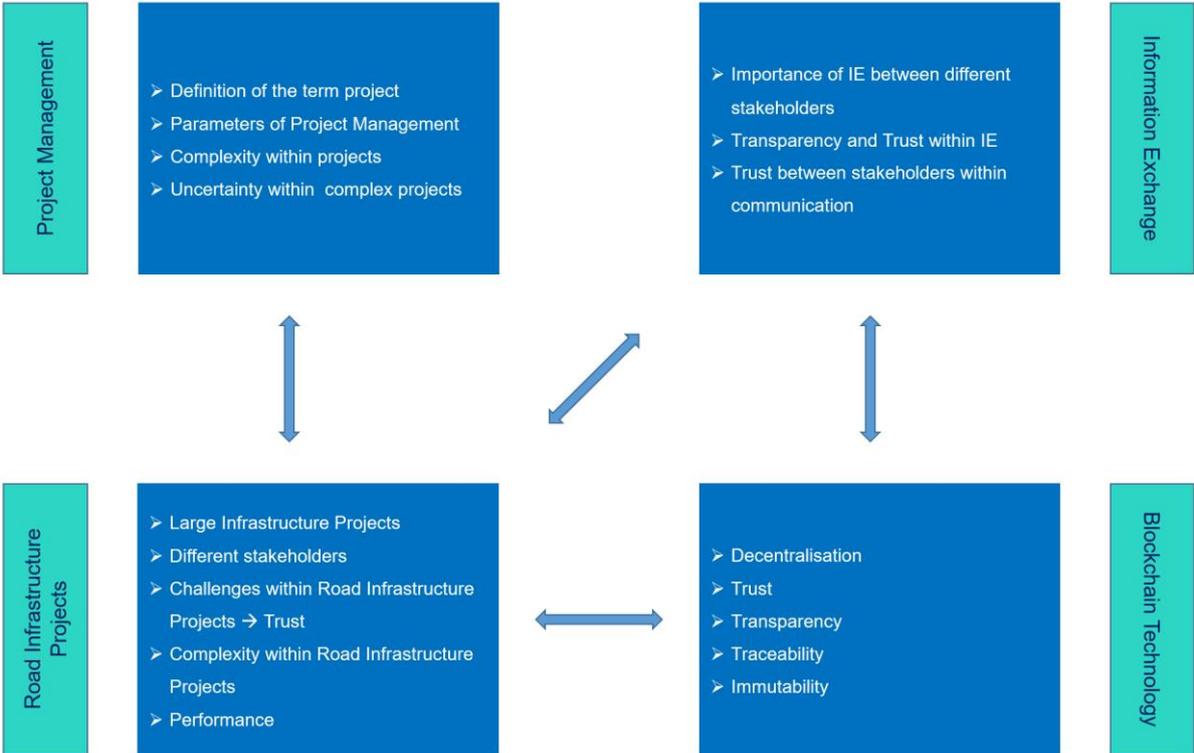
Figure 2-17: Conceptual Framework

2.8 Chapter summary

This chapter has investigated the theory and literature of project management, road infrastructure projects, BT and IET. The aim of the chapter was to provide a wide understanding of the current state of knowledge regarding the principles of BT and in which

fields this technology can be used in road infrastructure projects in relation to information exchange management. Trust is an issue within road infrastructure projects. Hence, the study so far demonstrates the importance of the implementation of a technology which enables us to increase the transparency and trust in a project. With the help of this literature review, the themes are addresses that will be investigated through the research. Based on this, the enablers and barriers for the present research were reviewed. An operating system can provide a number of advantages, with the help of BT, interconnected with different stakeholders. Based on this, the development of a theoretical framework and the benefits of this were identified. Concluding, this chapter identifies the motivation for this study through demonstrating the enablers of the principles of BT for road infrastructure projects.

Mobility needs to be strengthened, the economy should be treated with care and the growth should be secured. To ensure a working road infrastructure, investigations need to be made to have a future thinking regarding road infrastructure in every country. A working road infrastructure enables social participation, intelligence logistic and climate-friendly mobility. The problems that road infrastructure faces these days are too little budget, and mega- projects are time-consuming and, because of the over-complexity in planning projects, often lead to a standstill. Another problem which is receiving attention in road infrastructure projects is that many different stakeholders are involved in one mega-project. The problem with this is that they are all from different sectors and every sector is working differently. The literature review cleared up the fact that, for the above-mentioned reasons, many road infrastructure projects are being carried out inefficiently, but there are also positive examples. The question remains open as to whether the application of new technologies, such as BT, can make both efficient and inefficient projects even more successful.

With the help of the interviews conducted in the current research and the literature review about information exchange management, the idea is to develop the framework of a thorough information management process through the whole life cycle of project management. With

regard to the principles of BT, the question is whether there will be a change in the way of working. Several barriers and challenges have to be overcome in terms of transparency, traceability and immutability, and what companies think about them. The statement which needs to be proved is that it is not only the technology that needs to be changed, it is also the cultural thinking and cultural change. Where we are in terms of a collaborative way of working and what can be optimised also need to be discovered. It is mandatory that a better information exchange management system needs to be thought about, not only to reduce failure costs but also to enhance the whole process in project management.

3 Research methodology

3.1	Introduction
3.2	Philosophical research
3.3	Research philosophies
3.4	Research apporaches
3.5	Research design
3.6	Researcher´s decision
3.7	Reserach strategy
3.8	Time horizon
3.9	Chapter summary

Figure 3-1: Overview of chapter 3 – research methodology

3.1 Introduction

In this chapter on the research design, the foundations for the research philosophies and the research methodology are laid out. To understand the choice of method, it is important to get to know which philosophy and approach is used. The end of this chapter will summarise which philosophy and method is used for generating the final research framework.

For the research itself, it is necessary to understand the different philosophical perspectives and which are the ones used for the present research. This helps in understanding and developing the current knowledge. It is also said that methods are secondary to the paradigm, which is defined as the basic belief (Creswell, 2013). With the research philosophy, important assumptions are made about the way the researcher views the world and about the way the results will be understood. The research philosophy helps in understanding how the researcher views the world. It helps to capture the inductive and deductive research and the ontological,

epistemological and axiological perspectives. In the figure below, Saunders' research onion is visualised. This research onion includes the research philosophy, approaches, strategies, the method choices, and, in the inside, the techniques and procedures. To understand the onion, we have to start at the outside layer, which protects the inside layers. This whole research onion builds the foundation of the whole research methodology (Saunders et al., 2009, p.109). The outside layers need to be peeled off to get from the outside to the inside.
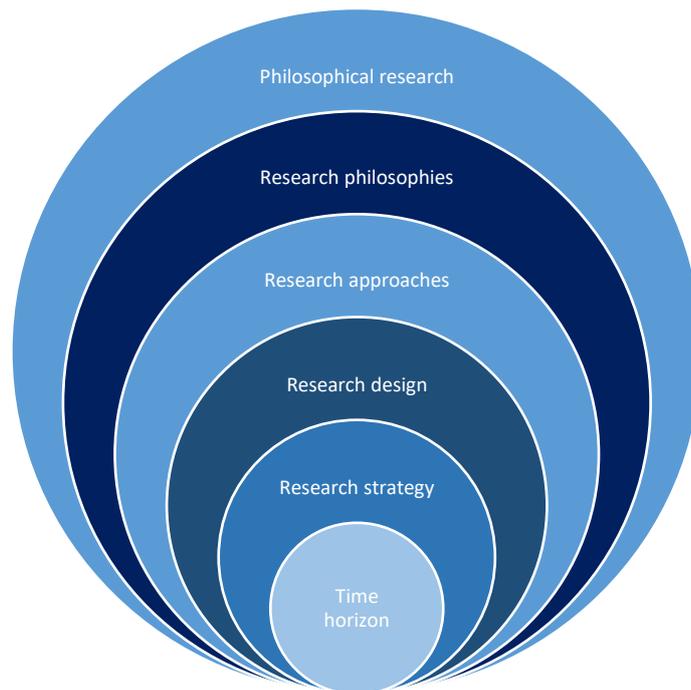
Figure 3-2: Research onion (Saunders, 2009)

It can be said that the outer layer is the most important layer, because it points out and describes the way the researcher views the world.

3.2 Philosophical research

The meaning of the word philosophy is love (philo) of knowledge (sophia) and it is used to announce the reflection of fundamental principles. Nowadays, it has become a concept of the body of knowledge and a chain of analytical skills (Brinkmann, 2018). The theoretical question is "What is the nature of reality?" (Brinkmann, 2018, p.7) and the practical one is "How should

we act?" (Brinkmann, 2018, p.7). The philosophy is a huge area which does not focus on one special topic; the idea behind it is that, with questioning and a special approach, a special subject is being characterised. Substantial questions do arise in the field of philosophy (Saunders, 2009).

3.2.1 Positivism versus post-positivism

Positivism and post-positivism must be contemplated as philosophies used in science for scientific investigations. The two of them are to be considered as two independent philosophies. On the hand the positivism emphasizes the importance of objectivity and the need to study observable components. On the other hand, the post-positivism is a philosophy that rejects positivism.

The worldview of the positivist is called the scientific method or doing science research (Creswell, 2009). Positivism is a direction in the philosophy that demands that findings which are supposed to have the character of knowledge should be limited to the interpretation of the 'positive', i.e. actual, sensually perceptible and verifiable findings. This line of thought can be found, in fact, in antiquity with the Greeks. The positivist is thinking that all knowledge is based on perception. True knowledge can only be gained through experimentation, and metaphysics is impossible for a positivist (Saunders, 2009). It is important to note that the approach of the positivist is that the real truth is nowhere to be found (Phillips and Burbules, 2000). To measure the social world of a positivist, an objective method should be used (Easterby-Smith et al., 2012). Following the statement by Rehmann and Alharthi (2018), positivism supposes that the truth subsists independently from humans and is nothing which is affected by human senses. Popper (1959) argues that humans will never be in a situation to obtain a general pledge. An example that philosophers often use is the example of the white swans. Although the result of an observation has been that all swans are white, it is not proved that all swans are white (in fact, they are not).

Post-Positivism emerged in the 20th century. In the post-positivism it is said, that scientific thinking is similar to the common sense of humans. In contrast to positivist, post-positivists points out that it is not possible to rely on observations always. The post-positivism approach assumes that every method can have errors and that these errors only can be avoided, if more than one method is chosen (Popper, 2002).

3.2.2 Realism

"Making the hidden obvious" (Brinkmann, 2018, p. 64) is the strategy of realism. The term realism encompasses a variety of philosophical positions, according to which phenomena independent of human consciousness exist which affect us, and which we can describe linguistically. Realistically, these are discussed with regard to very different phenomena, so that one speaks more precisely of realism with regard to a specific problem area. The understanding of realism is that something is recognised only with cognition (Saunders, 2009). Bhaskar (2008) brought forward the argument that no patterns are needed to make realism exist, because it exists independently from any structure. Hence, no experiments are needed to consider a condition and its consequences, made by humans (Easterby-Smith et al., 2002). Maxwell (2012) noted that critical realism is a combination of realist ontology with a constructivist epistemology. It can be said that, holistically, the world combines the characteristics that remain independent of humans with knowledge that is built through human occupations. Hadot's (1981) understanding of realism is that realism is a special way of life and an existential attitude to it.

3.2.3 Interpretivism

Interpretivism is a "response to the over-dominance of positivism" (Grix, 2010, p.82). In interpretivism, the role of humans as social actors needs to be understood. For the interpretivism approach, the situations in which the researcher finds himself/herself need to be understood, which is essential for the position he/she takes (Taylor, 1985). The difference here

is that the human is acting as an object, like a computer, or acting as a person. Interpretivism can be explained in relation to a play. Every actor plays a role in a play and acts in a way which can be interpreted by a human. To reflect this in real life, acts can be interpreted according to different meanings in life (Saunders, 2009). Mostly in interpretivism, researchers collect qualitative data over an extended period of time, such as through interviews and focus groups (Cohen et al., 2007). It can be concluded that interpretivism uses an inductive approach. The goal is to understand aspects with their correlations (Rehman and Alharthi, 2018). Gergen (1985, p.266) stated that "what we take to experience the world does not in itself dictate the terms by which the world is understood".

3.3 Research philosophies

When a piece of research is conducted, basically, there is no right or wrong. Also, the selected research philosophy significantly influences the relationship between the existing knowledge of the researcher and the procedure that is developed. In simplified words, the research philosophy is the way in which the researcher views the world (Saunders at el., 2012). Because of that, it is mandatory to give special attention to the research philosophy. Moreover, is it essential to ponder the chosen philosophical approach in terms of represent potential alternative approaches (Saunders et al., 2012).

In general, the research philosophy can be explained by two major adoptions, the ontological and the epistemological assumptions. To complete these two assumptions, the axiological, rhetorical and methodological assumptions need to be included in the research philosophy (Collis and Hussey, 2009).

To obtain an understanding about the five research philosophies, they are explained briefly in the following:

> ➢ Ontology "is concerned with the nature of reality" (Saunders et al., 2012, p.130)

- Epistemology "concerns what constitutes acceptable knowledge in a field of study" (Saunders et al., 2012, p. 132).

- Axiology "is a branch of philosophy that studies judgments about values" (Saunders et al., 2012, p.137)

- Rhetoric "is concerned with the language of research" (Collis and Hussey, 2009, p.60)

- Methodology "is concerned with the process of research" (Collis and Hussey, 2009, p.60)

The ontology, epistemology and axiology are theoretical perspectives (Crotty, 1998). As Collis and Hussey (2009) mentioned, it is not possible to adopt these assumptions freely. They need to be given to other assumptions as well.

The five mentioned perspectives will be explained below.

3.3.1 Ontology

Referring to the section above, "ontology is concerned with the nature of reality" (Saunders et al., 2012, p.130). The understanding of this is that the ontological assumption gives a general understanding about how the researcher views the world and the nature of research (Creswell, 2009).

In the literature, a lot of different approaches can be found that explain the ontological assumptions. In the following sub-section, only the most important considerations will be explained.

The question behind ontology and metaphysics is, "What can be said to exist and how?" (Brinkmann, 2018, p.7). Physics itself explains how different objects move through space and time. Ontology constitutes a deeper investigation in terms of what space and time finally are (Brinkmann, 2018). Starting out from Aristoteles, ontology is understood as the 'first

philosophy'. It is defined as: being (philosophical theology), the soul (psychology) and the context of all beings in the whole cosmology (Kunzman et al., 1991). The term ontology means the study of being. Saunders (2009) outlined that ontology is split into objectivism and subjectivism.

Bryman (2012) argued that, in the view of objectivism, social aspects appear independent of a social performer. Subjectivism is the opposite of that. In subjectivism, the social aspects arise from social performers and they are dependent on and are influenced by the awareness and the understanding of these. It is said that reality in the view of subjectivism is socially constructed.

The thinking behind ontology is the researcher's view of the nature of reality or being. Both are able to be used in business and management research (Saunders, 2012). It also can be said that ontology relates to characteristics of the real world (Creswell, 2013). There are four different types of ontology:

1. Realism (the world has only one truth); it can also be said that the world can be discovered and be explained through the application of scientific methods.

2. Internal realism (there is one truth, but this is not accessible); it is said that the activities of knowing of the humans creates what is known.

3. Relativism (the world has many truths, but the truth is independent from the discovery process) and

4. Nominalism (the reality is created by humans (Smith et al., 2012). Nominalism can also be described as a 'looping effect', because it is said that interpretations are made by interpretations (Brinkmann, 2018).

3.3.2 Epistemology

The difference between epistemology and ontology is that ontology explains the "what" and the meaning behind epistemology is "what it means to know" (Crotty, 1998, p.10). Eldabi et al. (2002) noted that epistemology is related to the conviction about the way in which knowledge is constructed. In this conjunction, it can be said that knowledge is something which can be appropriated or is something which is based on personal experience (Burrell and Morgan, 1979).

The epistemology is the doctrine of the condition, nature and limits of knowledge. The relationship between knowledge - subject, - object and - content is addressed. Epistemology deals with the preconditions and foundations of knowledge in the individual sciences. Its methods, principles, concepts and goals are clarified and subjected to critical examination (Kunzman et al., 1991). Epistemology describes the researcher's view in terms of what constitutes acceptable knowledge (Saunders, 2009). In epistemology, a major difference between objectivist/positivist and subjectivist/constructivist is made (Crotty, 1998). The area of epistemology describes how knowledge is generated. Psychologists reject the idea that human thought and behaviour can ever be studied objectively. They argue that there is no single objective reality. Rather, each of us constructs our own understanding and interpretation of 'reality' embedded in the context of our interactions with others. 'Reality' is therefore highly individual and subjective (Grieg and Taylor, 1999).

Similar to ontology, Saunders et al. (2012) and Bryman (2012) classify epistemology into four approaches: positivism, realism, interpretivism and pragmatism. Positivism assumes that only facts that can be observed can be used to obtain data and facts for a law. Saunders et al. (2012, p. 136) noted that realism is a similar approach to positivism as "there is a reality quite independent of the mind". Opposite to positivism and realism is interpretivism. In an interpretivist approach, the researcher needs to recognise the different interpretations of the different humans with their different roles in the society. This leads to the need to adopt a

particular attitude to understand different situations and details in that reality. Last but not least is pragmatism, in which "the most important determinate of the epistemology, ontology and axiology you adopt is in the research question" (Saunders et al., 2012, p.109).

3.3.3 Axiology

Different to epistemology and ontology is axiology. Compared to epistemology and ontology, axiology is a relatively new research philosophy. This philosophy was applied in the twentieth century. Axiology investigates the issues which arise from the moment human beings begin to reflect on conditions of life, the structure of reality and the order of nature human beings are placed in (Hart, 1971). Axiology is the researcher's view of the role of values in the research. During the whole research, the researcher needs to highlight which value the view plays in all stages of the research (Saunders, 2009). This means that it can be said that the researcher is not forcing his/her view on people.

Regarding the axiological approach, it is considered that the researcher needs to be able to formulate their own values, as these are the foundations of the conclusions and deliveries of the research (Heron, 1996; Saunders et al., 2012).

Referring to the assumption that it is not possible to conduct a study completely value free, Bryman (2012) mentioned that because of the principle of objectivity, research, that is based on the positivist research philosophy, can be undertaken that is value free. With the exception of the value-free (positivism) philosophy all other philosophies are value-driven. According to Saunders et al., (2012) are the different philosophies value-driven to different degrees from the value-laden realism to the value-bound interpretivism.

3.3.4 Rhetoric

The meaning of rhetoric is the chosen language that is used to document a piece of research (Collis and Hussey, 2009). From a rhetorical perspective, it is mandatory that the language reflects the values and the choices philosophy involved in the research.

This significant meaning of the language can be seen when the formal style of research from a positivist perspective and research from an interpretivism perspective are compared. In an interpretivism study, a variable style is used and normally a first-person wording is used. In contrast, in positivism a passive style is used and it is free of the researcher's values (Collis and Hussey, 2009).

3.3.5 Method(s)

The method also plays a significant role in the whole research. Because of the importance of this, it will be reviewed in an extra chapter. The background of the methods is about the procedure regarding how the whole research is undertaken (Saunders et al., 2012). Some of the methodological considerations are the methods, the research design and the time horizon.

The reason why the methodology is mentioned in this chapter as well is because the above-stated philosophies have a significant impact on the chosen method. This can be explained with the following example mentioned by Collis and Hussey (2009). When a positive approach is chosen, for example, concepts need to be used that will support the positive approach with the help of large samples. In the case of an interpretative approach, methods with small samples will be better.

3.3.6 Philosophical assumption

Research philosophy	Understanding	Questions
Ontology	The ontology is the understanding of what is reality	• What is the nature of reality? • What is the world like?
Epistemology	The understanding of how the reality can be known	• How can we know what we know? • What is the considered acceptable knowledge? • What constitutes good quality data? • What kind of contribution to knowledge can be made?
Axiology	The understanding of values	• What is the role of values in research? • How should we treat our own values? • How sould we deal with the values of research participants?

Figure 3-3: Philosophical assumption (Brinkmann, 2018)

3.3.7 Philosophy of the researcher

The research philosophy which is used for the purpose of this study can be seen in ontology. As mentioned above, the ontology is split into four different types. Normally, the truth can be seen from a realism perspective, but in this thesis nominalism is used due to the fact that interpretations are made from interpretations. Nominalism says that there is not only one truth; the idea behind this is that people try to understand how everybody acts. So also from subjectivism can be spoken. In subjectivism, humans obtain opinions from others and also get an understanding of different views and different behaviours. In this thesis, a subjectivist/constructivist approach is chosen.

This approach can be explained in that way because the researcher will conduct focus groups and semi-structured interviews. Through this procedure, the researcher will obtain different views and opinions and will try to understand how every individual participant is acting. It also needs to be understood that the results will only be brought to the current research the study

itself is not capable of conducting investigations with all the groups and stakeholders that are experts in this area.

3.4 Research approaches

As the different philosophies have been described and it has been explained which view the researcher will follow, in the next sub-chapter the several research approaches will be introduced.

3.4.1 Deduction

The research approach of deduction is also known as the testing theory. In this approach, a theory or hypothesis is developed and a design is created to test it, as illustrated in Figure 3-4 (Saunders, 2009; Brinkmann, 2018).

Theory → Hypothesis → Testing → Confirmation/rejection

Figure 3-4: Deductive research approach

Braun and Clark (2006) mentioned that, in the deductive approach for the coding, a framework with the corresponding topics is used. The framework is usually structured with a start list (Miles and Hubermann, 1994), and, in the analysis of the data, it is expected that certain core capabilities will be included (Bradley et al., 2007). The deduction is using existing knowledge to test a hypothesis.

3.4.2 Induction

On the other hand, the induction approach is the building of theory (Saunders, 2009). The inductive approach refers to "approaches that primarily use detailed readings of raw data to

derive concepts and themes" (Thomas, 2006, p.238). Curry et al. (2009) mentioned that in the inductive approach all data are analysed section by section, and based on this data codes are collated to paragraphs and section of texts. Through this procedure, the results and findings of a study, different then to deduction, are gathered through the analysis of the data and not of the expectations of certain core capabilities (Thomas, 2006).

| Observation | Pattern | Hypothesis | Theory |

Figure 3-5: Inductive research approach

The goal in inductive research is that a structure is gathered through the data collection. Based on this gathered data, a theory can be developed (Rehman and Alharthi, 2018). In other words, the induction is going from a detailed analysis to general knowledge.

3.4.3 Abduction

Different to deduction and induction, abduction starts with a classification to something and makes the indeterminate more determinate to enable actions (Alvesson and Kärreman, 2011). Charles Sanders Peirce named this approach in 1934 as a supplement to deduction and induction (Van Maanen et al., 2007). Through the abduction approach, an understanding is developed for contingent situations to identify if a setting becomes more clear and convertible (Brinkmann, 2018). A five-step strategy was developed by John Dewey (1910/1991), which can be referred to as the abduction approach:

1. A real doubt is generated, because of an unresolved problem.

2. The problem is particularised, as data is collected systematically about the given problem.

3. The investigator sets a hypothesis to solve the problem.

4. This hypothesis is elaborated and compared to other possible solutions. Based on this, the effects of the proposed hypothesis are considered.

5. Lastly, the hypothesis is tested by an experiment, whether the problem can be solved through this hypothesis or not.

3.4.4 Research approach of the researcher

Related to the explanations in the previous sections the research approach for this work is the abduction. The abduction combines the deductive and the inductive approach. The reason for the combination is because of, with the help of the deductive approach an existing theory is used, a hypothesis will be developed that will be tested afterwards. with the help of the inductive approach. With the help of this approach data will be collected and based on the collected data the final holistic framework will be created. The way forward is explained in more detail by the following 5 steps applied within the scope of this thesis:

1. The unresolved problem faced in this thesis is the fact that different stakeholders do not trust each other in road infrastructure projects.

2. The challenge with not trusting each other was supported by the results of the data collection conducted through the focus groups and the semi structured interviews.

3. The hypothesis that was made through research is that the principles of the Blockchain Technology can support in the challenge of not trusting each other in the field of information exchange.

4. The hypothesis is elaborated with the help of the creation of a theoretical framework in the current research work.

5. The hypothesis has not been tested yet, but this is mentioned in the chapter about limitations and in the recommendation for further works.

3.5 Research design

In a research study, a research design is needed. A research design is a technique for collecting, analysing, interpreting and reporting the data gathered during the research. Different models are available for this. But which models are available? In this chapter, two models will be described and at the end the model that will be used by the researcher is defined. It is important to understand why a specific model has been chosen, because this will set the logic and will explain the interpretations at the end of the study. Saunders et al. (2012, p.159) stated that the research design is "the general plan of how you will go about answering your research question(s)". In terms of the research design, the researcher also needs to make a decision about whether to choose a mono-method or a multiple method.

Basically, there are two different ways two conduct a piece of research (Bryman, 2012; Saunders at al., 2012):

> ➢ Quantitative research design: based on a positivist research philosophy and a deductive research approach, usually numeric data are generated through a quantitative research design.

> ➢ Qualitative research design: based on an interpretivism research philosophy and an inductive research approach, normally non-numeric data are gathered through a qualitative research approach.

Based on the explanation of quantitative research and qualitative research, three models will be described, the multi-methods, the mono-methods and the mixed-methods (Creswell, 2009).

3.5.1 Quantitative research

When a quantitative study is undertaken, a clearly defined method is required. But the simplified definition from the beginning of the chapter does not meet the complexity of the

mentioned research approach. According to Creswell (2009, p.4), a more detailed definition of quantitative research is:

"*Quantitative research is a means for testing objective theories by examining the relationship among variables. These variables, in turn, can be measured, typically on instruments so that numbered data can be analysed using statistical procedures. The final written report has a set structure consisting of introduction, literature and theory, methods, results, and discussion (Cresswell, 2008). Like qualitative researchers, those who engage in this form of inquiry have assumptions about testing theories deductively, building in protections against bias, controlling for alternative explanations, and being able to generalize and replicate the findings.*"

A number of techniques have been developed to conduct quantitative research. Schwandt (2001) explained quantitative research as something that is described in an amount or a number. As quantitative research data is normally numerical, it is often used in statistics. Another area where it is used is when different variables need to be compared with each other (Saunders et al., 2012). Normally, quantitative research has a logical and linear structure. Within this structure, analysis and measurements are made to identify the relationship of different data sets (Eldabi et al., 2002).

Quantitative research replicates the positivist approach, whereby a matter is presented scientifically or a result is an independently measurable characteristic. In quantitative research, a deductive approach is often used. With the help of collected data, the researcher is able to reflect if the results can be confirmed or should be disconfirmed. The goal of a quantitative study is to answer a specific question (Creswell, 2009).

Quantitative data is numerical data which helps to meet special objectives. For example, the data can be a range from simple counts, prices or rental costs. Quantitative data is often used in conjunction with random samples. Quantitative means all the data used for data collection technique and analysis procedures (Saunders et al., 2012).

Finally, it can be said that the content of quantitative research is the following (Cobin and Strauß, 2008):

> - Linear research process
>
> - Standardised approach
>
> - Hypothesis testing
>
> - Representative samples
>
> - Explain, measure, behave
>
> - Measurements of variables

➜ Experimental design

In conclusion, the impression is created that a quantitative approach can also be seen as an experimental design.

Relating to studies of construction project management, which is relevant to the topic of this thesis, Amaratunga et al. (20002a, p.22) mentioned the following strengths:

> - Comparison and replication are allowable
>
> - Independence of the subject observed by the researcher (observer)
>
> - Subject under investigation is objectively measured
>
> - Reliability and validity may be determined more objectively than in qualitative research
>
> - Strong in measuring in descriptive aspects; and
>
> - Emphasises the need to formulate hypotheses for subsequent verification

Amaratunga et al. (2002a) also mentioned the weaknesses of quantitative research. From their perspective, this type of research only gives a short picture of a special situation and the disadvantage is that the meanings behind data and numbers are not analysed in more detail.

3.5.2 Qualitative research

The use of qualitative research is a well-established approach. Traditionally, qualitative research has been assessed in studies in which flexibility is needed. The difference from quantitative research is that qualitative research refers to non-numeric data. One of the main goals of qualitative research is to obtain an understanding about the doings and saying of others (Schwandt, 2001). With the help of qualitative research, researchers are able to obtain new findings and understandings.

A more detailed definition of qualitative research is given by Creswell (2009, p.4):

"*Qualitative research is a means for exploring and understanding the meaning individuals or groups ascribe to a social or human problem. The process of research involves emerging questions and procedures, data typically collected in the participant`s setting, data analysis inductively building from particulars to general themes, and the researcher making interpretations of the meaning of the data. The final written report has a flexible structure. Those who engage in this form on inquiry support a way of looking at research that honours an inductive style, a focus on individual meaning and the importance of rendering the complexity of a situation (adapted from Creswell, 2007)".*

Porter (2007) noted that there are two ways of defining qualitative research. The first definition refers to a method that can be used to collect and analyse data, and the second one relates to the conjectures of epistemology and ontology. Basically, it is said that there is no clear definition about qualitative research found in the present literature (Creswell, 2009). A piece of qualitative research tends to be the result of an interpretivism approach; in that research, knowledge is generated through the intermediation between humans to make it more descriptive in nature.

Norman Denzin and Yvonne Lincoln defined qualitative research as:

Qualitative Research is a situated activity that locates the observer in the world. Qualitative Research consists of a set of interpretive, material practices that make the world visible. These practices transform the world. They turn the world into a series of representations, including field notes, interviews, conversations, photographs, recordings, and memos to the self. Other qualitative data are videos, questionnaire surveys, documents as (reports, meeting minutes, e-mails) or newspaper articles.

At this level, qualitative research involves an interpretative, naturalistic approach to the world. This means that qualitative researchers study things in their natural settings, attempting to make sense of or interpret phenomena in terms of the meaning people bring to them" (Brinkmann, 2018, p.5). Qualitative data are all data which relate to non-numeric data. This data is more complex. Examples of qualitative data are data like interviews or policy documents (Saunders, 2009). The analysis of the data of a qualitative study is made through induction. It is noted that this research method is used as a tool, when a group or individuals attached to a social or human problem needs to be explored and understood (Creswell, 2009). A typical qualitative research procedure is that multiple forms of data collection are used. In the present research, focus groups and interviews will be used. Based on these collection forms, the researcher analyses and reviews the data, categorises them and puts them into themes (Creswell, 2009). The important fact is the understanding of the content of the data. The researcher generally tries to understand the knowledge, values and beliefs in terms of the study (Bryman and Bell, 2011). The advantage of using this approach is that it is less structured than the quantitative approach, so it gives the participants more flexibility in their responses and it is possible to speak out on issues that appear to be important (Yauch and Steudel, 2003).

Mayring et al. (2007) argued that the qualitative approach includes the following parameters:

➢ Circular research process

➢ Open approach

➢ Exploratory design

➢ Small samples, case orientation

➢ Understand, describe, experience

➢ Interpretative paradigm

➢ Constructive design

Compared to the quantitative approach, the qualitative approach can be seen as a constructive design.

3.5.3   Research choices
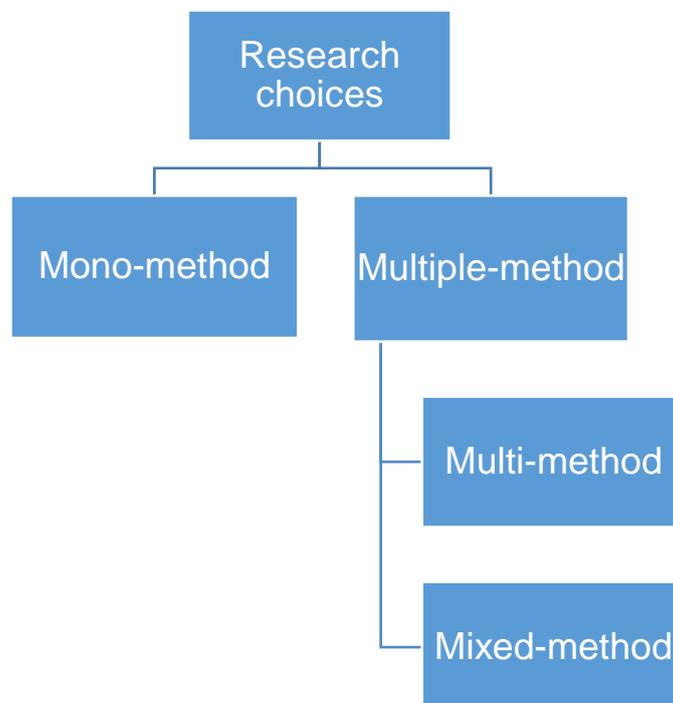
Figure 3-6: Research choices (Saunders, 2013)

For choosing a method for the study, it needs to be used a mono-method approach or a multiple-method approach. The mono-method approach comprises only one data collection technique with an appropriate analysis procedure (Saunders, 2009). Tasjakkori and Teddlie (2003) noted that using a multiple-method approach is reasonable, as the data will be trusted for answering the research question. In the current study, a multi-method approach, using a qualitative approach, is chosen, which belongs to the multiple method, the multi methods and mixed-methods approaches are explained in the following chapters in more detail. For completeness, the section starts with a description of the mono-method.

3.5.4 Mono-method

Although the mono-method approach is not used in this study, it will be discussed for completeness. When a mono-method approach is chosen, only one data collection technique will be used and only one corresponding analysis procedure (Saunders, 2009). A study conducted in 2020 identified 127 articles to investigate which strategy was most often used – was it the multi strategy, the mixed strategy or the mono strategy? The study found that it was the mono strategy (Vizcarguenaga-Aguirre and López-Robles, 2020). The mono-method approach is classified into the simple mono-method approach and the complex mono approach. The main statement of the mono-method approach is that "one type of method is generally better than another" (Hassard and Pym., 1993, p.28). On the other hand, the argument of the complex mono-method approach is that "one type of method is better than another for the purpose of addressing a particular theoretical issue" (Hassard and Pym., 1993 p.28).

3.5.5 Mixed-method

A mixed-method is chosen when a qualitative and a quantitative study is executed in an experiment design. A mixed-method approach combines quantitative and qualitative data. It is a term from the Anglo-American debate on methodology in the social sciences and education,

which has been used since the end of the 1990s. Specifically, since the publication of the monograph "Mixed Methodology" by Abbot Tashakkori and Charles Teddlie (1998), it has gained great prominence. Until the quantitative data is useful, it has to be analysed using special techniques. With the help of charts and statistics, it is possible to describe relationships and trends within the collected data (Saunders, 2009). Mixed-methods approaches are known to be used when the philosophical assumptions have pragmatic knowledge claims. These approaches are sequential, concurrent and transformative. As already mentioned, it is not just a mixture of quantitative and qualitative data and analysis; it is also used when open- and closed-ended questions need to be answered and when emerging and predetermined approaches exist. The following practices are used by the researcher in a study when a mixed-method approach is chosen:

- ➢ Quantitative and qualitative data is collected

- ➢ Data at different stages of the enquiry is integrated

- ➢ Visual pictures of the procedures in the study are presented

- ➢ The practices of qualitative and quantitative research are employed (Creswell, 2009).

3.5.6 Multi-method

A research is called multi-method when the chosen method is focusing either on qualitative or on quantitative data (Collier, 2008). In the mixture of multiple methods, it is mandatory that more than one data collection procedure is used with links to analysis techniques (Tashakkori and Teddlie, 2003). In the current thesis, the chosen method is multi-method research and qualitative data will be used. Research using qualitative data is eclectic, leading to the statement that multi-methods are characterised in three different ways. One way is the relationship to interpretative and constructivist approaches. The second is because of the growing number of interconnections between qualitative and quantitative research tools, and

the last is with regard to the increasing diversity of techniques focused on convention qualitative traditions (Colllier, 2008).

Based on the considerations above an approach for the research needs to be identified. As the researcher wants to generate a holistic framework through to the study a multi-method approach is chosen. The methods that are chosen in the study are focus groups and semi-structured interviews. With the two independent sources of data the methods will corroborate the research findings. The researcher wanted to establish how the principles of BT can utilise the management of road infrastructure project management. In order to find an answer on this, the researcher decided that it is essential to choose two methods of the qualitative approach.

> Analysing in which fields the principles of the BT in the life cycle of the project management can be used (focus groups)

> Digging deeper into the different phases and discussing the possibilities in more detail (semi-structured interviews)

3.6 Researcher´s decision

From the view of the researcher using participants that are directly working in the road infrastructure sector and who are involved in the related challenges every day, these two methods were the most valuable ones for this research. These two methods are the method of the focus groups and the semi structured interviews. This is also underlined, by the thinking of the post-positivism approach which says that at least 2 methods need to be used, to make sure, that results are not falsified. Because of that the multi-method approach has been chosen.

3.7 Research strategy

There are a number of instruments available for gathering data in a piece of research. With the help of the research strategy, the researcher is able to answer the research question. Each available strategy is linked to a quantitative, qualitative or mixed-methods research design (Saunders et al., 2012). The research strategy is "the methodological link between your philosophy and subsequent choice of methods to collect and analyse data" (Saunders et al., 2012, p.173). Creswell (2009) mentioned that over the last few years more strategies have become available for the analysis of data. Hence, only a number of the most common strategies will be explained in a compendious form in the following section.

3.7.1 Experiment

The reason for an experiment is to study aetiological conjunctions. An example of this is that sometimes it needs to be investigated "whether a change in one independent variable produces a change in another dependent variable" (Hakim, 2000, p.98). A study regarding an experiment is conducted systematically in a laboratory setting to obtain an understanding of the relationship of different parameters to each other (Collis and Hussey, 2009).

3.7.2 Survey

Normally, a survey is associated with quantitative research, regarding questionnaires or structured interviews. The purpose of this approach is to examine patterns (Bryman, 2012). Saunders et al. (2012) argued that normally this research type is used in deductive research and is really popular in the field of business management research, as it is possible to collect a large amount of data with this approach.

3.7.3 Ethnography

Ethnography is a holistic study and normally uses qualitative methods. Ethnography is used when groups in their natural setting need to be studied over a period of time. The aim of the ethnography approach is to describe and interpret the shared patterns such as behaviour, language and beliefs of a group of interacting individuals (Creswell, 2013). It is important in this approach that the cultural group of individuals has to be studied as an intact group in its natural setting (Creswell, 2009). This requires often extensive participant observations, trust from the participants, and a strong strategy to deal with the fact of being a researcher and being involved in the social life of the participants (Saunders, Lewis and Thornhill, 2012).

3.7.4 Phenomenological research

Phenomenological research: in this type of study, it is significant to gather meanings and insights into the meaning of the social phenomena. The phenomenology approach identifies and holistically understands the meaning of human experience as described by the research participants (Amaratunga et al., 2002; Creswell, 2009). In this light, phenomenology "sees social phenomena as socially constructed, and is particularly concerned with generating meanings and gaining insights into those phenomena" (Saunders, Lewis and Thornhill, 2007, p. 606).

Phenomenology builds on the work of the German philosopher Edmund Husserl (1859-1938) from a philosophical perspective as well as the work in social phenomenology of the Austrian social scientist Alfred Schütz (1899-1959) (Schwandt, 2001; Outhwaite, 2003). Furthermore, it must be pointed out that the German philosopher Georg Hegel (1770-1831) earlier argued that phenomenology would refer to "knowledge as it appears to consciousness" (Moustakas, 1994, p. 26).

According to Moustakas (1994), phenomenology studies a phenomenon as it appears to individuals in their consciousness. Moustakas (1994) further argued that the "very appearance

of something makes it a phenomenon", and any phenomenon can be the start of a study (p. 49). This approach is commonly used in qualitative research (Amaratunga et al., 2002; Creswell, 2013), which aims to identify, deeply understand, explain and describe a common or shared subjective experience of several individuals in terms of a phenomenon (Easterby-Smith, Thorpe and Lowe, 1991; Schwandt, 2001; Creswell, 2013). This description, then, is different to explanations of analyses and keeps as much originality as possible and results in, e.g., "ideas, concepts, judgement and understanding" (Moustakas, 1994, p. 52).

However, phenomenologists are further concerned with delivering a reinterpretation, new and fuller meaning, while looking at a phenomenon from new perspectives and, most importantly, questioning the current meanings. Hence, phenomenology is characterised by objectivity and as a critical approach that "calls into question what is taken for granted" (Crotty, 1998, p. 83). Phenomenological studies usually consist of data collected from individuals who have experienced the phenomenon, which then will be analysed to extract the meaning and the essence of collected experience in order to describe the phenomenon (Moustakas, 1994). Consequently, this approach is best suited for studies that seek to develop practices, policies and deeper understanding of a phenomenon through experiences of it that are shared by several individuals (Creswell, 2013).

3.7.5 Researcher's decision

According to Popper (2002) the post-positivism approach that every method can have errors and that these errors only can be avoided, if more than one method is chosen (Popper, 2002).

The multi-method research design for this work will be implemented utilising two different research strategies. In a first step, focus groups will be conducted with several organisations from the construction industry. With the first data collection - the conduction of the focus groups _, the foundation for the basic knowledge and understanding will be laid. This will help to meet

objective 1. Based on this, in a second step, data will be collected with the help of semi-structured interviews. The semi-structured interviews will help in meeting objectives 2 and 3.
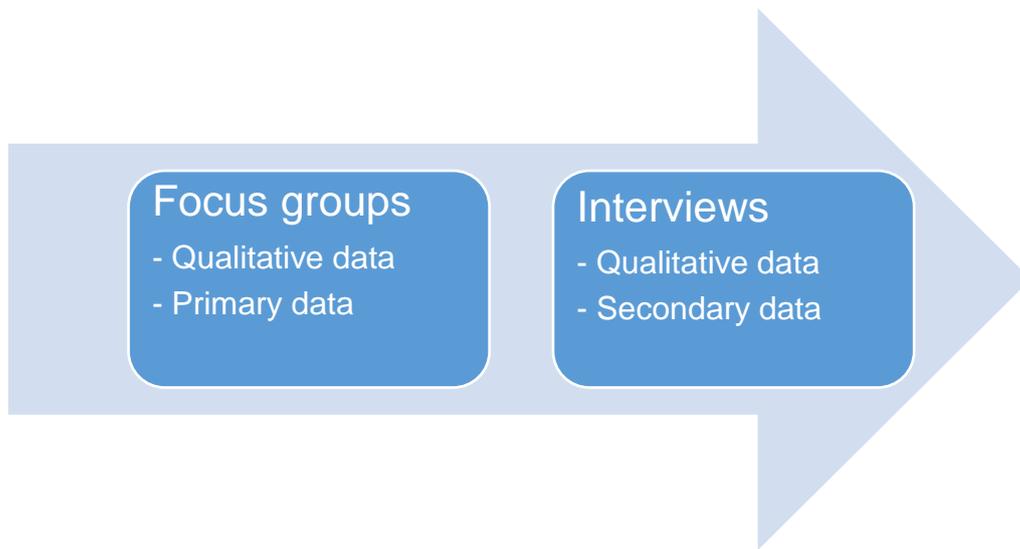
Figure 3-7: Methodological choice of the researcher

3.8 Time horizon

One mandatory part of the research design is the time horizon. At the beginning of the research, the time horizon that will be used for the data collection needs to be considered. Normally, two time horizons are differentiated. In simple terms, whether the research will take place in a particular time or over a given period with a series of data collection needs to be considered. The decision about this depends on the research question. The two different time horizons will be explained below:

3.8.1 Cross-sectional studies

A cross-sectional study is chosen when the research needs to be undertaken, for example in a special time frame. Through this study, data is gathered in different contexts to obtain a variety of special cases to a special point of time. This study of the time horizon is often used when the time is constrained or resources are limited. An example of when a cross-sectional

study is used is when it needs to be explained how factors or parameters are allocated in different organisations. The challenge with this study is that sometimes it is hard to select appropriate sample sizes, and explain based on these samples the existing phenomena under that study from the factors and give an explanation for the reasons for possible correlations. An advantage of a cross-sectional study is that it is inexpensive and an end is foreseeable, because the time frame is limited. A cross-sectional study is often used in a qualitative approach. In a lot of research, interviews are conducted over a special period of time (Bryman, 2012; Collis and Hussey, 2009; Saunders et al., 2012; Robson, 2002; Easterby-Smith et al., 2008).

3.8.2 Longitudinal studies

A longitudinal study is normally used when in a study change or a development needs to be studied. An example of a longitudinal study is the UK television series "Seven Up". In this series, the progress of a group of people was charted every seven years. With the help of this study, the researcher was able to gather a rich set of data that helped in developing theories about the development of humans (Adams and Schvaneveldt, 1991).

With the help of this example, it is understood that the data gathered through a longitudinal study is from the same group that is questioned several times over a long time period. This kind of study is normally used when time is not constrained and when the change or the development of a phenomenon needs to be investigated. The challenge of this study is that the research normally runs over a long period of time. Normally, these studies are time consuming and expensive (Bryman, 2012; Collis and Hussey, 2009; Saunders et al., 2012).

3.8.3 Researcher's decision

For the present research, a cross-sectional study is chosen. This type of study is chosen because of the available resources for the work and the time constraint that is connected with

this type of study. During the study, no change to or development of the collected data is expected.

3.9 Chapter summary

To understand the shape of the investigation, the research approach and philosophical perspective of the current researcher need to be understood. The goal of qualitative research is the development of new theories or hypotheses. Normally, this approach is conducted through a couple of special individual cases, which are chosen by the researcher. The evaluation of the data happens through an abductive procedure. On the other hand, quantitative research aims to test existing theories or hypotheses. As the researcher wants to generate a holistic framework, in other words a new thesis or hypothesis will be formed, for enabling the principles of BT for managing road infrastructure projects, a qualitative research method with an abductive procedure is chosen. From an ontological point of view, the researcher is using the nominalism approach due to the fact that interpretations are made from interpretations. Thinking in an ontological approach, the research uses the thinking of a subjectivist/constructivist, because the foundation of the knowledge is generated based on individual sciences. With the help of a qualitative approach, focus groups and interviews will be conducted. Finally, it can be said that a multi-method approach is chosen. The whole procedure of the philosophical perspective can be seen in Figure 3-8.
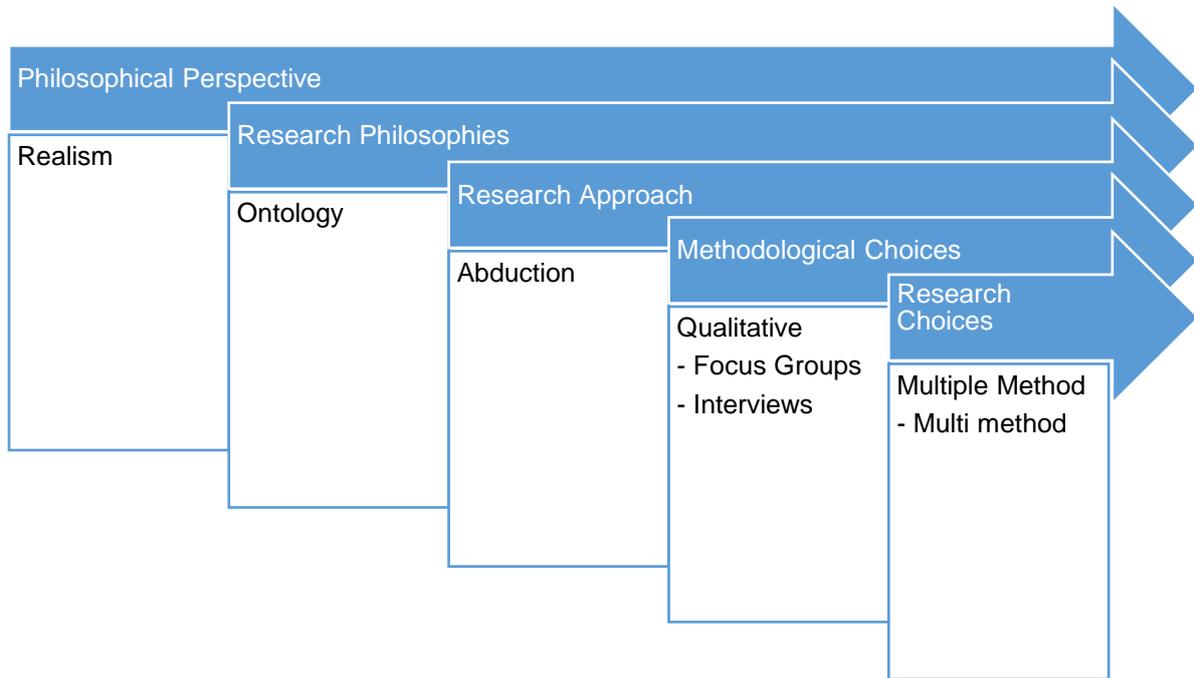
Figure 3-8: Summary research design method of the present study (created by the researcher)

4 Research method

4.1	Introduction
4.2	Selected research strategy
4.3	Data collection and analysis
4.4	Focus Groups
4.5	Semi-structured interviews
4.6	Research framework
4.6	Ethical compliance
4.7	Summary

Figure 4-1: Overview of chapter 4 – research method

4.1 Introduction

The previous chapter ended with the explanation of the research strategy for the holistic framework that needs to be developed through the thesis. The holistic framework is the final goal of the whole research. This chapter will define the techniques used to collect the data for the research at hand. As a multi-method research approach, with qualitative data, is chosen in the current research, the collection of qualitative data will be explained in more detail in the section on research methods.

Chapter 3, on the research methodology, discussed the philosophy, methodology and research choices that need to be made when a research design is constructed. As described in the above chapter, it is mandatory for the researcher to understand why a special philosophy and methodology were chosen. Either is it a qualitative approach or a quantitative approach. The two research methods differ in their target intention. While qualitative research aims to

gain deep insight and a comprehensive understanding of the research subject, quantitative research aims to examine large amounts of material. As the researcher's study is in the field of an area in which no research has been conducted so far, the most important thing is to gather deep insight and, because of that, qualitative research, in terms of focus groups and semi-structured interviews, was chosen.

As within the chapter on research methodology, existing tools and methodologies are adopted in the current chapter, and a detailed discussion will be developed regarding the chosen research method based on the research question in this study. Hence, the chapter provides a step-by-step guide through the data collection and data analysis process, dealing with the logic around the research choices that were made.

Although the research question has already been mentioned in the introduction chapter, it is repeated here to keep in mind what will be answered at the end of the thesis based on the literature review, the conducted focus groups and the conducted semi-structured interviews. The research question that has been developed and should be answered in the doctoral thesis is the following:

"How Can the Principles of Blockchain Technology Be Utilised for Managing Road Infrastructure Projects?"

So that the research question can be investigated in a structured way, the following aim and objectives have been synthesised. With the help of these aim and objectives, a defined approach is predetermined.

1. To identify in which aspects of managing projects the principles of Blockchain Technology can be effectively utilised. (RO 1)

2. To explore the interrelation between the mechanisms of the principles of Blockchain Technology and the performance of Managing Road Infrastructure Projects. (RO 2)

3. To appraise the barriers to and the enablers to the utilisation of Blockchain Technology in the context of Road Infrastructure Projects. (RO 3)

4. To develop a framework for the utilisation of Blockchain Technology to support the management of Road Infrastructure Projects. (RA)

The purpose of the initial research objective, RO 1, is to consider that, with the help of focus groups and based on the conducted literature review, an answer will be found regarding the stage of digitisation in which the construction industry stands in the era of industry 4.0. The principles of BT are used as the technology in industry 4.0. Based on this, the question will be answered which beneficial parameters of BT can be effectively used in the process of project management in the field of road infrastructure projects. RO 2 builds on RO 1 and addresses the topic through a combination of the literature review and the collected data through semi-structured interviews. The semi-structured interviews were conducted firstly with experts in the field of road infrastructure and secondly with experts in the area of BT. The third research objective, RO 3, expands on RO 2 and will discuss what the barriers to and the enablers of the principles of BT are. This will also be investigated with the help of semi-structured interviews. Finally, with the research aim, RA, a holistic framework for the implementation of the principles of BT to support the management of road infrastructure in terms of an information exchange, project will be developed.

The already mentioned methods such as semi-structured interviews and focus groups will be explained in the following sub-chapters in more detail. Prior to discussing the procedure of the focus groups and the semi-structured interviews, general data collection steps, like data organisation, the procedure and the analysis process itself, are explained as an introduction.

To obtain an answer to all of these it becomes clear that the research method is important and mandatory for the whole research, as it builds the essential basic structure for the whole investigation.

Regarding the methods taken in the study, the procedures, the data collection approach, the organisation of the research and the analysis of the whole procedure need to be explained in

every detail (Moustakas, 1994). Hence, this chapter will provide an overview focused on the evaluation and the reliability of the research approach.

The current research includes the following two methods (Saunders et al., 2012):

> ➢ Focus group: a focus group can be defined as a group interview with a topic defined in advance and a focus on an interactive discussion between the different participants.

> ➢ Semi-structured interview: a semi-structured interview is an interview with a prepared structured and phrases, but the interview itself is flexible, so that the researcher does not have to use the questions from the prepared questionnaire as a rigid template.

4.2 Selected research strategy

This section provides an account of the data collection method in this study. In this section, an overview is generated that describes the methods that will be utilised in the research. For collecting the qualitative data, a multi-method research type was chosen. The techniques that are chosen for this doctoral thesis are to conduct evaluation focus groups, and assemble semi-structured interviews. Both methods have specific advantages and with the help of both methods a notable result is expected (Morgan, 1996). The mentioned advantages are described in more detail below, in Figure 4-2.

Method	Description
Literature review	The literature review gives a foundation for the whole study. Mainly, the literature review supports the researcher to obtain an understanding of the state of art of the four main topics discussed in the research: Project management, road infrastructure projects, BT and information exchange. Further, Meredith (1993) mentioned that a literature review is required to distinguish patterns, themes and issues for defining the gap in the knowledge at the end (see section 2.6). In conclusion, the literature review is necessary for the development of the holistic framework in the end.
Focus group	Focus groups are a great method for the researcher to obtain an understanding of the knowledge and the experiences of the participants. As it is an open discussion between the participants, the participants exchange many experience. Smithson (2008) supports this statement, as it is brought out that focus groups enable the formulation of understanding and insights. In the present research, the focus groups provide the basic understanding for answering the research objectives (Morgan and Krueger, 1993). Therefore, in the research two focus groups were conducted with five and six participants with experiences in the field of project management. Smithson (2008) stated that a combination of focus groups and interviews delivers a strong approach in terms of the research methodology.
Semi-structured interviews	Easterby-Smith et al. (1991) reported that the conduction of an interview is one of the best methods for collecting useful information during a piece of research.

Figure 4-2: Description of the methods

4.3 Data collection and analysis

Prior to a detailed explanation of the chosen methods in the current research, a general overview about the data handling and the organisation of the data will be given.

4.3.1 Participant information sheet and consent form – data collection

Before the researcher was able to start collecting the data, the participants needed to be informed about the procedure. It is mandatory for the participants to be given an understanding of how the data will be treated and what will happen during the data collection, and about the research itself, and it is also significant for them to understand what will happen with the data when the research is finished.

In order to identify the participants for the focus groups or the semi-structured interviews, the potential participants were asked to study the *participant information sheet* that was provided by the researcher. The participant information sheet is shown in appendix B. If they agreed with the information on the participant information sheet, they were requested to accept and sign the provided *consent form*.

The *participant information sheet* is structured into the following sections:

> ➢ It is explained, with which methods the researcher will conduct the study.
>
> ➢ The purpose of the study is explained with the help of the research objectives.
>
> ➢ The participants are informed why they have been invited to the study and if they have to take part.
>
> ➢ In terms of the anonymity and confidentiality, it is described what will happen if the participants take part.
>
> ➢ The procedure of the recording of the data collection is explained.
>
> ➢ The possible disadvantages or risks from taking part are clarified together with the possible benefits of taking part in the study.
>
> ➢ The participants are informed about how the data they provide will be treated and that taking part in the study is kept confidential.

> One of the last sections defines what will happen to the results of the study and who the study will review. So that the participants feel confident, what will happen if something goes wrong is also explained.

> Finally, a data protection notice is mentioned with contact details for further information.

After reading and studying the participant information sheet, each participant had to accept the following statements on the consent form: The consent form is shown in appendix A.

1. I confirm that I have read and understand the information provided for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and that this will not affect my legal rights.

3. I understand that any personal information collected during the study will be anonymised and remain confidential.

4. I agree to take part in the above study.

5. I understand that the interview will be audio recorded and I am happy to proceed.

6. I understand that parts of our conversation may be used verbatim in future publications or presentations but that such quotes will be anonymised.

Finally, this document is signed by the researcher and the participant. Both the researcher and the participant have a copy of the consent form. If the procedure of the participant information sheet was read by the participant and the consent form was signed, the researcher was able to start conducting the focus group or the semi-structured interview.

4.3.2 Data handling and storage

After the researcher obtained the signed consent form, the focus groups and semi-structured interviews were conducted.

The procedure in general was similar for both the focus groups and the semi-structured interviews. The researcher gave an introduction into the research, conducted the focus group or the semi-structured interview, transcribed these data and finally analysed the data with the help of thematic analysis.

After every transcription of the data collection, the recorded file and the transcribed document needed to be stored in a safe place. The storage place should only be accessible by the researcher and needs to be saved with a secure password. Any electronic data containing personal information and confidential data in terms of the research, are stored securely on LJMU password-protected computers. To preserve anonymity, the file of the recording and the documents should not indicate the identity of the participants. The described procedure was utilised through the whole research. To guarantee participant anonymity, every participant was given a special code by the researcher. Thus, the anonymity of the participants is preserved through the whole research and also when the research is finished.

4.3.3 Qualitative data analysis

Section 3.5.2 mentions what qualitative data are. The following section will support in answering the question about what the understanding of qualitative data analysis is. The understanding of qualitative data analysis is a proceeding in that the researcher transforms the collected data into an explanation, understanding or interpretation. It is important, as mentioned in Chapter 3, as the researcher is identifying someone´s interpretation of a subject or a theme; the researcher is analysing why a participant has that special point of view of a topic and how the participant came to that special point of view.

Figure 4-3: Three steps before starting with the analysis

As visualised in Figure 4-3, it is mandatory to consider three steps before starting the analysis. To begin this process, the design of the project needs to be planned and it needs to be understood, mainly by the researcher, what the purpose of the study is, and what important information needs to be identified. After the purpose was understood, it was first necessary to check the sources and resources and where they come from; this related mainly to the literature review. Following this treatment, the sources need to be checked to see if they are reliable. After all of these three steps are understood, checked and investigated, the analysis can start.

4.3.4 Recording qualitative data

So that the data can be documented and analysed, the research process also includes the recording of the qualitative data. Through the recording procedure, a high-quality recording is proposed to prevent challenges in the later research (Johnson, 2002). DiCicco-Bloom (2006) mentioned that weak batteries, numerous background noises and a poor placement of the recording machine affect the quality of a recording. All qualitative data gathered through the data collection are recorded through the researcher's mobile phone and through the Microsoft application Teams. The two data sources have been chosen in case one data source breaks. The advantage of using Teams is that with the help of Microsoft Stream the recorded sessions are automatically transcribed, so it is easier for the researcher to transcribe the data. The automatic transcription by Microsoft Teams also gives the researcher a quality check of the transcribed data. The reason why the focus groups and the semi-structured interviews were

recorded, is because this gives the researcher the possibility to focus on asking the questions and concentrate at the same time on the words of the interviewee during the data collection. After the interview or the focus group is completed, the researcher is able to re-listen it. The theme of recording the data was also mentioned in the participant information sheet. By signing the consent form, the participants confirmed that the researcher is allowed to record the conduction of the focus groups or the conduction of the semi-structured interviews.

4.3.5 Transcribing qualitative data

One of the advantages of transcribing the data is that the researcher is able to use direct quotes from the data.

Qualitative methods offer an effective way of conducting inductive research (Creswell, 2009). To use data from qualitative research, the first step after the conduction and the recording, is to transcribe the data. Transcribing the data, these are the data from the focus groups and the interviews in the present research, is a strenuous and time-consuming phase (Magnusson, 2012). This needs to be considered during the whole step of the data collection. The procedure for transcribing a recorded session is that small segments of the speech need to be listened to and played back word for word. A recommendation is to listen to short segments, because sometimes it is hard to understand what the speaker has said. This leads to the fact that the transcription should be made straight after the recording. The interviewer is still in a position to remember the spoken words, attitudes and the body language of the participant. Microsoft Stream is the tool that will be used in the present research for transcribing the interview data.

Although the only content that will be analysed is the spoken words of the participants and not of the researcher, the words of the researcher also need to be transcribed for completeness.

4.3.6 Tools for the analysis

It is necessary to clarify exactly what is meant by analysing the research data. Two procedures were used to analyse the data in this study. In the first step, the researcher analysed the data on paper. As the second step, the software tool NVivo was used.

Since qualitative data analysis software programs were first developed, these tools have become well known for the analysis of qualitative research data. Tesch (1989) mentioned that, with the help of computer-assisted analysis software, during the analysis time can be saved, procedures can be generated in a more structured way, data completeness can be ensured and a kind of flexibility during the process is guaranteed.

With the help of these tools, it is possible to code and to fetch data by allowing complex and extensive coding schemes to be made more easily. Based on this, statements and hypotheses can be generated from the collected data (Richards & Richards, 1987; Hesse-Biber et al., 1991). Another advantage of these analysis software programs is that the data analysis can be improved and the whole analysis process is more transparent and more comprehensible (Fritz, 1990; Morison & Moir, 1998).

There are a number of instruments available to support the analysis procedure. Although the tools do not analyse the data, they do offer a vast aid in the management of the data and analysis process (DiCicco-Bloom, 2006).

4.3.6.1 NVivo 12

To facilitate the analysis, the CAQDAS (computer added qualitative data analysis software) package NVivo 12 will be used as one of the main analysis tools.

NVivo 12 is a tool with three different functions. Firstly, it is an organising and thinking tool. The tool helps in managing data and in operating ideas. With the help of this tool, thematic maps and conceptual maps can be generated based on collected data, gathered knowledge

and new ideas. In terms of an analysis tool, data can be requested. Current or complex questions can be asked of the data and all relevant answers on a question can be required. It also can be used as an experimental tool for visualising and developing data in terms of relationships or differences; these evaluations can then be used in reports, journals or dissertations (presentation, training, Liverpool John Moores).

The main advantages of NVivo 12 are that this tool is portable, it has a high security level, it supports searching, it is adaptable, it promotes in-depth analysis and with it an auditable trail is available (Woods et al., 2016).

4.3.7 Thematic analysis

Thematic analysis is a widely-used qualitative data analysis method. It is one of a cluster of methods that focus on identifying patterned meaning across datasets (Bould, 2018). The method which will be used for the thematic analysis is the method of Braun and Clark. To categorise the data from the focus groups and the interviews, they have to be developed in categories and these attached to meaningful chunks of data. The analysis will be executed as mentioned in the following (Saunders, Lewis and Thornhill, 2009):

- Deriving categories

- Unitising data

- Recognising relationships and developing categories

- Developing testable propositions

- Quantifying your data

- Structuring data using narrative

Braun and Clarke (2006) recommend a six-step guide for conducting the analysis:

Step 1: Become familiar with the data	Step 2: Generate initial codes	Step 3: Search for themes	Step 4: Review themes	Step 5: Define themes	Step 6: Write-up

Figure 4-4: Six steps for conducting the thematic analysis

The initial step in the thematic analysis is reading and re-reading the transcripts from the data collection. It is essential that the researcher is familiar with the collected data. In this step, it is advocated that the first notes are written down. In step 2, the data should be managed in a reasonable and systematic way; that is the coding step. Coding means that a lot of data are reduced to pieces of the same meaning. In step 3, codes are brought together to themes. Step 4, 'review themes', investigates if the chosen themes make sense and if the collected data do support the themes. When different themes overlap, it also needs to be investigated if they are separate themes or if they can be put together. Step 5 is the final improvement of the themes. In this step, it makes sense to generate a thematic map which will understand how themes relate to each other and what themes and sub-themes exist. Finally, in step 6 of the thematic analysis the writing up is carried out; this is usually as a report article or a dissertation. In the previous section it was explained in a general overview, how the data will be managed and analysed. In the next two sub-chapters the procedure of conducting a focus groups and conducting a semi-structured interview will be discussed in more detail.

4.4 Focus groups

The focus group method belongs to the qualitative research approach. With the conduction of a focus group by bringing a group of individuals together, eliciting a topic and asking the group to discuss it, meaningful information on a particular topic emerges. A focus group works best if the participants share their opinions and views of a theme in a broad view. The method of a focus group enables an understanding about the 'why' behind the 'what' of every single participant (Morgan, 1990).

According to Bradbury-Jones et al. (2009) and Palmer et al. (2010), focus groups can be used when a phenomenological study is conducted. In recent years, the utilisation of focus groups in phenomenological studies has increased. As this type of study is normally investigating personal experience and not group interactions, as this is done through focus groups, there are still some sceptical voices (Smith, 2004). Finally, Smith (2004, p.50) stated that, if "the researcher is convinced that participants are able to discuss their own personal experiences in sufficient detail and intimacy, despite the presence of the group, then the data may be suitable". Hence, it needs to be guaranteed that the focus group is the correct method for the current research.

The sociologist Robert Merton and the market researcher Alfred Goldman developed the idea of the focus group. This underlying theory was summarised in four major objectives, the focused research, the group interactions, the in-depth data and humanistic interviews, by Stewart and Shamdasani (2015):

> ➢ Focused research: the researcher has an interest in learning the actual situation and conducting a study about a special and precise situation.

> ➢ Group interactions: the interactions that are made in a focus group are influenced by group compositions, interpersonal influences and research environment factors. The researcher is interested in this type of method to understand the dynamic of the group that is having consequences on individuals' perceptions, information processing and decision-making.

> ➢ In-depth data: researchers expect to obtain data which go beyond superficial explanations through a relatively small number of questions which are focused on a certain topic and discussed in detail.

> ➢ Humanistic interview: the interview includes empathy, openness, active listening and various types of interactions.

As with every other research method, focus groups have strengths and weaknesses. On the one hand, the main strength of the use of the focus group method is that it is a method with an efficient data collection, that on a special topic can be focused and the faith in group interactions. On the other hand, weaknesses of the method are that the research can influence the group, that a participant in the group can influence other participants, that a participant can have influence on the opinion of the others, or that it is questioned if the theme is appropriate (Morgan, 1997). As the strengths outweigh the weaknesses, the researcher decided that the focus group approach is the appropriate qualitative method for the current research.

4.4.1   When to use a focus group

To gather the data for the first objective, "To identify in which aspects of Managing Projects the Principles of BT can be effectively utilised", the focus group method was used. This is a selected research technique, in which the data are collected through a group interaction with a topic the researcher has put forward. The difference to other research methods, for example interviews, is that during a focus group session no one should operate like an interviewer. Because of the steadily increasing implementation of the focus group method, the recent years have shown that it is a successful research method (Henderson, 2017).

A focus group is a research method in which data are gathered through a group discussion with a defined topic (Morgan, 1997). It also is defined as a group interview and is a well-established and important research method (Bryman, 2012). Sociologist Robert Merton and his colleagues invented the focus group and it has been used since the 1920s (Wilkinson, 1998). In 1946, this method was used for marketing research and is part of the social sciences. Since that time, the method has become indispensable (Stewart et al., 2006). Many researchers have utilised focus groups for measuring perceptions that are only accessible with the help of group interaction (Smithson, 2008). A major advantage of a focus group is that it can be seen as a controlled group discussion, which is set through a discussion (Smithson,

2000). When a focus group is conducted, three characteristic features need to be distinguished (Wilkinson, 1998). Firstly, a focus group provides an approach of the conceptions and requests of the participants. Secondly, it encourages the preparation of a detailed report. Lastly, it offers the opportunity to observe the process of collective meaning-making. This method is used in social science research for collecting qualitative data (Morgan, 1997; Smithson, 2000). Focus groups offer an effective way of answering the research question, especially when data need to be collected which are difficult to obtain (Morgan, 1997). The benefit of the focus group approach is that it can be used to study the ideas and experiences of a targeted group of people who are discussing a special and focused subject (Morgan and Krueger, 1993).

4.4.2 Explanation of focus group discussion and focus group interview

Another term for the focus group is group setting. A focus group/group setting is a focus group interview in which a group of people are being interviewed together. The role of the interviewer in a focus group is as moderator. The moderator is only asking the questions; the discussion itself is between the interviewees and not between the interviewer and the interviewees (Qu and Dumay, 2011). Boddy (2005) defined focus group discussions and focus group interviews. In a *focus group discussion*, the participants discuss the topic with each other and the researcher mainly adopts the role of a moderator. Normally, the whole discussion is in a friendly mode. The participants discuss, try to convince each other of their viewpoint, they ask each other questions and finally disagree or agree with each other. The moderator brings new topics into the discussion and asks for a deeper understanding of the participants' knowledge. A *focus group interview* is different to a focus group discussion. The researcher (moderator) is controlling the participants in a way in which they act as respondents. Group discuss with each other is avoided. Mainly, the discussion is guided through the moderator and the participants individually. Focus group discussions are more common in qualitative research than focus group interviews, which leads to the fact that in the present research a focus group discussion is chosen.

4.4.3 Sampling strategy

According to Silverman (2013), is the strategy for the use of a focus group dependent on the research problem. For example, when an in-depth knowledge needs to be derived from a topic it is helpful to discuss this research problem with a group with several participants. The aim of this strategy is to gather an insight and understanding into the in-depth knowledge within the groups (Morgan and Scannell, 1998).

When a focus group is conducted, its composition needs to be considered as this is one of the main elements in the analysis (Barbour, 2007). As Stewart and Shamdasani, 2015) noted, interpersonal relationships play an important role. Interpersonal factors are influences like the group cohesion and the social power that exists in a focus group. Hence, several parameters need to be considered in the constitution of a focus group:

> ➢ Homogeneity: when the homogeneity in a focus group is discussed, this refers to the background of the participants in terms of their profession, for example (Morgan, 1988). It is mainly about the interoperability of the participants as the interoperability facilitates the discussion of the theme of interest (Morgan and Scannell, 1998). This is a significant issue for the researcher, as it needs to be ensured that there is no authority relationship between the focus group participants which could suppress free speech.

> ➢ Segmentation: according to Morgan and Scannell (1998), segmentation is the creation of different homogenous focus groups based on special criteria that ascertain that the researcher's interest is considered. In the current study, segmentation is not undertaken as the split between project managers and engineers will not bring any value to the research.

> ➢ Acquaintance: this refers to whether the participants are strangers or if they are well known to each other (Morgan, 1997). Usually, it does not make a difference, but it is important to question if the participants within a focus

group can discuss with each other in a comfortable way. In the current

research, it is not important as within every focus group the participants are

from the same company and are well known to each other.

Basically, it is mandatory that the participants within a focus group are comfortable to talk to

each other, so that the aim of the researcher, gathering data through a productive discussion,

will be achieved (Morgan and Scannell, 1998). This is significant for every single focus group.

Hence, the configuration of the focus groups in the current study is discussed in the next

section.

4.4.4 Conducting focus groups in this research

In the following section, the organisation, the procedure and the analysis of the focus groups

will be described based on the arguments in the sub-chapters above.

4.4.4.1 Organisation of the focus groups

Companies Selection Criteria

The first step in the process of the focus groups was to define the selection criteria for the

companies that will attend the focus groups. So the researcher defined selection criteria

(Knoedel, 1993). Criteria for selecting the companies were as follows:

> ➢ Work experience in project management;

> ➢ Experts in the field of project management;

> ➢ Interest in new technologies.

With these criteria it is ensured that the companies participating are having the right

experiences.

Participant Selection Criteria

Knoedel (1993) mentioned that the researcher has to define selection criteria for the conduction of a focus group. This is an important step for the data collection. The selection criteria for the exploratory focus groups are:

> ➢ At least three years' work experience

> ➢ Experienced engineer in the field of road infrastructure projects (municipalities, highways, the rail sector, bridges or airports)

> ➢ Employed as a project manager, an engineer, a consultant or expert in the field of project monitoring

The background of all participants in both focus groups is in the field of civil engineering and their profession is working as a Project Manager. All Project Managers had at least three years' work experience and were acting in a consulting function next to their function as project manager.

These selection criteria were chosen to ensure that the participants have a general and wide understanding of the field of road infrastructure projects. The choice of experienced participants gave the researcher the opportunity to talk to people with a high level of knowledge and skills.

4.4.4.2 Procedure of the focus groups

The conduction of the focus group is based on the framework provided by Knoedel (1993). To set a well-structured focus group, the four steps see Figure 4-5 need to be adhered to.

Figure 4-5: Conduction of a focus group (Knoedel, 1993)

In a first step, the discussion guidelines need to be formulated and the objective needs to be identified. Building on this, a target group of participants needs to be described. In advance, the researcher needs to think about the number of the focus group sessions and for the close a proper analysis is needed.

Set objectives

In order to understand how to conduct a focus group, the discussion guidelines need to be determined. In principle, two types of guidelines are differentiated, the topic guide and the questioning route. Krueger (1998) points out that in the topic guide a list is generated which points out the study topics. Within the questioning route, a complete list of questions in whole sentences is generated. The role of the presenter in the focus group should not be underestimated. The more structured a focus group is, the more involvement by the host is to be expected (Morgan, 1997). The recommendation by Wilkinson (1998) is to test every quantitative research method in a pilot project. This recommendation was realised by the researcher and the focus groups and the semi-structured interviews were tested in pilot projects.

Target the participants

Secondly, an in-depth investigation needs to be conducted which will analyse what the participants' characteristics have to look like. For the whole research, it is mandatory that the right people are participating (Sage, 2009). In general, there are two different kinds of participant groups (Fern, 2001). In one option, a homogeneous collocation is possible and the other option is a heterogeneous collocation. One major advantage of homogeneous collocations is that a more in-depth conversation can be held. The reason for this is that all participants have experiences in the same area, so there is more rapid discussion about the required topic in a focus group (Fern, 2001). The other advantage is that participants feel more self-reliant, because it is known that all participants have the same experience (Knoedel, 1993).

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Another recommendation for conducting successful focus groups is to make small groups. The major advantage for this is that the participants have more time to talk about the topics than this is possible within large groups (Fern, 2001; Morgan, 1997). Around five participants is ideal (Morgan, 1996). The idea is to have small groups, so that all participants will be more active and feel more confident of stating their knowledge and their experience (Sim, 1998). Another advantage of small groups is that they deliver more in-depth information in a short period of time (Knoedel, 1993).

Prior to planning the number of participants for a focus group, the following questions need to be asked (Morgan and Scannell, 1998, p.73):

> ➢ Have the participants a high level of involvement with the topic?
>
> ➢ Are participants emotionally caught up in the topic?
>
> ➢ Are the participants' experts or do they know a lot about the topic?
>
> ➢ Is the topic controversial?
>
> ➢ Is the topic complex?
>
> ➢ Is the goal to hear detailed storied and personal accounts?
>
> ➢ Do recruitment factors limit other options?

As most of the questions can be answered with a "yes", smaller groups are recommended for the current study. The researcher decided that in the current research five to six participants will be involved in one focus group.

Determine sessions

In Knoedel´s (1993) third step, when preparing to conduct a focus group, the number of sessions needs to be defined. The factors affecting the number of sessions are regulated by the variability of the participants, the level of structuring and the availability of the preferred participants (Morgan, 1997). Morgan (1997) points out that, if more focus groups are

conducted, a major research team is needed. To gather a reliable answer to the research question, a required number of sessions is necessary. From Knoedel's (1993) perspective, this can be achieved by conducting two homogeneous focus groups. Because of this recommendation, the researcher decided to undertake two homogenous focus groups for the current study.

Analysis

Knoedel´s (1993) fourth step for the focus group procedure is the analysis step. The approach in the analysis is the same as in every other qualitative method evaluation. The difference between the analysis of an evaluation of interview data and focus group data is that it is unavoidable that the participants within a focus group will influence each other (Morgan, 1997). Smithson (2000) points out that in the evaluation of the focus group data there is no right or wrong. The analysis of a focus group is the product of a human with a certain interactivity.

Nevertheless, it needs to be considered that the data analysis in a qualitative research approach is more than just analysing a text. According to Creswell (2009), proper qualitative research involves the preparation of the data, the execution of different analyses and the interpretation of the data.

The process and the purpose of these focus groups is to development a strategy: how BT can be described in an ordinary way for the implementation of the interviews. The focus groups will be the basis for the preparation of the interviews.

The purpose of the first objective is to obtain a generic understanding of how much knowledge project managers have in the area of BT. With the help of the results of objective 1, the interview questions will be prepared, which will be in the field of road infrastructure projects.

The idea of starting with focus groups in the whole research is that different people in a company can come together and discuss internally about the experience they have of industry 4.0 and the principles of BT. The introduction of industry 4.0 was chosen because BT is part

of it. Starting with a focus group makes sense in this stage, because in a group it is easier to share thoughts about new technologies, especially when it is that new, as is the case with BT.

As the theme of the thesis is utilising a new technology, the concept of guiding through a presentation together with questions was chosen. The themes needed to be discussed precisely to generate high-quality data. The researcher started with a general introduction and focused on two main topics during the focus groups. As the type focus group discussion was chosen, the focus group was structured in terms of the researcher guiding the conversation, so that the different focus groups could be compared with each other. But the researcher was only acting as the moderator and let the group members discuss with each other and did not interrupt them.

The data collection of the whole study started with the exploratory focus group. The first objective which needed to be investigated was "To identify in which aspects of managing projects the principles of BT can be effectively utilised". This objective is crucial for the whole study. With the results of this focus group, the foundation for the next steps is laid. Thus, it was mandatory that the right participants were chosen.

The first step was to plan and conduct the exploratory focus group. The exploratory focus group was chosen as the primary method. Thus, several selections needed to be made:

> ➢ Method of the discussion concept (topic guide through a presentation, guide through questions or a mixture of both)

> ➢ The number of topics to be discussed

> ➢ Dimensions of the structure of the focus group

Many researchers have utilised focus groups to measure their collected data in qualitative research. In the exploratory focus groups in the present research, around five participants and one observer were involved and one focus group took 90 minutes. As is recommended, two

focus groups were conducted in the present research. When the participants were invited to the focus group, the purpose of the research was clearly explained to them.

In the following figure, the key steps of the focus groups are demonstrated.
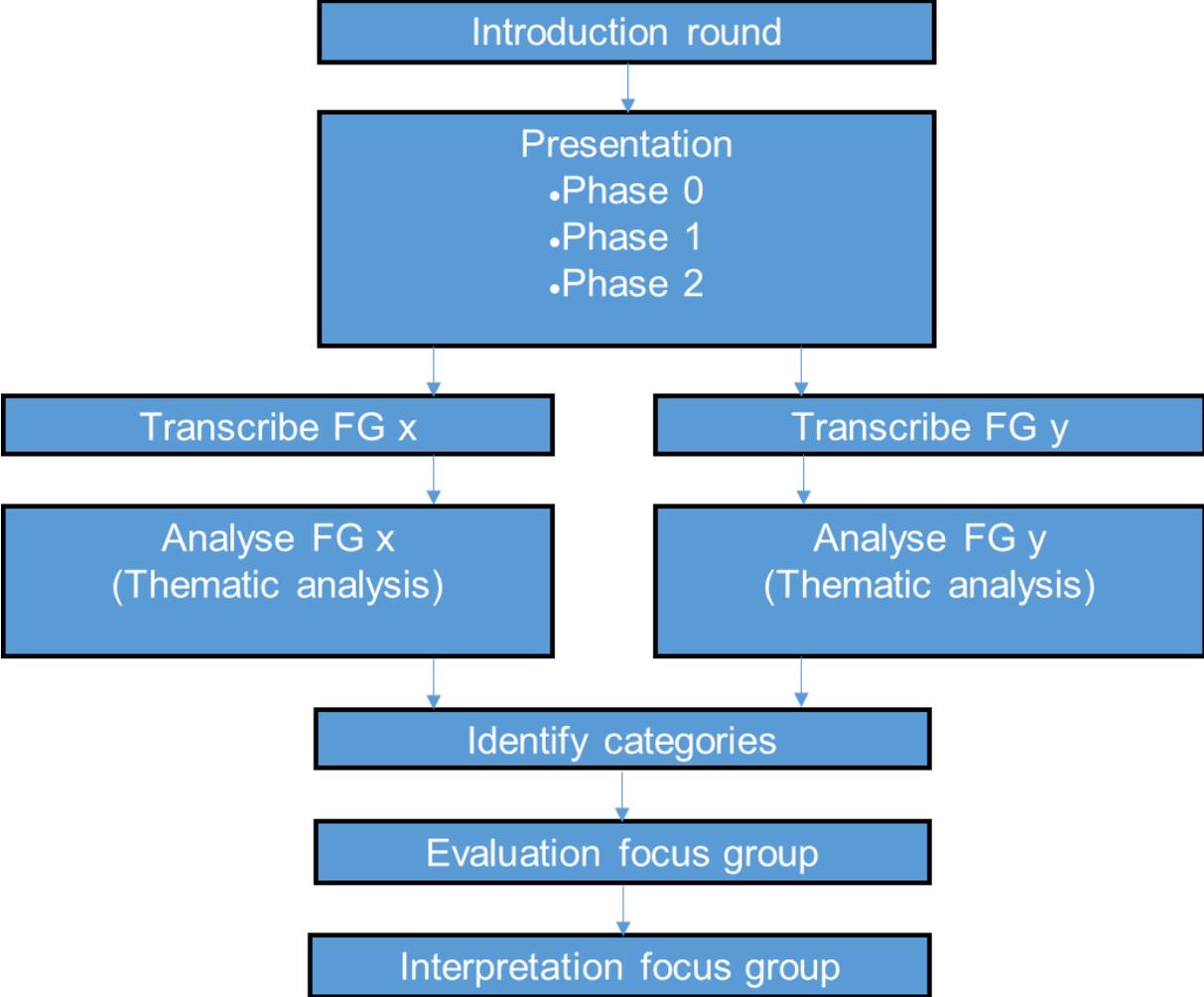
Figure 4-6: Key steps of the executive focus groups

Related to the first phase of the research, in total two focus groups were conducted. Both focus groups were transcribed and analysed with the help of thematic analysis. In the next step, the results from the two executive focus groups were put together. Previously, a pilot focus group was conducted. The idea of the pilot focus group was to find out the best way to arrange a focus group for the present study. During the pilot focus group, the researcher learned how to deal with the timing. The researcher also realised that it would be a huge benefit if the focus

groups could include an observer who could support the researcher, providing feedback on the participants' reactions and the researcher's presentation. Another result of the pilot focus group was to prepare all the materials in advance. The preparation included cards that would help in explaining the principles of BT, for instance. For the general participation in the focus group, the participants and the chosen companies needed to have specified criteria. For the executive focus groups, the researcher was looking for individuals who held or had held project management roles with employment in the private, public or voluntary sector. If this relevant experience did not exist, the potential participants were not allowed to participate. The two focus groups were executed in two different companies, in different locations. These two focus groups were analysed and the results of this will be used for the further research in this thesis. After the pilot focus group was completed, the researcher carried out the first proper focus group with Company X. Company X works in the field of Lean Management and Change Management. The second focus group took place in Company Y. Company Y is an international consulting company in the field of construction and in the real estate sector. Its main services are development, process consulting, infrastructure consulting, project management and engineering.

Figure 4-7: Executive focus group with company x

Both focus group sessions started with an introduction round. During the introduction round, every participant explained about their existing working experience, about the projects they were part of and the available knowledge of BT. Conspicuous in Company X was that most of them already had prior experience with BT. The reasons for this were different. One reason, for example, was that the participants were already interested in the technology itself and in new technologies in general. Other reasons were that one of the participants had invested in bitcoin some years ago and another had experience with BT during their master´s thesis. As the participants already had a basic knowledge in the field of BT, it was easy for the researcher to conduct the focus group, because not much explanation was necessary in terms of that complex technology. Although the participants had existing knowledge about the technology, for the researcher was it important to put the focus on the principles of BT. Focus on the principles of BT is important, as the goal of the study is not to implement a BT into a project. The goal of the study is to use the principles of BT and work with these advantages in future projects.

The situation regarding the knowledge of BT was completely different in the focus group in Company Y. None of the participants had any experience with the technology, and the only knowledge they had was from the news or with a correlation to Bitcoin Blockchain. So at the beginning it was a challenge for the researcher to explain that the focus was on the principles of BT and not the technology itself.

After the researcher explained about the principles of BT, both focus groups had the same state of knowledge.

Although the state of knowledge, before the researcher's explanation, in terms of the technology was different in the two focus groups, it should be said at the outset that the result in the end was similar in both focus groups, in Company X and in Company Y.

All of the attendees in both focus groups were very positive and interested in supporting the research by their participation in a focus group.

4.4.4.3 Analysis of the focus group data

The analysis of the data of the focus groups was conducted through six steps.

Step 1 – The researcher´s personal experience is described

Starting with the analysis of the data the personal experience of the researcher has to be described. To focus completely on the participants this step is executed to put aside the personal view (Creswell, 2013; Moustakas, 1994).

The researcher has a significant amount of experience in the field of road infrastructure projects. She is educated in the area of civil engineering with economics and is having a master´s degree in the area of civil engineering with economics. She worked for 4 years in a British company as a project manager on various international projects.

On the basis of this, the researcher believes there is an urgent need to improve the collaboration of the different stakeholders in a project regarding trust within road infrastructure

projects. The researcher also believes that this theme will be improved with the help of a new technology as the BT

Since the experiences and beliefs of the research are understood now the next step in the data analysis can be viewed in more detail.

Step 2 – The data are prepared

As it was already explained were all focus groups audio recorded. The next step of the analysis involves the transcription of the recorded data into text data. The transcription of the data is the basis for the analysis (Stewart and Shademasani, 2015). For the work presented here a detailed one-to-one transcription is produced. Next to the audio recorded data also the observer´s notes are taken into account and added to the transcription to include non-verbal communication and therefore obtain a more complete picture (Stewart and Shademasani, 2015).

Step 3 – The data are read

After the transcription is completed the transcript will be read through carefully several times to gather an understanding about the general sense of the data (Creswell, 2009).

Step 4 – Significant statement are identified

After the general sense of the data is understood a list of significant sentences and phrases is generated (Creswell, 2013). This task was undertaken with the help of NVivo and the coding function of the tool is used to identify the important sentences.

It needs to be taken into account that there are three strategies to code focus groups (Morgan, 1988, p.60):

1. all mentions of a given code
2. whether each individual mentioned a given code or
3. whether each group discussion contained a given code.

Step 5 – Themes are created

Creswell (2013) mentioned, that this step is mandatory for the identification of the main themes. The fundamental statements are grouped in themes with a three level hierarchy: high-level theme, medium-level theme and meaning-level theme (see Figure 4.8).
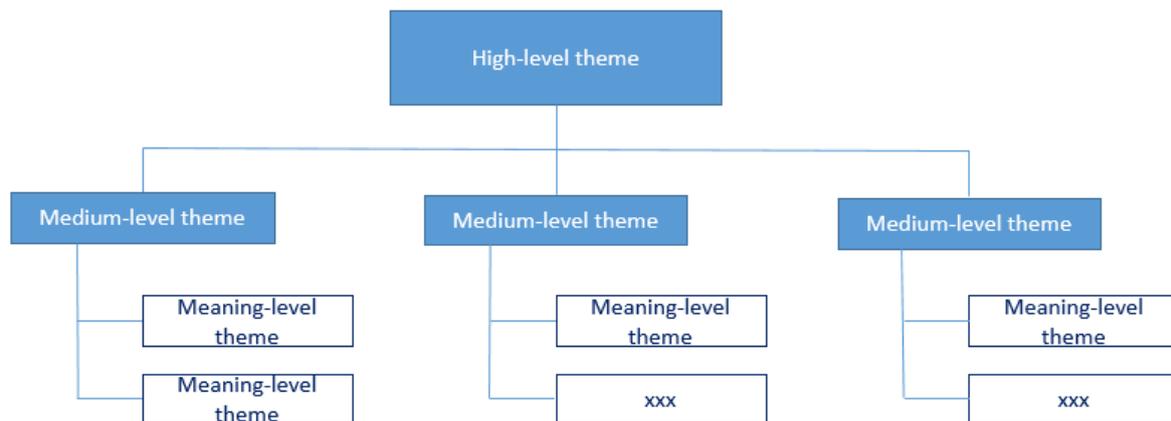
Figure 4-8: Focus groups - theme hierarchy

Step 6 – Composite description is written

The description written in step 6 is divided into two parts, into the textual and into the structural part. The textual description contains the "what" was experienced and the structural description contains the "how" the experienced happened. In the structural description everything is about the reflection of the setting and context (Creswell, 2013).

4.5 Semi-structured interviews

Based on the focus groups, the researcher will conduct face-to-face interviews. The reason why interviews were chosen for the second objective is that, with the help of the focus groups, the researcher obtained a general overview about the understanding and knowledge of project management so far. The first parameters were analysed in which the principles of BT can be used. With the help of the interviews, it is expected that, with every single interviewed person, the topic can be analysed more deeply. The questions for the planned interview will be

generated due to the results from the focus groups that have been gathered so far. With regard to the interview process, this will be a similar process to the focus groups. The interviewed people will be given a detailed description in advance about BT and what has been found out so far. With the help of this, the goal is to get a deeper look at the topic.

Saunders et al. (2009, p.318) explained that an interview is: "a purposeful discussion between two or more people".

When this research mentions interviews, it means qualitative interviews. Qu and Dumay (2011) mentioned that the qualitative interview is one of the most important data collection methods. In qualitative interviews, the researcher normally conducts the interviews with the participants face-to-face, by telephone or through webinars (Creswell, 2009). Because of the Covid-19 pandemics, all interviews were conducted through webinars in the current research. The chosen tool for the webinars for all of the interviews was the tool Microsoft Teams.

The interviews conducted in the current research are semi-structured interviews. One interview lasted between 45 and 90 minutes. With this type of interview, only a few participants are interviewed. The participants have the chance to share their opinions and experiences (Creswell, 2009; Merriam, 1998, Bogdan and Biklen, 1992).

With the interview procedure, what the interviewed person sees as a relevant topic has to be considered, as well as how they view the world and what characterises their living environment (Creswell, 2009).

4.5.1 When to use an interview

A well-planned interview can provide a lot of valuable data. Different to other methods, an interview gives the researcher the opportunity to learn about the knowledge of others. Sometimes, it seems like the researcher and the interviewees do speak the same language, but the understanding and the worldview are completely different. This can be attributed to the various cultural meanings (Qu and Dumay, 2011).

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An interview is not a common conversation. It is a conversation in which the interviewer is learning from the interviewee and the goal is that most of the time the interviewee should talk. It can also be said that the researcher can be seen as a participant, one who is learning from the interviewee (DiCicco-Bloom, 2006).

4.5.2   Explanation of semi-structured interviews

The semi-structured approach was chosen because during this process familiar, open and direct questions can be used. During the interviews, the researcher had control over the conversation and the interaction between researcher and interviewee.

As is described in the above section, the nine steps recommended by Creswell (2013) are used for the conduction of the present research. With the help of the interviews, RO 2 and RO 3 will be answered.

> ➢ To explore the interrelation between the principles of Blockchain Technology and the performance of Managing Road Infrastructure Projects. (RO 2)

> ➢ To appraise the barriers and the enablers to the utilisation of Blockchain Technology in the context of Road Infrastructure Projects. (RO 3)

The interviews were structured in a semi-structured way. The process of the interviews was that questions were prepared which needed to be answered by the interviewees, but it was also the case that the researcher asked the interviewees to explain their experiences and memories and with the help of this, reflections and opinions were made.

4.5.3   Sampling strategy

A qualitative interview is not a negligible method; because of this it does need more than concentrated listening. In order to get the most out of it, an interview needs detailed planning and detailed preparation (Qu and Dumay, 2011). There are three different types of interview: structured, semi-structured or unstructured (Alvesson, 2003).

A *structured interview* is in general a straightforward procedure. A number of prepared questions are asked and only a limited range of possible reply options of special categories are allowed. Sometimes, even special response options are given. Because all interviewees are asked the same questions, it is normal to validate the findings (Fontana and Frey, 1998; Berg, 1998). In a structured interview, the same process and the exact same wording of all the questions is used for every participant (Naoum, 2007; Oyegoke, 2011).

In contrast, an *unstructured interview* is completely different. Hannabuss (1996) noted that the interviewees feel more valued and more relaxed, because the shape of the interview fits the situation and habit of the participants. It is assumed that the interviewees do not know the required questions in advance (Fontana and Frey, 1998). In an unstructured interview, no predefined questions are used and actually there is not even a detailed interview guide. Often, the interviewee leads the interview, rather than the interviewer (Naoum, 2007; Oyegoke, 2011; Bryman, 2012). The type of conversation in an unstructured interview is more conversational style than formal interview style' (Bryman and Bell, 2007). In every type of unstructured interview during a piece of research, the outcome of every interview is different as the phrasing and the process change within every interview. An unstructured interview is used when the depth of an area needs to be explored (Saunders at al., 2009). Normally, this type of interview is used in a qualitative method approach (Bryman, 2012; Saunders at al., 2009).

Of utmost importance in the qualitative research methods is the *semi-structured interview*. A semi-structured interview is more formal than an unstructured interview, but less structured than a structured interview (Naoum, 2007). The semi-structured interview involves a row of prepared questions, which are adapted in an orderly way to the conversation. The researcher does work here with a prepared guide, but the questions are more from a general perspective and it is possible that they do vary during the interview (Bryman, 2012). This type of method is used with pleasure, because it is a flexible, approachable and understandable procedure. Particularly, it allows respondents to express their answers in the way they think and use

language (Schwartzmann, 1993). The purpose of using semi-structured interviews is to explore a specific understanding within a research project (Naoum, 2012).

Certainly, all three types of interviews have the same purpose with the goal being to elaborate detailed and clear responses (Qu and Dumay, 2011). The chosen type of interview in the current research is the semi-structured interview.

As the aim of the research is to gain insights in the field of the challenges of road infrastructure project management in combination with new technologies and obtain an understanding of information exchange in combination with the principles of BT from an industry view, the nature of a qualitative interview is chosen. The whole research started with a general view of the topic, but very quickly moved to a clear focus on the challenges and issues. Bryman (2012) noted that, if more specific issues need to be addressed, a research project tends to use semi-structured interviews. Additionally, the random method of an unstructured interview might not be seen as a reasonable method that can be used with experts and well-organised project managers from the road infrastructure and BT industry. Because of that, the researcher has chosen the more structured way of an interview approach, the semi-structured interview approach. It is assumed that this approach is the most suitable for this research because it will help in gaining an understanding of what is happening in the actual road infrastructure projects. The researcher will obtain feedback after every semi-structured interview about the research, and with every interview the researcher will obtain an understanding of new themes that were not considered in advance and will have the ability to collect a rich set of data.

4.5.4 Conducting the interviews in the current research

In the following section, the organisation, the procedure and the analysis of the semi-structured interviews will be described based on the arguments in the sub-chapters above.

4.5.4.1 Organisation of the semi-structured interviews

With the help of the semi-structured interviews, the knowledge of a special topic in a particular group is shared. In terms of the research question, it is recommended that the interviewees are from a homogenous group and are interested in the same critical topics (McCracken, 1988).

As the selection of the interviewees affects the quality of the survey of work, an in-depth investigation of the chosen participants is needed. The attributes and manners of the interviewees influence the results (Denzin and Lincoln, 2017).

All the participants of this research will be adults with relevant experience in the field of project management, lean management or consultancy, which relates to project management or lean management.

Knoedel (1993) mentioned that the researcher has to define selection criteria for the procedure of the semi-structured interviews. This is an important step for the data collection. The selection criteria for the semi-structured interviews are:

> ➢ Work experience of at least three years
>
> ➢ Experienced engineer in the field of road infrastructure projects (municipalities, highways, the rail sector, bridges or airports) or
>
> ➢ Experience with BT for at least three years
>
> ➢ Employed as a project manager, an engineer, a consultant or expert in the field of project monitoring

These selection criteria were chosen to ensure that the participants had a general and wide understanding of the field of road infrastructure projects or the field of BT. The advantage of the choice of experienced participants gave the researcher the opportunity to talk to people with a high level of knowledge and skills.

4.5.4.2 Procedure of the semi-structured interviews

In conducting the interviews in the current research, the approach suggested by Creswell (2013) is used. This nine-step procedure is shown in the below figure.
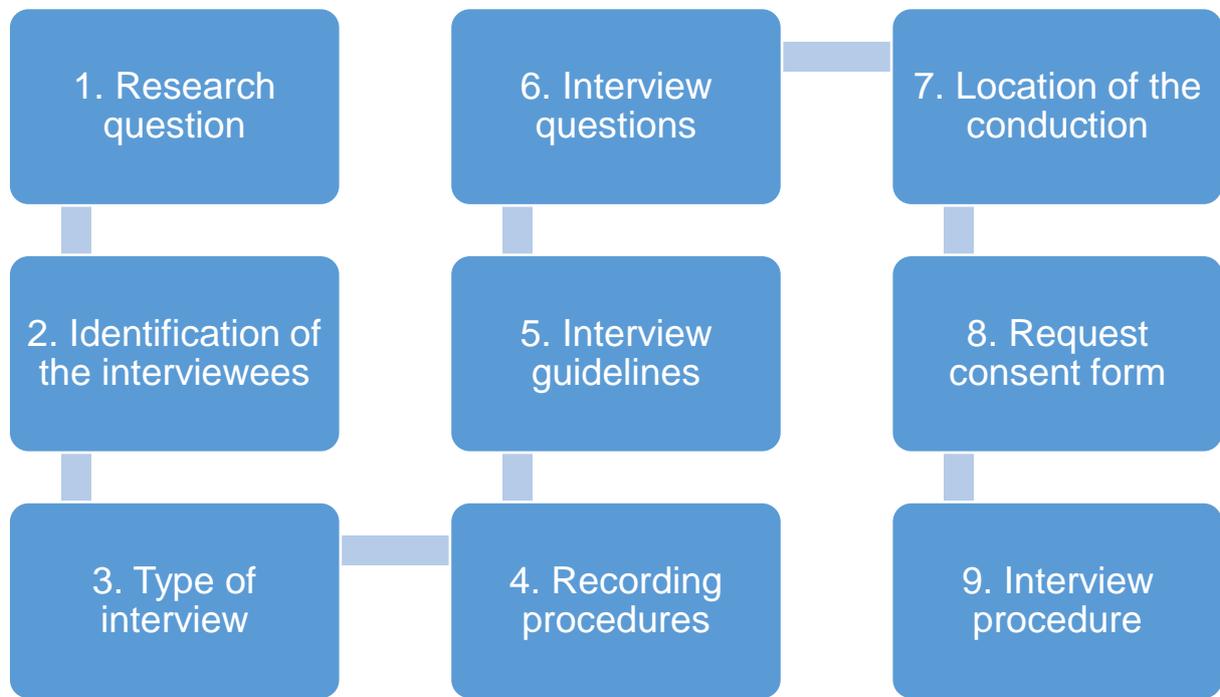
Figure 4-9: Procedure for the conduction of the interviews (Creswell, 2013)

The first step in conducting the interviews, is to understand the research question/questions that should be answered within them. Similar to the focus group procedure, a detailed description is needed for the interviewees. When the interviewees are described, the interview type needs to be decided – whether it is a structured, a semi-structured or an unstructured interview. To generate high-quality recorded interviews, a well-established recording procedure has to be chosen. Following this treatment, a structured interview guide needs to be developed. On completion of the interview guide, the process of creating the interview questions is carried out.

 As is recommended in the conduction of the focus group, a pilot project to test the interview questions is suggested. A quiet location should be used for the interviews, to ensure the high

quality of the recorded data. In the eighth step, the general set up for the interviews is made. This includes the consent form and the participant information sheet, which describes the research, the researcher's topic and how the data will be treated. Finally, the interview procedure involves the collaboration between the researcher and the interviewee. The interview procedure is as follows. After the recording started, the researcher began to ask the interviewee questions. At this particular time, the researcher needs to control any inexactitude in the answers. This procedure is mandatory to avoid measurement errors. The four sources for errors in an interview are: (1) the interviewers, (2) the interviewees, (3) the questions and (4) the type of data collection (Denzin and Lincoln, 2017).
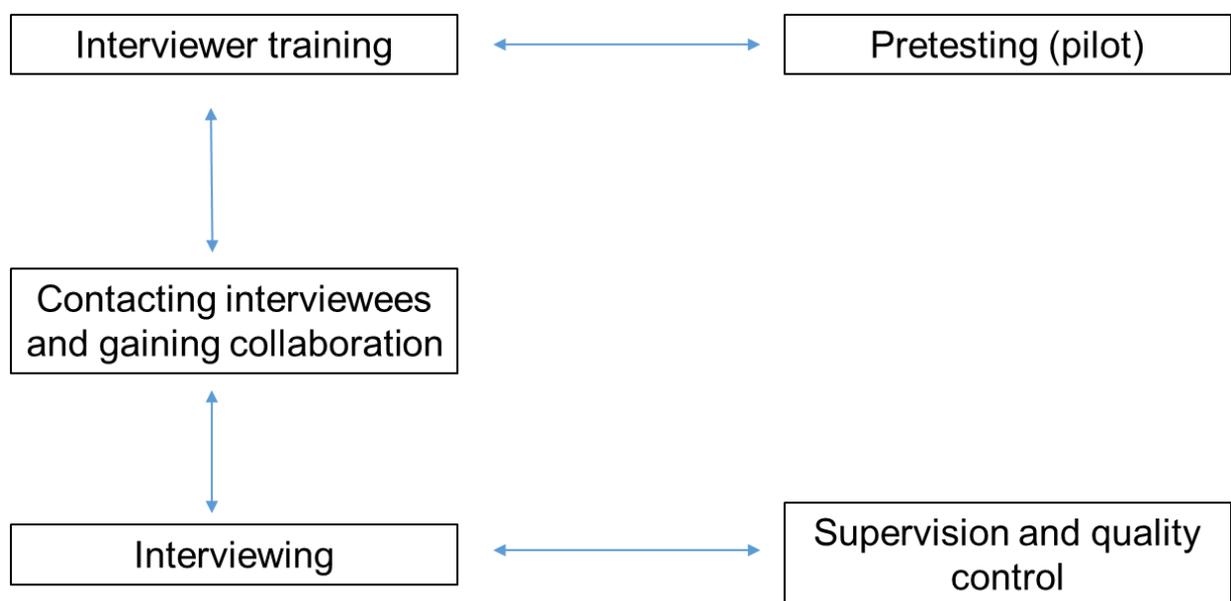
Figure 4-10: Steps in the interviewing (Creswell, 2013)

The above figure shows the steps in conducting an interview (Creswell, 2013). Prior to commencing the interviews, the recommendation is to test the interview questions in a pilot interview. After a successful pilot interview, the interviewees will be contacted and the researcher needs to investigate how a collaboration in terms of the results will work. Once the interviewing is completed, the interviews themselves need to be controlled with regard to the quality.

The use of qualitative interviews is a well-established approach. The interviews were conducted in three different steps. In the first step, the interviews were conducted based on the results of the executive focus groups. The participants of this group are part of the road infrastructure sector. Some were part of the building owner group, some were part of the silo building group and some were part of the silo operating group. The principles of BT were introduced and the idea was to find out in which fields the principles can be used. Some suggestions were made by the interviewer and some new ideas were generated by the participants. In the next step, participants were chosen who worked or who had experience with BT. The goal with this group was to obtain a better understanding of the technology itself and in which areas of application it is already used.

The same procedure was used for all of the semi-structured interviews. The four steps are visualised in Figure 4-11 Before starting with the questionnaire questions, the researcher introduced herself in terms of her background, what she studied and the reason for the topic and the research. After this introduction, interviewees answered the first set of questions in the field of the general information/description. After this, the second part of the questionnaire was answered.

| 1. | • Introduction of the researcher (background, study, why the existing topic)
• Presentation of the research topic by the researcher
• Answer upcoming questions to the general introduction |

| 2. | • Introduction of the interviewee (general information, questionnaire)
• Answering questions of the questionnaire |

| 3. | • Transcribing the interviews directly after the conduction
• Analysing the interviews with the help of thematic analysis |

| 4. | • Summarise all collected data in one table |

Figure 4-11: Four steps of the semi-structured interview procedure

Normally, an interview took around 45 minutes. At the beginning, the researcher gave an overview about the principles of BT and explained why this technology had been chosen. The interview approach was split into two parts. In the first part, the researcher provided a general overview and in the second part the focus was on road infrastructure projects, new technologies and BT. The questions were separated into two fields. The interviews started with the interviewees' general information/description. In the second part, new technologies, existing experiences with new technologies and the principles of BT were discussed. The second part was structured chronologically. It started with questions in the field of new technologies and questions on industry 4.0. As BT is part of industry 4.0, questions on BT were asked after the topics about the new technologies had been discussed. The reason that the interviewees' general information was first was so that the researcher understood in detail who she was talking to. Secondly, different participants were chosen, with different working areas,

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responsibilities and different work experiences; thus, one goal was to find out what different groups thought about the topic in order to analyse whether or not there is a difference.

These semi-structured interviews provided a large set of significant clusters to the research. The second part of the interview questions started by talking about new technologies, industry 4.0, and the theme of what tools are used regarding the digitisation. Additionally, these findings may help the researcher to understand how the participants handle the digitisation in principle. One unanticipated finding was that the majority of the participants (road infrastructure project management) are not familiar with digitisation. It was conspicuous that the participants were afraid of the advantages that new technologies and digitisation bring. The example the participants named regarding the digitisation was SharePoint. But the participants' understanding of using share point was: "*How can I use SharePoint, which only one person has access to?"*

The majority of the participants were afraid of the transparency new technologies brought. The present study, the findings showed that the participants were ambivalent about the transparency. When transparency was discussed, a bigger part of the participants confirmed that the advantage of transparency in principle would bring a huge benefit for processes and projects in the road infrastructure sector. But the participants did not want to have transparency in their own projects. It is interesting to note that, although the participants do see the advantages, they are afraid of it at the same time. The reason why they are afraid of new technology is mainly the big theme of trust. In terms of trust, a lot of different perspectives arose:

> ➤ "If every document, every conversation and every contract were transparent for all stakeholders, project managers and groups in a project, the participants were afraid of what would happen if a mistake was happening. They were afraid that, in such a case, they might lose their profession or their job".

> ➤ "Another issue was not losing their job, but a fear of the conflicts that can appear because of the mistake".

> ➤ "With respect to the topic of trust, the challenge of different stakeholders' expectations also arose".

> ➤ "One of the hypotheses that emerged during the research was that the participants with a long history in the industry were more afraid of new technologies than participants with a shorter history. These participants did not only see the challenge with the different stakeholders' expectations, they also saw the challenge with the competition on principle. What was mentioned through several interviews was the fear of sharing information, because it is not clear what will happen to this information in the future".

Based on these conversations and the background the researcher gathered, the researcher was able to explain the advantages of the principles of BT. The reason why BT is so different to other technologies, is the decentralised system it is built on. The decentralised system can be explained with the help of the distributed ledger. The principles of BT allow an increase in trust during a process, for instance. This is because of the different chains that are encrypted. To sum it up, this means that the process itself can be transparent, but the groups that are standing behind a process can be made non-transparent.

Contrary to the researcher's expectations, only one of the participants of the experts of the road infrastructure sector had previous experience with the technology.

A big topic that was discussed during the semi-structured interviews was if the principles of BT can help in terms of the immutability and the security of the data. These themes were also discussed because it needed to be understood whether there is even a need for the security and the immutability. Rapidly, it became obvious that the security factor the technology is given is not needed in the projects, because the issue of the existing road infrastructure projects is

not the fact that these projects are hacked. However, this study confirmed that the principles of BT are associated with the immutability. What the participants highlighted is that a system is mandatory for them in which documents, processes and contracts can be made immutable. The term immutability does not mean that they do need a tool in which a document, for instance, cannot be changed; it is more important that a document is traceable if it is changed, and why, when and by whom it was changed.

After the basic knowledge and understanding of the technology was discussed and analysed in the semi-structured interviews, the questions went more deeply into project management and its different phases. The interviewees needed to think about in which phases of project management they could recognise the benefits of the technology. It can therefore be assumed that the participants do see the benefits of the technology in nearly all phases, but the results showed that they see it in terms of the information exchange

4.5.4.3 Analysis of the semi-structured interviews

The use of qualitative interviews is a well-established approach in the research field. Basically, the conducted interviews were split into two parts. In the first part, participants in the road infrastructure sector were interviewed. After the interviews were conducted, they were transcribed and with the help of the deductive category application the content was analysed. The process of steps 1 and 2 was repeated several times in order to remove disagreements and open questions. Analysis was based on the conceptual framework proposed by Mayring (2010). The process model of the inductive category application is that it starts with a question, problem or the goal of the analysis. Based on this, theory-based definitions are made to structure the dimensions as a main category and possibly in sub-categories. Further theory-based formulation of definitions is made and anchor examples and coding rules are generated. In the next step, the categories and the coding guide are revised, which is also known as the formative reliability check. In conclusion, a final material pass is carried out with evaluations,

summative reliability tests and possible quantitative analysis (e.g. frequencies). This procedure can be seen in Figure 4-12.
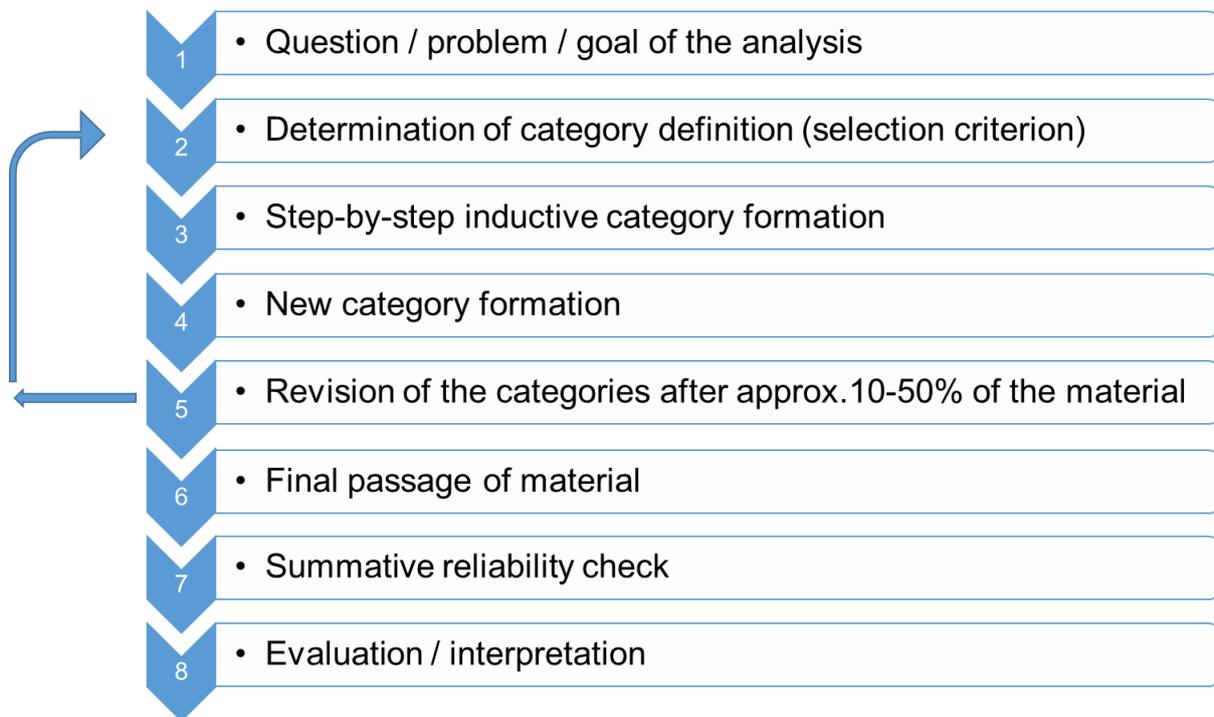
Figure 4-12: The process model of the inductive category application (Mayring, 2010)

4.6 Research framework

The methods used to develop the holistic framework at the end of the study were presented at the beginning of the chapter. With the help of these methods, the three research objectives and the research question stated in Chapter 1 will be answered. A lot of different methods were investigated carefully, to make sure that the right methods for the research were chosen. It can be assumed that with the chosen methods the best possible evidence and support for the hypotheses and scientific proposals will be obtained.

To obtain a basic understanding of the whole research and as an introduction, research objective 1 was also answered with the help of the focus groups. To address research objectives 2 and 3, semi-structured interviews were conducted to explore an understanding

whether there are interrelations between the principles of BT and road infrastructure project management. With the help of the semi-structured interviews, the barriers to and the enablers of this technology in the field of road infrastructure project management will also be understood. These methods will enable the researcher to ask questions about the mentioned two topics in correlation with the information exchange.

In the research, two different methods were chosen because of the different understandings and meanings of the different research objectives.

Additionally, the research methodology would be incomplete without considering the validation 'evaluation' of the research (Amaratunga et al., 2002). Further, it is important to note that the phenomenologists believe in the idea that there is no single reality to get 'right' – but cannot escape a sneaky feeling that, in fact, reasonable conclusions are out there somewhere (Miles and Huberman, 1994). There is, further, a blurred language in the context of evaluate quantitative and qualitative research in the literature (Amaratunga et al., 2002). Several terms that have evolved over the last three decades regarding validity in qualitative research are from Lincoln and Guba (1985), who used terms such as credibility, transferability, dependability and conformability to reach the trustworthiness and correctness of a piece of research; these terms are translated from the conventional terms internal validity, external validity, reliability and objectivity. Lincoln and Guba's term transferability is often referred to as generalisability (Ritchie, Spencer and O'Connor, 2003). Eisner (1991) uses terms such as credibility (which will be achieved through multiple types of data structural corroboration, consensual validation (which pursues the agreement of competent others that the study is right) and referential adequacy (which focuses on the importance of criticism to reveal the subject in order to add understanding). Lincoln and Guba (1985) further state that the trustworthiness of a study is simply reached by convincing the researcher and his or her audience that the findings of the study are worth paying attention to and to take account of them. Another context of trustworthiness within interpretative research is described by Angen (2000), when validation is

the 'judgement of trustworthiness or goodness' of the research. However, following the evidence from Creswell (2013) and Whittemore, Chase and Mandle (2001), the term validation (validity) is accurate and is preferred in this research over historical terms such as "trustworthiness' and 'authenticity".

Therefore, validation in qualitative research is seen as the endeavour to evaluate the results regarding their accuracy (Creswell, 2013). This is doubtless in harmony with the general view of value in research within but not exclusive to the built environment, which derives from valid results (which are the product of collection, interpretation, analysis and evaluation of data) and their contribution to knowledge and value (Amaratunga et al., 2002). Further, validation in qualitative research is demonstrated by Angen (2000) as a process to evaluate the truth of the findings, and validity means the attempt to have something valuable that can be trusted and convincingly described within a human community.

The problem of qualitative research is the vertical monopoly which results from a single performance of the research processes through only one researcher and the concentration on the findings (What) and not on the way to them (How) in their reports (Miles and Huberman, 1994). To cope with this problem, it is recommended to use multiple validation strategies or at least two validation strategies for qualitative enquiries (Creswell, 2013).

4.7 Ethical compliance

Prior to commencing the study, ethical clearance was sought, because the involvement of human participants is needed and the use of data collected through the interviews and the focus groups. DiCicco-Bloom (2006) highlighted that four ethical issues need to be considered. Firstly, the unpredictable damage of a risk needs to be avoided, secondly, the information of the participants has to be kept confidential and lastly, the participants have to be informed about the study. Hence, in June 2019 this research successfully received ethical approval from the Research Ethics Committee of Liverpool John Moores University. Before the interviews

and the focus groups were conducted, a participant information sheet was sent to the participants which explained that all the gathered data would be treated confidentially on both sides, the researcher and participants. Based on the participant information sheet, a consent form was added that needed to be signed by the researcher and the participants. The participant information sheet and the consent form can be found in appendices A - D.

4.8 Summary

This chapter has introduced a general overview of the research, with the chosen methods. The chapter discussed the procedure for the research aims and objectives with the appropriate method of data collection. Why the methods were chosen for the research, how they have to be used, how they were used in the study and how they were inserted in the present research were all explained. The first part of the chapter explained which steps need to be made for the analysis and how the data will be stored. This chapter also includes a section which describes the basic participant requirements. In addition, the analysis technique for the data collection is described.

The first method chosen in the research was the focus group. As a general understanding of the themes needed to be gathered, it was decided that two focus groups would be adequate.

The second method chosen in the research was conduction of semi-structured interviews. Based on the experiences that emerged through the focus groups, 20 semi-structured interviews were undertaken. These interviews were divided into two parts. First of all, experts from the road infrastructure sector were interviewed and, in a second step, experts with background knowledge of BT were interviewed.

Last but not least, the ethical compliance is mentioned, and without this no research would be possible.

5 Findings

5.1	Introduction

5.2	Findings / focus groups

5.3	Findings / semi - structured interviews

5.4	Chapter Summary

Figure 5-1: Overview of chapter 5 - findings

The findings of the current research can be divided into two parts. In the first part, the findings of the focus groups will be shown and discussed. Secondly, the semi-structured interviews findings will be presented and interpreted. The semi-structured interviews were conducted with experts of the road infrastructure sector and with experts of the field of the Blockchain Technology. Based on the discussions and the interpretations of the results of the focus groups and the semi-structured interviews, the foundation for answering research objectives 1-3 will be laid. Prior to this, the chapter will start with a brief introduction. Furthermore, the chapter will provide detailed information about the findings and the process of the analysis of them. The procedure of the both methods is the same. Firstly, the descriptive data will be described, secondly the analysis of the data to descriptive data will be interpreted and lastly a summary of the results of the focus groups and the semi-structured interviews is given.

5.1 Introduction

Following a chronological order, the research results, the findings and the discussion, will be presented in the next two chapters, Chapter 5 (findings) and Chapter 6 (discussion and framework development).

In the current chapter, the findings of the data collection from the focus groups and the semi-structured interviews will be discussed.

In this chapter, the results of the data collection and the therefore conducted analysis are presented. The first data collection area to be addressed is the conduction of the focus groups. The conduction of the focus groups also supports in answering the first research objective. In the focus groups, the topic was where the industry stands in the era of industry 4.0 and in which areas the principles of BT will fit in the whole process of the project management.

Based on the focus groups, semi-structured interviews were conducted to answer research objectives 2 and 3. Here, semi-structured interviews were used. Experts in the field of road infrastructure and experts in BT were interviewed. One of the aims of the semi-structured interviews was to explore if there is an interrelation between the principles of BT and the road infrastructure sector. Based on this, the barriers to and enablers of BT for road infrastructure projects were identified. Finally, a brief overview will be given of the whole life cycle of road infrastructure project management. This will define in which phases of road infrastructure project management the principles of BT can be utilised.

To answer the research aim and to generate the framework, all data from the conducted focus groups and semi-structured interviews needed to be evaluated. Based on the evaluation of the focus groups and the semi-structured interviews, the findings of the research were compared and analysed to the literature review. The development of the holistic framework and the mentioned analysis will be discussed in Chapter 6.

Each chapter/sub-chapter related to the findings will begin with a detailed description of the procedure for the different methods and how they were conducted to build a rich contextual understanding of every single phase in detail. Based on this, every type of focus group and interview will be disassembled to provide a detailed description of the analysis during the whole data analysis process. From a chronological perspective, this will begin with the results of the focus groups and will be followed up by the results of the semi-structured interviews.

Basically, it needs to be kept in mind that that the goal of the thesis is to answer the following question:

How Can the Principles of Blockchain Technology be Utilised for Managing Road

Infrastructure Projects?

5.2 Findings / focus groups

This sub-chapter is dedicated to the analysis of the qualitative data collection through the focus groups. The focus groups are the foundation of the data collection method and identify the general understanding of the two main topics. The in-depth analysis of the whole research will be made through the semi-structured interviews. With the help of this method, the understanding and the knowledge will be enhanced; this will be presented in the chapter findings/semi-structured interviews.

The aim of the focus groups is to collect data that are required to answer the research objectives and question. In particular, the focal point during this data collection will be to answer the following research objective:

Objective 1: To identify in which aspects of managing projects the principles of Blockchain

Technology can be effectively utilised.

In the following sub-chapter, detailed information will be provided regarding the procedure and the findings of the first conducted method. Firstly, the descriptive data of the focus group will be described, including the detailed procedure. In the next step, an overall understanding of the analysis will be given with the first meaningful statements.

5.2.1 Descriptive data

Once the final presentation – for the conduction of the focus group itself -, with its introductions, explanations and questions, was developed and translated, the researcher carried out an

analysis to find the right organisations that could support the study. Two companies were identified and their directors were contacted through an e-mail, with an explanation about the research project and with an explanation of why the companies were the right ones to support the research. Finally, both companies confirmed their support of the research.

In total, two exploratory focus groups were conducted. One was conducted in April 2019 in Stuttgart and the other was conducted in October 2019 in Zürich. The first focus group comprised five participants and the second focus group, six participants. Each also included an observer. The role of the observer was to give feedback to the researcher in terms of the content of the focus group and the observer also provided an analysis regarding what was noticed about the procedure of the focus group. This additional analysis helped the researcher in assessing the results of the focus groups. As the observer was not allowed to be involved, he was able to closely focus on the whole proceedings all the time. The focus group discussions were recorded with two recording devices (notebook and iPhone) that were placed on the table. Figure 5-2 provides the layout for both focus groups.
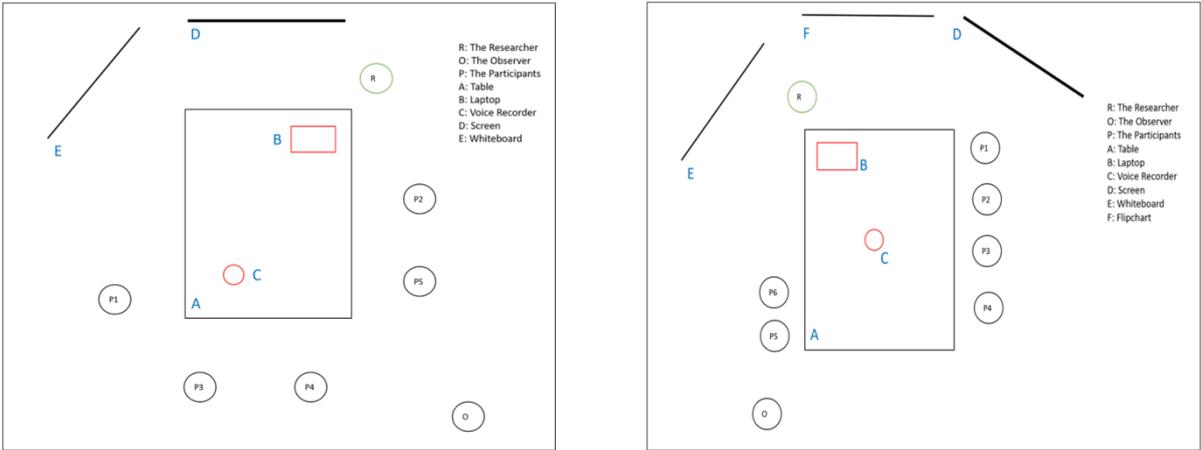
Figure 5-2: Layout of the two exploratory focus groups – physical set up

All participants of the focus groups were employed through professional project management bodies and worked in the construction industry. At the beginning of each focus group, the participants introduced themselves and, before the focus group started, the participants had

to give the signed participant information sheet to the researcher. Most of the participants were consultants with many years of experience in the construction industry.

After the criteria have been set, they were compared with the existing contacts of the network of the researcher. The network is composed through previous studies and research projects they already have been conducted. The participants complying with the criteria were invited via email. With that email the potential participants were given information about the research. The selected participants were compared with the criteria of the requirements of the focus groups to make sure that the most suitable participants were selected to answer the research question in the end. The constitution of the focus groups is shown in the following Table 5.1.

Participant	Position	Experiences (Years)	Participant	Position	Experiences (Years)
Focus Group X (#FG X)			**Focus Group Y (#FG Y)**		
#P 1.1	Director/Professor	>5	#P 2.1	Project Manager	>3
#P 1.2	Project Manager	>3	#P 2.2	Project Manager	>3
#P 1.3	Project Manager	>3	#P 2.3	Project Manager	>3
#P 1.4	Project Manager	>3	#P 2.4	Project Manager	>5
#P 1.5	Project Manager	>3	#P 2.5	Project Manager	>5
			#P 2.6	Project Manager	>3

Table 5.1: Focus groups – participant profiles

5.2.2 Questions in the focus groups

As a foundation for the conduction of the focus groups, the researcher presented a presentation that was prepared in advance. This presentation was structured into three phases, the introduction phase (phase 0), the phase of the technical perspective (phase 1) and the brainstorming phase (phase 2). The presentation started with *phase 0*, which was the

introduction phase. In that phase, the focus group participants needed to answer the following question and descriptions:

> What is your role in the company?

> What is your role in the projects?

> How many years of experience do you have in the field of PM?

> Please give a short summary of your current/past projects.

In a next step, *phase 1*, the technical perspective was discussed. In this phase, the following topics were introduced by the researcher and were analysed by the participants.

> The researcher explained the development of the industries 1.0 to 4.0.

> The researcher explained industry 4.0.

> The researcher explained BT and also showed use cases from other industries, in which BT was already used.

> The researcher highlighted the principles of BT.

> The participants obtained a basic understanding/idea of BT.

> Challenges and advantages of BT were introduced by the researcher.

In *phase 2*, a brainstorming section was put into the focus group session in which the participants were discussing the advantages and disadvantages of industry 4.0 and, based on this, the participants discussed the advantages and disadvantages of BT.

Phase 0

Starting with the whole conduction of the focus groups, every participant needed to introduce herself/himself, even the researcher herself. Although the observer was not part of the focus groups, in terms of the discussion, he also briefly introduced himself. In the current research, the introduction round was more important for the researcher, as for the participants, as the

participants in the focus group already knew each other. But in general it was important for the individuals to obtain an understanding in terms of the current different knowledge about BT.

Phase 1

Phase 1 is mandatory for the conduction of the focus group, so that all participants have the same understanding and knowledge of the study and of this new technology. To explain BT, the finance sector was used. The whole explanation was made with the help of posters and cards. The aids which were used were a PowerPoint presentation, a flipchart and a white board. The flipchart was used for the explanation of BT and the whiteboard was used for gathering the advantages and disadvantages of industry 4.0 and BT through the study. The advantages and disadvantaged were written on post-its.

After phase 1, phase 2 was conducted as the brainstorming phase. The questions and topics that were discussed here were the following:

- Find out the characteristics of BT in projects

- Collect participants' ideas regarding BT and in which fields it can be used

- Where do they see advantages and disadvantages of that technology?

- What are the participants' experiences of industry 4.0 and what experiences do they already have with BT?

- Discuss the advantages and disadvantages of industry 4.0/BT.

Based on the given presentation by the researcher and the explanations the researcher made, the researcher was able to conduct the focus groups and analyse them.

5.2.3 Analysis of the data to descriptive data

The audio recordings of the two focus groups are presented in two different verbatim transcripts of more than 20,000 words. The result of the evaluation showed that the participants

contributed more than 80% of the time. This supports the idea of the conduction of the focus groups, that the researcher did not influence the discussion.

The execution of the focus groups was recorded through a mobile phone and a laptop. In the next step, the focus group discussion was transcribed. As the focus groups were also recorded through Microsoft Teams, and Microsoft Teams has a transcription function, the interviews of the focus groups were transcribed with the help of Microsoft Teams. The transcription of the focus groups was checked paragraph by paragraph by the researcher, to make sure that the whole focus group discussion was transcribed correctly.

In order to measure the different focus groups with each other, as an introduction, the researcher gave a presentation and the same questions were used in each focus group. To control for bias, the observer was involved in the focus group observation to give neutral feedback to the researcher. The focus group was tested once, to increase the reliability of the results of the focus groups. Prior to analysing the focus group data, the transcripts were checked several times to understand the issues. After the familiarisation with the data, the thematic analysis was conducted, as is described in section 4.3.7. In the two transcripts, more than 200 significant statements were identified. As the focus groups were the foundation for the whole research, the statements provided significant meaning for the whole research and the next steps that will be conducted in the research. Some significant statements are listed in the following:

> "*In terms of project success, it would be great to have a tool for the whole process, that provides transparency, traceability and immutability*" (#FG Y).

> "*The principles of the BT would be a great benefit in the contracting in the life cycle of a project*" (#FG Y).

> "*As we do work most of the time with post-its, we do need a system that will provide a digital solution for this, that also makes sure that the data are not falsified*" (#FG X).

> ➢ "*It also needs to be thought about the fact that the digitisation itself is not improving the whole process; it also needs to be thought about how the digitised process will be implemented*" (#FG X).

> ➢ "*As communication is one of the most important factors in a project, it would be great to have a system that would provide a transparent and secure way to communicate*" (#FG Y).

These significant statements were one of the results of the coding of the data that was made through the thematic analysis. During the coding process, the questions that were asked within the focus group discussions were taken into consideration as well as the characteristics of the common meanings that were generated through the analysis.

5.2.4   Results of the thematic analysis (focus groups)

As explained in the previous chapter, one of the first interactive tasks in the focus groups was that the participants had to deliver the advantages and disadvantages of Industry 4.0. For the purpose of analysing the advantages and disadvantages, the participants were asked to write their thoughts on post-it notes. The disadvantages were written on red post-it notes and advantages on green or yellow ones. The participants had five minutes for the task and after the task was finished, every participant presented the results in front of the group and put the post-it notes on the whiteboard provided. Figure 5-3 shows a photograph of the results of focus group "y".
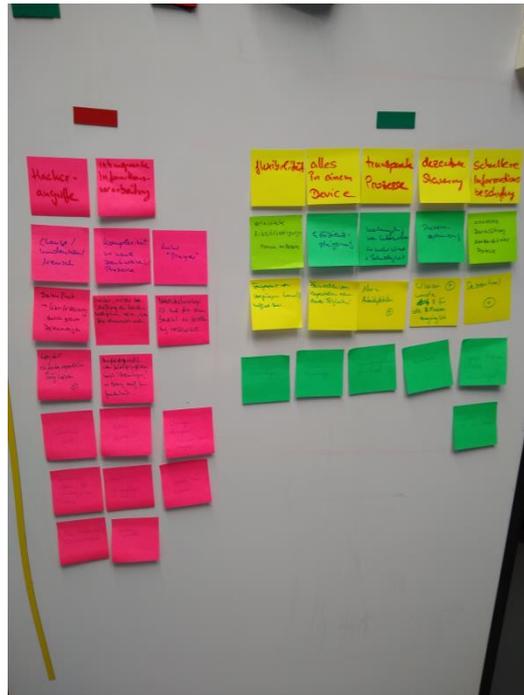
Figure 5-3: Advantages and disadvantages of industry 4.0 (results of focus group "Y")

5.2.4.1 Advantages of industry 4.0

All the advantages the focus groups suggested are listed in the following in note form. After this statement of items, the notes will be put together into groups.

Without any structure, the notes were gathered in a first step:

> ➢ Information linking
>
> ➢ Leads to more knowledge
>
> ➢ Faster exchange of information
>
> ➢ Process optimisation
>
> ➢ Efficiency increase
>
> ➢ Efficiency
>
> ➢ Faster implementation of standardised processes
>
> ➢ Faster information acquisition

- ➤ Interconnectivity

- ➤ Transparency of processes can be possible

- ➤ Decentral

- ➤ Transparent processes

- ➤ Decentralised control

- ➤ Knowledge is made accessible to the masses

- ➤ Freeing up capacity – redundant activities

- ➤ Targeted use of resources → sustainability

- ➤ Facilitated work conditions (human – robots)

- ➤ Flexibility

- ➤ All information is in one device

- ➤ Workflows → time for smart things

- ➤ Smart approaches

- ➤ Control options for processes

The main advantages the participants came up with are the following:

- ➤ New technologies do help in the evaluation of a lot of data

- ➤ Increase of efficiency

- ➤ Faster implementation of standardised processes

- ➤ Transparency of processes

- ➤ Regulation of processes

- ➤ Workflow management

5.2.4.2 Disadvantages of industry 4.0

As well as advantages, disadvantages were also mentioned with regard to Industry 4.0. In terms of the disadvantages, the summed-up notes were as follows:

➢ Data flood – excessive demand due to large amounts of data

➢ "Change Management" – how will the human being be involved in the whole process in the future?

➢ Increase in hacker attacks

➢ The speed of technologies in the daily working area can be overwhelming

Constitutive on the investigation in the field of industry 4.0, for the participants of the focus groups, it was easier to understand the role of BT in industry 4.0. Thus, it was possible to use this transition to dig into the BT. In the focus groups and with the knowledge from the literature review, possible advantages and disadvantages appeared and how they can be transformed to the road infrastructure sector.

With the help of these achievements, it was also possible to make a connection between the project management of common projects and the project management of road infrastructure projects and in which areas BT can be used here. In both focus groups it became apparent that BT can be used in contracts which need to be used by all sub-contractors and can be used as a tool for the transparency of the working hours.

During the discussions, it was asserted that company "X" is already using the principles of BT. The explanation for this is the following. In meetings company "X" has with their client, labels are used that are normally put on a whiteboard or a flipchart. After every meeting, all participants take a picture of the whiteboard; as a result, the picture is given a time stamp, and everybody is clear on the project status and what the next steps which were discussed in the meeting will look like. So the evidence for this whiteboard or flipchart is not in one centralised system; it is on every single participant's mobile phone (which can be simplified and seen as

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a decentralised system). And, in case somebody wants to change the processes on the whiteboards (without informing the other participants), the transparency of the decentralised system will show that data were falsified.

> #FG-X: "In our company we already do use the principles of Blockchain Technology. We are using a paper-based blockchain. When we are planning our processes, we do plan this with the help of a whiteboard and post-its. At the end of every meeting, all attendees of the meeting take a picture of the whiteboard. For example, when 20 people attend the meeting, we have 20 pictures which show the same data. Just in case somebody wants to move a post-it, we have enough evidence, that it was not discussed like that during the meeting. Means we are having something like a time stamp, which is secure and encodes the whole process."

In the discussion about the advantages and the disadvantages, the decentralised system was mentioned as a big gain and constitutive on these processes the following parameters were mentioned: transparency, traceability and processes can no longer be falsified.

The security is made through the decentralised systems a blockchain is offering, which also gives a guarantee of traceability and trust.
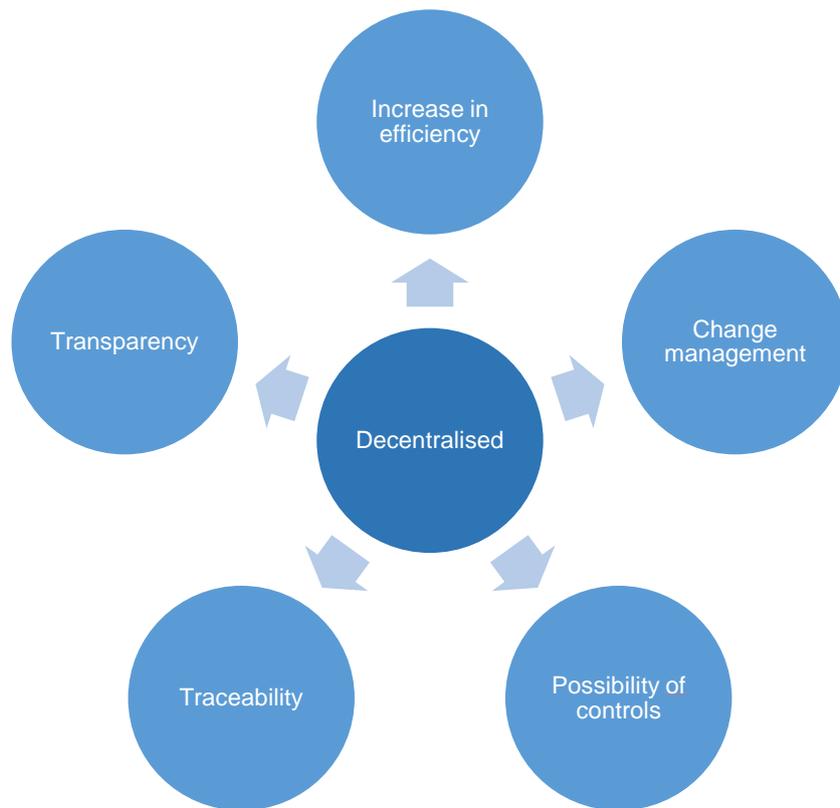
Figure 5-4: Results of both focus groups – advantages of Blockchain Technology

Company "Y" is also supporting the idea that the principles of BT are already implemented in our daily life:

> *#FG-Y: "When I order a car, for example, I get a clear*
> *overview in which phase my car is at the moment in the*
> *manufacture. When I order a package, for example, I can*
> *follow it all the time with the help of the tracking and tracing. I*
> *do really like this way of transparent processes. I do like this,*
> *it saves my time and I can do a better planning."*

Company "Y" mentioned, with regard to that statement, that they do see in terms of traceability the BT as offering, a big advantage in the field of contracting. If all contracts were stored in a way in which they were visible for all stakeholders in the project, it would speed up the processes. Company "Y" thinks that, because the contracts are not accessible for everybody

all the time, the first delays start in the beginning of the project. It was also mentioned that, with the help of the visibility of the contracts to all stakeholders, the attempts to deceive will be reduced.

Another participant in the focus group mentioned the planning/design phase, in which the principles of BT may help.

Again, it is noticeable here that the main advantage of the technology is that it is under a decentralised system. And the decentralised system offers a lot of different advantages, like transparency, traceability, increase in efficiency, change management and the possibilities of control.

Disadvantages which were mentioned are that there is still less experience with the technology and that the technology itself is very complex to understand.

What was found was that the attendees of the focus groups were really open to new technologies and especially to BT. In the focus groups, objective number 1, "*To identify in which aspects of Managing Projects the Principles of BT can be effectively utilised*", was analysed. The first parameters were found in which BT can be used in the field of project management. The idea at this stage is that the BT can be used in different phases in the lifetime of a road infrastructure project as for example in the contracting or in the planning phase or in the representation of the whole process in the project management. This will be analysed in the next steps, in the semi-structured interviews, in more detail.

5.2.4.3 Advantages and disadvantages of the principles of blockchain technology

The advantage that BT provides lies in the fact of the decentralisation. A central system, for example in a bank, has the following advantages and disadvantages.
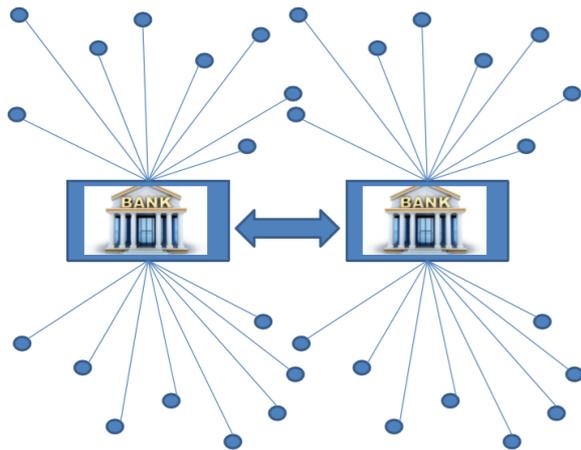
Advantages
- Secure storage
- Carry out transactions
- Documentation

Disadvantages
- Transaction costs
- Time
- Risk of insolvency
- Hacker/insider attacks
- State surveillance

Figure 5-5: Central system

On the other hand, the advantages and disadvantages of a decentralised system, as the BT is using it, are the following:
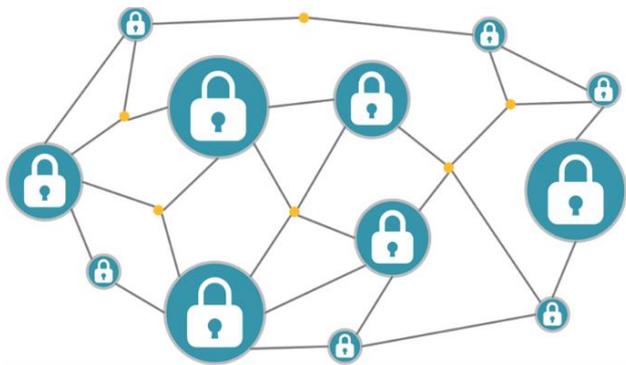
Advantages
- Decentralisation
- Tamper-proof
- Failsafe
- Direct
- Transparency

Disadvantages
- Huge data capacity
- Challenge to incorporate into IT
- Landscape high power consumption

Figure 5-6: Decentralised system

With the help of Figure 5-6 the derivation of the principles of the BT are visualised and explained, as mentioned above.

5.2.5   Summary focus groups

To analyse the first objective of this research, focus groups were carried out. The whole data collection of the research started with focus groups to obtain an understanding of the state of the art regarding where the industry in the era of industry 4.0 and digitisation stands. The goal

of the focus groups was to find out what the advantages and disadvantages of industry 4.0 are and where these can be found in BT. To summarise, the research investigated the meaning of the principles of BT and in which fields these principles can be effectively utilised in the field of projects in the construction industry. To obtain a basic understanding of industry 4.0, BT and project management in the construction industry were the focus and at the beginning it was not important to focus on the road infrastructure. The following figure provides a first understanding and answering to RO 1, "*To identify in which aspects of Managing Projects the principles of BT can be effectively utilised*".
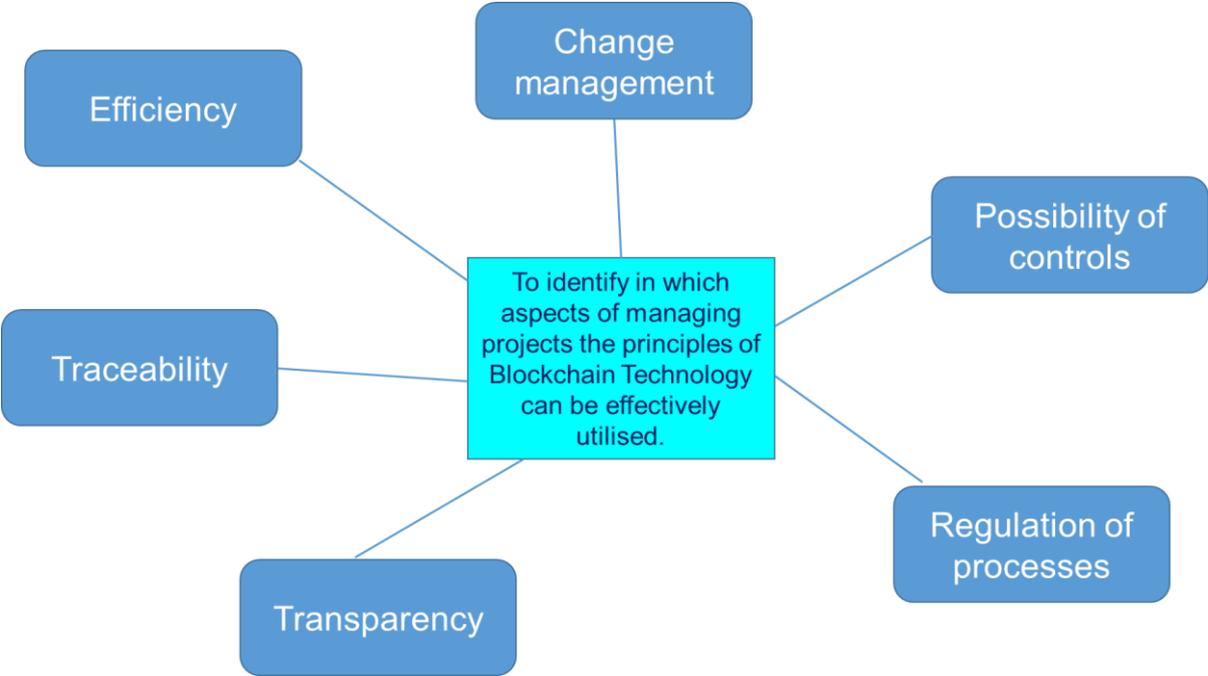
Figure 5-7: Results of research objective 1

The purpose of the focus groups was to utilise the basic knowledge of the research and the fundamental ideas. To underline the importance of the research, specialists and well-experienced project managers in the field of project management were chosen. Thereby, the understanding of the topic was improved.

Beyond that, it turned out that the understanding of BT was different in the two focus groups. The researcher also realised that most of the participants thought of the Bitcoin Blockchain when discussing the principles of BT. Although the Bitcoin Blockchain is a great example for explaining BT, it needs to be mentioned, that the transformation of the technology to other fields, next to the finance industry, is working. At the end of the two focus groups, all the participants had the same understanding of the principles of BT and understood the difference between the BT itself and the principles of BT.

5.3 Findings / semi-structured interviews

This sub-chapter is dedicated to an in-depth analysis of the qualitative data collected through the semi-structured interviews. With the help of this method, the understanding and the knowledge about the already gathered data will be enhanced.

The aim of the semi-structured interviews was to collect data required to answer the research question and objectives. In particular, the focal point during this data collection will help to answer the following two research objectives:

Objective 2: To explore the interrelations between the principles of Blockchain Technology and the performance of Managing Road Infrastructure Projects.

Objective 3: To appraise the barriers and the enablers to the Utilisation of Blockchain Technology in the context of Road Infrastructure Projects.

In the following sub-chapter, detailed information will be provided regarding the procedure and the findings of the second conducted method. Firstly, the descriptive data of the participants of the semi-structured interviews will be described. In the next step, an overall understanding of the analysis will be given with the first meaningful statements.

5.3.1 Road infrastructure experts

The conduction of the semi-structured interviews was parted into two parts. In the first part experts of road infrastructure sector were interviewed. After the criteria have been set, they were compared with the existing contacts of the network of the researcher. The network is composed through previous studies and research projects they already have been conducted. The participants complying with the criteria were invited via email. With that email the potential participants were given information about the research. The selected participants were compared with the criteria of the requirements of the semi-structured interviews to make sure that the most suitable participants were selected to answer the research question in the end.

5.3.2 Descriptive data

Semi-structured interviews in the field of road infrastructure were conducted with 15 participants. All of the participants were aged between 35 and 59 years during the study and the interviewed participants were based in Germany. The semi-structured interviews were conducted through the web, as it was not possible to do face to face meetings because of the Corona pandemic that started at the beginning of 2020. The interviews were conducted in the years 2020 and 2021.

Every interview lasted between 45 and 90 minutes. Each interview was transcribed directly afterwards by the researcher.

As the interviews with the experts of the road infrastructure involved 15 participants, prior to the analysis they were classified as in Table 5.2 below. To anonymise the number of participants the coding started with #RI-1 and ended with #RI-15.

Code	Area	Private / University	Total work experience (years)	Position
#RI-1	Road Infrastructure	Private	36	CEO
#RI-2	Road Infrastructure	University	20	Institue Director
#RI-3	Road Infrastructure	Private	5	Project Manager
#RI-4	Road Infrastructure	Private	30	Project Manager
#RI-5	Road Infrastructure	Private	19	Project Manager
#RI-6	Road Infrastructure	Private	25	CTO
#RI-7	Road Infrastructure	Private	20	Project Manager
#RI-8	Road Infrastructure	Private	20	Banker
#RI-9	Road Infrastructure	Private	24	Project Manager
#RI-10	Road Infrastructure	Private	23	Project Manager
#RI-11	Road Infrastructure	Private / University	26	CEO
#RI-12	Road Infrastructure	Private	20	CEO
#RI-13	Road Infrastructure	Private / University	23	CEO
#RI-14	Road Infrastructure	Public	24	Project Manager
#RI-15	Road Infrastructure	Public	5	Project Manager

Table 5.2: Selected participants for the individual interviews (road infrastructure)

5.3.3 Questions in the semi-structured interviews (road infrastructure experts)

Based on the findings that were gathered through the focus groups a questionnaire was generated for the experts of the road infrastructure sector.

The semi-structured interviews that were conducted with experts from the road infrastructure sector were split as follows. The questions were parted into two parts. It started with general information and descriptions of the participants and followed by questions about the road infrastructure and industry 4.0., see below.

1) General information/description of yourself

- What is your position within your company, what are your responsibilities?

- What is your total work experience?

- Please give a short overview about your organisation.

- What road infrastructure projects are you focusing on in your company? Highways, rail, bridges? Are you a public or a private company?

- How many projects does your organisation undertake per year?

2) Size and structures of new technology/experiences in the past

- Does your company support new technologies (Industry 4.0)? What experience do you have with new technologies? What technologies do you use? How do you handle the digitisation?

- Have you ever used BT?

    i) If yes, what is your experience with it?

- Do you think with the help of new technologies, especially BT, there is bigger security and immutability with projects?

- In which fields do you think BT can be recognised?

    i) Planning

    ii) Implementation

    iii) Anything else

- Some of the big advantages of BT are decentralisation, transparency and traceability. Using these advantages, it would be great to use them in the following fields:

    i) In the field of contracts.

    ii) In the visibility of processes.

    iii) In supply chain management.

- A big problem in road infrastructure projects is that a lot of different stakeholders are involved, with different interests. Do you think the technology can help solving this problems? If yes, in which fields?

- What else do you think about the research? Any comments? (These questions are shown in appendix E).

5.3.4 Analysis of the data to descriptive data (road infrastructure sector)

In total, 15 semi-structured interviews were conducted in part 1. Their transcription resulted in a total of more than 105,000 words. The researcher in the interviews talked less than 10% which means, that the participants contributed in the interviews predominantly.

The semi-structured interviews were recorded through a mobile phone and a laptop. In the next step, the semi-structured interviews were transcribed. As the semi-structured interviews were also recorded through Microsoft Teams, and Microsoft Teams has a transcription function, the semi-structured interviews were transcribed with the help of Microsoft Teams. The transcriptions of the semi-structured interviews were checked paragraph by paragraph by the researcher, to make sure that every single semi-structured interview was transcribed correctly.

All of the semi-structured interviews were analysed with the help of thematic analysis. The results were brought together with NVivo. The organisation and approach of the semi-structured interviews also started with a pilot semi-structured interview. Based on this, the researcher was able to optimise the conduction of the interviews. In order to participate in the semi-structured interviews, the participants and the chosen companies needed to have specified criteria. The researcher was looking for individuals who held or had held a project management role in the private, public or voluntary sector. It also was mandatory that the participants were experts in the road infrastructure sector. If they did not have this relevant experience, potential participants were not allowed to participate. These semi-structured interviews were analysed and the results of these will be used for the further research in this thesis. The main services provided by the companies are development, process consulting, infrastructure consulting, project management and engineering.

5.3.5   Results of the thematic analysis (semi-structured interviews)

As described in the methodology chapter, the data analysis is based on the thematic analysis. To generate a clear structure for the main themes, the following coding structure was created. The coding structure with its several codes and sub-codes will be explained in more detail in the following sub-chapters.
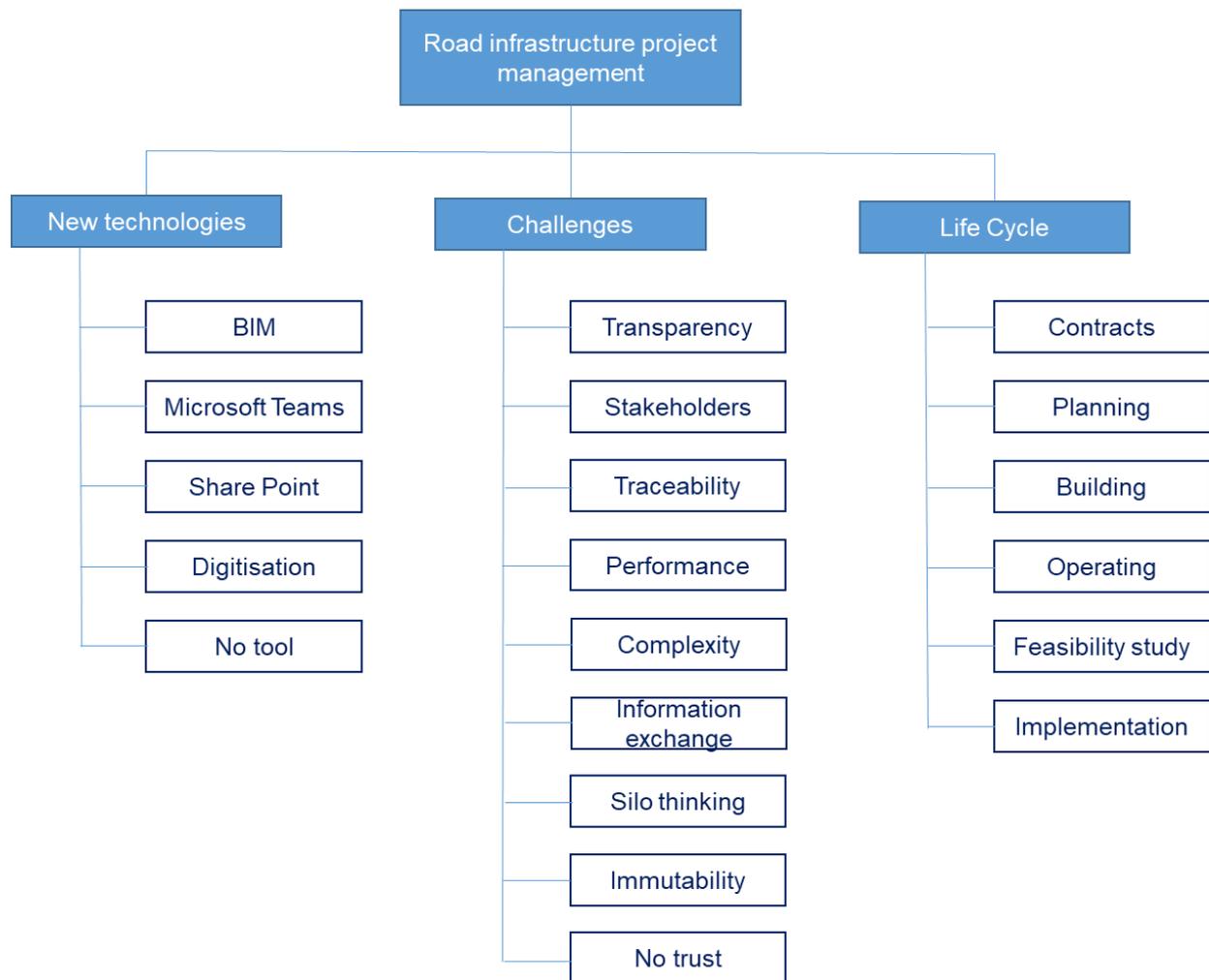
Figure 5-8: Coding structure for the category "road infrastructure project management"

Prior to the data analysis, the first three levels of road infrastructure project management, see Figure 5-8, were defined. While analysing the data in detail, the sub-codes of the three main categories were developed. In total, three codes and 19 sub-codes have been derived for the category road infrastructure project management. The 19 sub-codes were developed through the thematic analysis.

New technologies

The understanding of new technologies was defined by #RI-3 as the following: *"working with artificial intelligence, working on a cloud infrastructure and using web applications"*. The tool

that was mentioned together with new technologies in terms of communication is Teams. This was also mentioned by #RI-9, #RI-6 and #RI-1.

One participant revealed that he is concerned about new technologies. #RI-2 was afraid that the understanding of new technologies is wrong. New technologies cannot help in solving problems like different stakeholders having different interests, for example. He also mentioned that new technologies can call up needs that were not required so far. Prior to using new technologies, #RI-11 argued that it is important to identify what new technology is required'. From his point of view, a new technology should help to optimise whole processes, time should be saved, all participants involved in that process should have the same perception of that technology, the common need of that technology needs to be considered, and, in the end, it should help in making processes transparent, traceable and tamper-resistant.

For #RI-6, the huge advantage with this technology would be that it is not possible to use data wrongly, so this would make the work in projects so much easier.

It has been found that there are different perspectives when new technologies are discussed. When this occurred during the focus groups and the semi-structured interviews, the terms that were used the most were "BIM", "Microsoft Teams", "SharePoint", "digitisation" and "no tool".

BIM

On the one hand, some interviewees advocated that BIM was the new technology everybody was using and everybody was talking about. #RI-12, for instance, stated:

> *"We as a company do use the method of BIM. This means that we have one central platform with all required data and information. But from our understanding BIM is not a tool, software or interface; from our understanding BIM helps in working together in terms of collaboration. And the requirement for this [is] that the way people think needs to change. From my perspective BIM is the future*".

#RI-11 mentioned: *"We do have a lot of existing projects where we do use BIM. And in these projects it is realised how important this technology is. The highways in Germany A "xy" and A "yz" are using BIM and we also started a pilot project on main roads in Germany, where we use BIM."* This statement can also be underlined by #RI-1: *"All new projects we will plan and implement in the future, we will do this with the help of BIM."*

And on the other hand, there were interviewees who argued that they see BIM from a critical perspective, when it is not used in the right way. This was stated by #RI-1, who was also an advocate for the BIM technology. *"The challenge I do see with BIM is that a lot of people do want to use it, but they do not understand that, first of all, we do need everything digital. It is a challenge to use BIM when the project already started was not planned with BIM at the beginning. So the people need to understand that BIM needs to be involved in the process from the very beginning on."* #RI-3 saw the BIM technology from a critical perspective, because of the following: "*I do have the feeling that the road infrastructure industry is not willing to use BIM. Within every project we do have a lot of excuses why not to use BIM. Some do say we cannot use BIM because a road is divided into too many small sections, it is too expensive or things are held on to that have always been used that way."*

Microsoft Teams

As the semi-structured interviews were conducted when the pandemic started, a lot of the participants were talking about Microsoft Teams, when new technologies were mentioned. Their understanding of Microsoft Teams in terms of new technologies is that it helps in the field of information exchange and communication. #RI-5 stated that: "*The company I work for invested finally in the platform Microsoft Teams, which is my understanding of new technologies. Since we have used Microsoft Teams, the information exchange in the company is getting more easy and more transparent.*" This statement can be supported by #RI-3: "*In terms of the communication and the information exchange, we have used it for two years; we*

started with this before the pandemic, Microsoft Teams. For us, this is a real benefit and also helps in terms of transparency and traceability"

SharePoint

It is striking that SharePoint was seen by many of the interviewees as a new technology. "*[For] two years, the company I work for has implemented Office 365, so a great advantage for us is that we can use SharePoint.*" *(#RI-3).*

Digitisation

#RI-3, in the sub-section "*SharePoint*", highlighted that in terms of digitisation the company is up to date. #RI-12's understanding of digitisation was: "*Drones, BIM or at least the performance with the help of BIM, cross-project controlling and artificial intelligence.*" Regarding the digitisation, #RI-11 stated that: "*From my understanding, the digitisation includes a lot of different topics with a lot of different advantages. The main advantages from my perspective are to optimise processes, save time, create the same stakeholder perspective, transparency, immutability and tamper-proof.*"

No tool

Although we are living in the era of industry 4.0, a majority of the participants were not familiar with digitisation or with the tools of digitisation. This was stated by #RI-10: "*In terms of transparency, digitisation and a proper information exchange system, we are not using any tools or systems within the company itself. But our company is a successful company in the field of artificial intelligence.*" This was also supported by #RI-1: "*At the moment, we do not have a tool that brings all processes of a life cycle of a road infrastructure project together in terms of digitisation or new technologies.*"

Challenges

Through the conduction of the semi-structured interviews, the following challenges were mentioned the most. These parameters were analysed through the thematic analysis.

Transparency

As a result of the semi-structured interviews, the participants supported the idea that transparency through the whole life cycle of the project management is needed. This can be supported by a statement by #RI-4: "*Transparency is important especially for these partners that are working together in the project.*" This also will help as different stakeholders have different interests in the life cycle. This can be explained with the help of the planners' documents. The planners want to have the opportunity to plan for as long as possible. The building owner wants to have the results of the planning as early as possible with high quality, and the group that is building the project want to have the plans as early as possible. With transparency, every group would understand at which stage the others are at.

On the opposite side, participants were also found who viewed full transparency very sceptically. For example, one participant who was concerned about the transparency in the given technology argued that, "*because of the extremely secret information that is shared in the ordering letter, a process that is transparent for all participants is not wanted*" (#RI-8).

One of the most challenging topics within the whole data collection was transparency. This became clear because it was a vast topic for all participants, although different opinions of transparency were shared. This can be explained according to the participants who were talked to, as some wanted to have transparency through the whole process, such as starting with transparency from the feasibility study until the handover to the operation/service part. It was conspicuous that this was the understanding of the participants working in the field of building or implementing in a project. They explained the importance of transparency in the whole process thereby, that it is easier for them to implement a project when they understand the whole project from the first step on. The building owner group had quite a different understanding. This group mentioned only being interested in the outcomes of a special group and not in the work flows within a silo. This group also saw a problem with transparency in

terms of the strategic alignment of a special company, when different stakeholders are involved. This result emerged from the group of experts in the field of road infrastructure.

#RI-4 explained that what was getting lost was that the building owner and the building contractors have the same goal. RI-4 mentioned a project at a university in Germany. The goal of the project was to develop a tool, similar to BIM, with the option that the building contractor for example does not see what the building owner is doing. So at the end they developed such a tool but this is not the idea of full transparency during a project. T same situation occurs, ifcompanies are trying to find a solution, how SharePoint is used in a way that not everybody can see what the others are doing. This is not the goal of transparency.

#RI – 7 "The question is, do people want this transparency at all? When I look at the building now, transparency would help. But sometimes this transparency might be a problem for the decision-makers who ultimately sit in the offices."

In principle, most of the experts in road infrastructure projects mentioned that transparency in terms of the whole process in general would offer a huge advantage. This brought the issue of an appropriate tool to the fore. #RI-4 also made a comparison of the transparency related to the cultural change: "*Transparency, which will be inevitable in the future, will drive us into a cultural change. We need to deal with each other in a transparent way, [so] that we can reduce the asymmetry of information in the information exchange, like it existed in the past.*" #RI-7 mentioned the advantages of transparency in terms of the decision-maker. "*When I think about the whole construction phase, from my perspective, the transparency also would help them who need to make decisions.*" Contract letting was spoken about from the perspective of a planning engineer: "*Basically, an order-letting procedure runs through special requirements and here transparency is mandatory. If this transparency would be given in the whole life cycle, from my perspective, a lot of challenges would be reduced.*" (#RI-13).

Stakeholders

The next diagram will provide an understanding about the many stakeholders that are involved in such a project, and this will be explained in more detail with the planning phase.
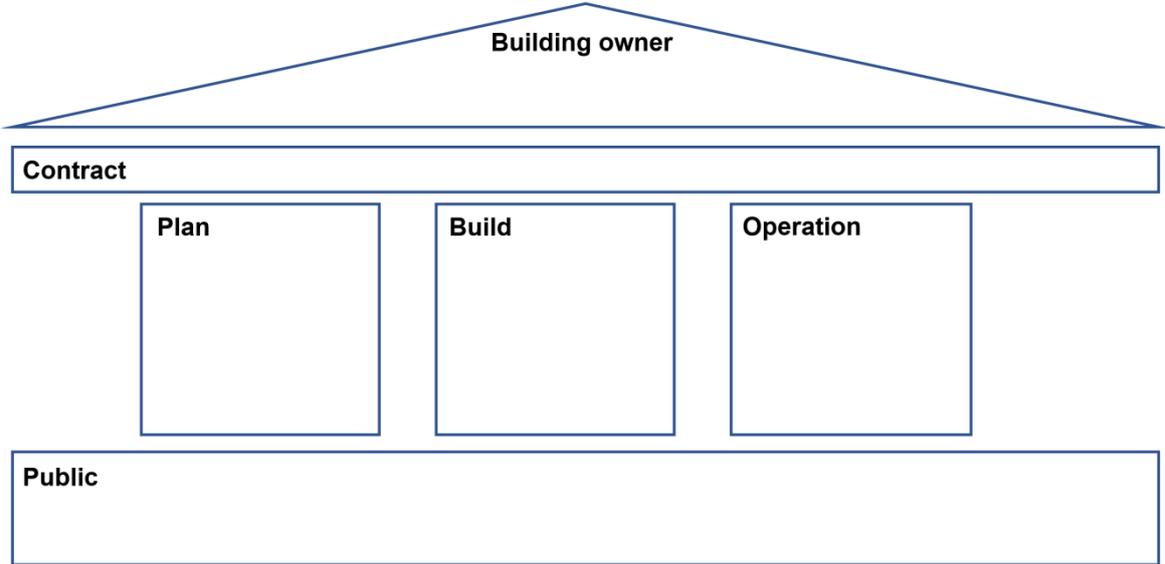
Figure 5-9: Different stakeholders in the life cycle of the project management in the road infrastructure sector

The participants in the semi-structured interviews were mainly interviewed in the groups named in Figure 5-9. As can be seen with the help of the house shown in the above figure, the building owner, the contracting and the public groups are involved in the life cycle of a project the whole time, whilst the planning, building and operating groups are only involved for a specific time. It is only visible in Figure 5-9 that all stakeholders have different interests in terms of the project life cycle.

To make it visible that there are even more different groups involved in terms of interest in such a project, the silo planning is separated into different groups based on an existing project. The silo planning is chosen because this is one of the most important silos in the whole life cycle o a project. This result arose through the semi-structured interviews with the experts of the road infrastructure sector.

Figure 5-10 provides an overview of what needs to be considered only in the planning phase. The planning phase stands for an example of the different phases in a life cycle of the project management of road infrastructure. It will demonstrate how many different themes in every phase need to be covered. As two semi-structured interviews were held with experts of the planning phase, it also became clear how important the information exchange and the communication during these phases are.

1. Planning region • Fauna • Flora • Biotope	2. Expert report • Forest part 1 • Forest part 2	3. Environment • Compatibility study • Species protection assessment
4. Noise / pollutants reports	5. Traffic Study	6. Geotechnical report
7. Survey/ measurement	8. Object planning • Traffic facilities • Engineering structure	9. Federal / government quote

Figure 5-10: Example of parts involved in the planning process

One example, how important a proper information exchange is, can be demonstrated with the help of the planning phase during the life cycle of a road infrastructure project. In the current example, 9 different themes need to be covered during this first phase. Within these themes, it is important that the different experts do communicate in a transparent way with each other. This can be seen for example in the first topic planning region. All experts of the areas of the fauna, flora and biotope need to talk to each other, best in a proper information exchange system that supports the security that all participants do have access to and that all information is up to date. So it is getting obvious, that it is important, to think about which groups in every phase need to work with each other.

The attitude of different stakeholders is argued by #RI-3. It is comparable to the other views that were already mentioned. The goal of the general planner, for instance, is to think about how the requirements of the contract can be implemented for a good price. The participants who have the responsibility for the whole pavement management, do want to have solutions that have long life cycles with low maintenance costs. And those who have the liability for the whole construction want to have a solution that can be implemented for a cheap price in a short time. This is an example of the challenge of bringing all these interests together.

#RI-2 described the numerous different stakeholders in a project and that from his perspective this phenomenon cannot be solved. "*It will always be the fact that road infrastructure projects a lot of different stakeholders will be involved. The whole project always needs to deal with different interests and areas, and from my perspective there is no tool or system available that can help in improving this problem.*" When the planning phase was discussed, #RI-13 did not see the problem with the different stakeholders' expectations: "*When we plan a project, we have a different office for every area, who do stand in a competitive relationship*, *but I expect that this is happening after the planning phase.*"

Traceability

The attitude that the principles of BT would deliver the required traceability in the life cycle in the project management of road infrastructure project was enunciated by #RI-6, who said that: "*Traceability in a road infrastructure project from the first step, the idea, until the operation would be an advanced step*". This statement was supported by #RI-3 and #RI-5 in terms of the whole life cycle in road infrastructure projects. Participant #RI-3 said that: "*Regarding the pavement management planning, the traceability is important from the bidding process on. Otherwise, the pavement management planning itself cannot be executed in an ordinary way and postponements of the entire pavement management planning can be foreseen from the beginning on*". Based on these statements, it is worth deliberating about whether the principles of BT could help in the challenge with traceability.

#RI-2 mentioned that the technology can help in terms of traceability regarding different project status to different timings the statues to a special time.

The above-mentioned transparency leads the majority of the participants to the topic of the supply chain or the transparency. #RI-9 mentioned that: "*We often have the problem that we do not know where our material is. This costs a lot of time and money. If a better traceable process for this could be given, the whole management of a process would work better.*"

Performance

When performance in the field of road infrastructure projects was mentioned, it was highlighted as performance as a term. It was more highlighted as the performance of the whole project. Also, in the data collection the different participants talked about the fact that performance can be measured, and that it would be a great advantage if the performance could be measured by the support of a tool, like can be given through the principles of BT (#RI-9, #RI-7 and #RI-4).

Complexity

"*Different to other projects [in] the industry, is the given complexity in a road infrastructure project. One part of the complexity is given in the information exchange, as a lot of different groups are involved and need to be updated. This also includes the public and tax-payers.*" (#RI-10). "*Because of the given complexity in a road infrastructure project, it is important that all stakeholders are involved in the process from the first step on.*" (#RI-13). Therefore, it is important to work on a proper partnership to maintain the whole team from a long-term perspective.

Information Exchange

#RI-6 highlighted the importance of a proper and transparent information exchange: "*The information exchange in a mega project represents a central topic. The bigger a project is, normally the more complex it is getting. And, usually, if a project has more stakeholders, the*

more complex it is getting. More stakeholders mean a lot of different expectations [of] the project, a lot of different experiences and a lot of different knowledge. So, a proper information exchange system is mandatory for the road infrastructure project management."

Silo thinking

Regarding the silo thinking, #RI-11 mentioned the need to be careful in mixing the knowledge of the different silos. Transparency is important, but it needs to be split in terms of who needs to know what. The building owner, for instance, is not interested in too much technical detail. #RI-4 also mentioned the silo thinking in terms of the thinking in not sharing information with each other, because of the age issue. He did not understand why the older generation did not share the existing information with the younger generation, and compared this with thinking in silos.

Immutability

Issues about the immutability in projects were mentioned by #RI-1. He explained this with the help of a document when a lot of different people are working on it. It is important that everyone knows what was added and changed and that these revisions are immutable. #RI-2 explained that: *"Normally there are two procedures. You have the need and we have the technology that is helping in fulfilling this need. The need that we are having in a project is that, if a plan is released, every stakeholder should be involved and it should be clear that this plan is immutable. So the planer, the building owner and the entrepreneur all have the same need."*

"*The traceability given through a decentralised system that can be used in road infrastructure projects provided an immutability of data*" (#RI-9). The participant also explained that the understanding of immutability, from his point of view, does not mean that data cannot be changed; it means that an existing data set cannot be changed, and, if it is changed, there is a new version of it. This statement was also supported by #RI-6: "*Regarding immutability, we do talk about different versions of data. And one special version cannot be changed.*"

No trust

A challenge that is faced in road infrastructure projects is the parameter of trust. This was mentioned by #RI-8, the view over a project from the building owner's perspective, and he said that: "*Especially the process of the order letting is extremely hard to handle. And all the information needs to be treated with an extremely high trust, because all of the information is extremely secret*". Regarding trust, #RI-6 put forward a different point of view: "*It needs to be considered that the challenge from sharing the strategic perspective is that partners we are working with today, are competitors in one of the next projects. So we need to be careful what for information we share between each other and what information we do not share.*"

Attitudes about the behaviour of trust were held in context with a partnership within a project. #RI-111 stated that: "*A huge degree of partnership and trust is needed in our road infrastructure projects, but in the traditional projects this is not available.*"

An important parameter in every project is the theme of trust and how the people involved handle trust. #RI-8 mentioned that participants in these huge projects do not trust each other because of the existing competition that they face in these projects: "*Trust represents a central issue in the contracting process. These processes are extremely difficult to manage. In this context, it is important then, as these processes must be handled extremely secretly. And here, it is not desirable to work transparently, because people simply do not trust each other.*" #RI-12 also mentioned the issue of not trusting each other in a project: "*In the road infrastructure projects I work in, the different stakeholders do not trust each other. So, a technology is mandatory that is used when you do not trust each other. From my perspective, the idea of the Blockchain Technology would make sense. This technology is used when stakeholders are involved who do not trust each other and with this technology data can be shared and be stored on a decentralised system.*"

Life Cycle

During the conduction of the semi-structured interviews, it was discussed and thought about, in which fields of the whole life cycle of road infrastructure project management new technologies such as the principles of BT can be used. Therefore, a holistic view on the whole life cycle of a project is required. This holistic view goes from "*from the first project idea, with the feasibility study to the completion and operation of a project*" (#RI-6) or in other words it can be said, the holistic view goes "*from the inception to the planning to the building to the handover*" (#RI-2).

Contracts

Being able to manage a project in a transparent way, #RI-1 mentioned: "*I do see a huge advantage in using the principles of the BT in the contracting*"; this statement was also supported by #RI-8: "*As the contracting is not a phase in the life cycle it is also an important parameter*", and #RI-13 mentioned that: "*Contracting needs to have the parameters of the principles of the BT*".

Planning

As the planning phase is one of the most important phases for #RI-13, "*It is mandatory to use such a technology in the planning phase, to be transparent and traceable.*" This statement was also mentioned by #RI-8, who compared the planning phase of a road infrastructure project with the planning phase in principle. It does not matter what project you are involved in or what you are doing in life. If an event is planned properly, everything will run more easily. He compared it with the example of driving into the holidays. "*When I would decide to go to a holiday and I would just jump into the car and drive to the planned place, I would [arrive really quickly] at the wished place. But what will happen when I am on the holiday? I will realise that I have forgotten the towel and swimming clothes, so I have to drive back and pick these things up. The person that would pack the things and make a plan in advance would not [arrive that quickly] at the place of the planned holiday, but would be less stressed, would have more time*"

on the holiday and it would be more cheap." The participant made that example to explain that this is an easy example out of normal life that can be compared to the construction industry.

Building

All of the 12 experts from the road infrastructure sector mentioned that the explained principles of BT would definitely make sense in the building phase. This opinion came up because the participants highlighted that the building phase is the most active phase in which the largest number of stakeholders are involved all the time. And having a transparent, traceable and immutable tool in that phase would bring big advantages to the whole project. What also was mentioned in that relationship was the issue of information exchange. The participants complained that a basic problem is that a lot of information gets lost because of the way the participants communicate with each other.

Operating

One important phase in the life cycle of a project is when it is handed over and the operating phase starts. In correlation with that, # RI-5 mentioned, together with the traceability, that "*When I think about our current project, a lot of challenges would have been spared if we could have had a tool in which the whole pavement management planning would have been more traceable for all involved stakeholders. The pavement management planning was done during the planning phase of the project from a theoretical perspective for the life cycle of 30 years. But, because this planning was not visible for all stakeholders, and because it was not visible for everybody, the operating phase team did the whole planning again. So in the end the whole team was not communicating with each, with costs to time and budget, and these issues would have been avoided with a traceable system for everybody.*"

Feasibility Study

#RI-6 mentioned the importance of a transparent process from the beginning on, stating that: "*The principles of the BT are mandatory, from my perspective, in all phases of the life cycle of*

the project management, so I think that we do need a technology that provides transparent and traceable processes, like are provided in the BT even in the feasibility study."

Implementation

The question that always arises is: *"How stable is a road infrastructure project management related to the information exchange under the explained challenges in a road infrastructure project?"* (#RI-10). #RI-5 also mentioned this: "*It would be great to have a proper information exchange system for the whole communication through the whole life cycle of a road infrastructure project."* Therefore, the predicament between the information exchange and the road infrastructure project management lies in its environment, regarding trust, less digitisation and less transparency.

5.3.6   Summary of the results of the road infrastructure experts

The current study in terms of the semi-structured interviews found that the different participants had different interests in the advantages of BT. One of the first evaluations was the question:

"What do the participants think about transparency in the whole process of a project in terms of the life cycle of the whole project management?"

Nearly half of the participants liked the idea of transparency of the whole life cycle of a project, almost another half liked the idea of transparency within a silo, but not in the whole process, and 2 participants, did not want to have transparency in a project. When it is talked about silos it is talked about the different phases in the life cycle of a project as for example the field of the contracting, the planning phase or the phase of the implementation. The results of the participants do show that in terms of transparency the opinions are different regarding the phase of the project. 13 of the 15 participants would like to have a full transparency between all different parties in the planning and the implementation phase. In the phase in which all the contracts are generated, 4 of the 15 participants do not want to have transparency in that

phase, as they do have the opinion that in that phase really sensitive data are shared, which should not be available for all parties.

Basically, the participants liked the idea of transparency in the separate silos. But this also depends on the field which is talked about. The results of the contracting silo show that not all participants liked the idea of transparency in here. This is also confirmed by a participant's statement:

> #RI-4: "It is possible, that people I work [with] today are competitors tomorrow, so you need to be careful, with ideas and strategic alignments that are shared in the contracting phase. It also needs to be [understood] that the new ideas I have in my company today, will have a second tomorrow".

Another important finding was that 13 of the 15 participants saw that the transparency in the planning phase was the most important.

This is also highlighted by the following statement: RI-1: "*Transparency in the planning phase is the most important.*" and also was mentioned here: RI-2 "*The quality of every project is in the planning phase, so transparency in here should be mandatory.*"

This also accords with the results of the transparency in the implementation phase. More than 80% saw transparency in the implementation as mandatory, as a lot of different stakeholders are involved in this process. #RI-1: "*A proper implementation phase can only be offered with a proper planning phase. So it is mandatory to have transparency in both silos*".

It is conspicuous that the willingness for transparency is much higher when the silos are observed individually than as a whole process.

One interesting finding in the study is that traceability and immutability are related to each other. This leads to the fact that it can be interpreted that a user feels that, whenever a process is traceable, it gives the feeling that it is immutable. Or, if a process needs to be changed, the traceability allows the user to understand who did the changing and why it was changed.

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All participants were in agreement with the topic of transparency in the field of supply chain management.

#RI-3 "*I see a big advantage in the use of principles of Blockchain Technology and use the transparency of it, in the field of asphalt transport and in the process of recycling*".

This statement also was supported by #RI-5: "...*this functionality can be used in the field of supply chain management in terms of monitoring the installation temperature, in which condition was the asphalt delivered, what time did the asphalt arrive, which of the supplier plants was used…*"

Most of the participants liked the idea of transparency within the life cycle of a project, but there also have been participants that did not like the idea of transparency or at least saw the critical factors of transparency. Critical factors that were mentioned were themes as competitive advantage, strategic alignment, no trust, being controlled or no interest in other stakeholders.

In order to build a bridge between the principles of BT and the road infrastructure, it needs to be investigated why some of the participants do not want to have transparency in the process of a road infrastructure project. One big theme of this is the topic of trust. But it is well known that trust is one of the reasons why BT should be used – because this technology can help in terms of people not trusting each other. It was very noticeable that the building owner group and the group working in the field of contracting were not really interested in the other stakeholders. For the building owners, the most important thing is that the whole process is running and that the funding will be used at the right time. #RI-8 mentioned that:

> "*It should not be forgotten that the construction industry is a highly competitive sector. So, especially in the tender and in the contracting phase, people do not want to work transparently and people do not want to share their knowledge and their data.*"

TI = Transparency and Immutability

Building owner
- no TI (3)

Contract
- no transparency (3)

Plan
- Fully TI (2)

Result P

Build
- fully TI (5)
- only in the silo (2)

Result B

Operation
- fully TI (3)

Result O

Public
- fully TI (2)
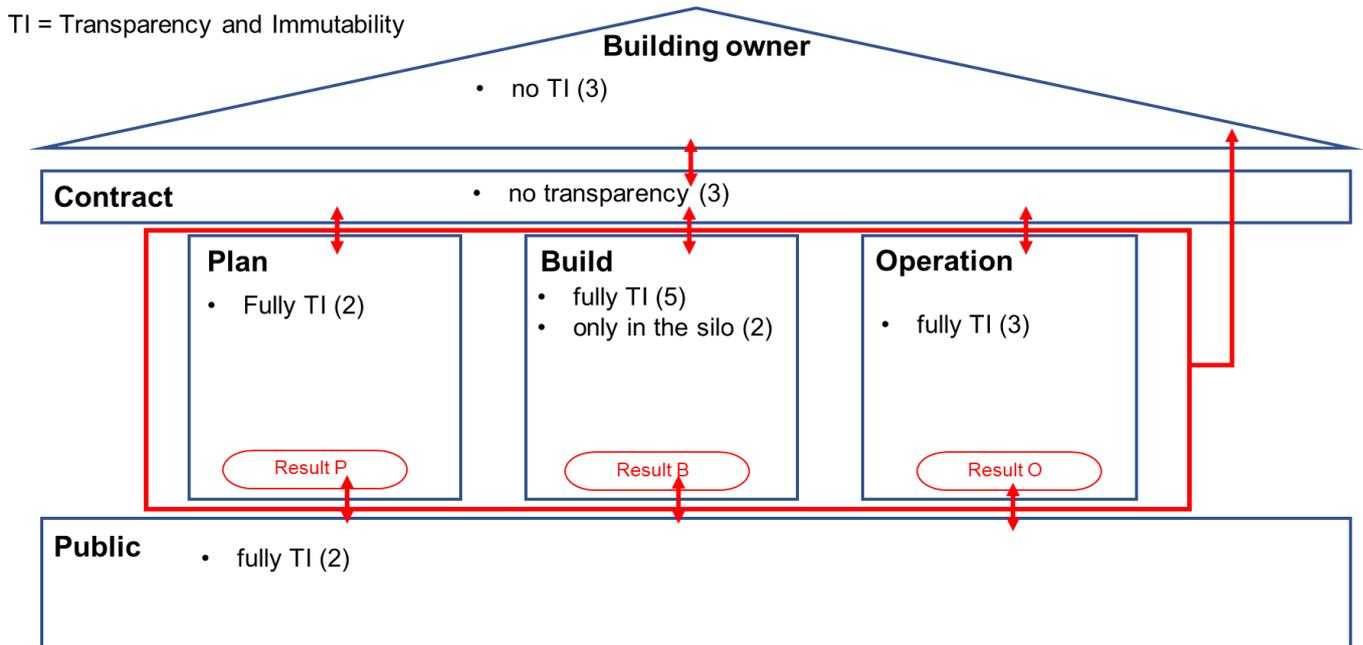
Figure 5-11: Results of the semi-structured interviews with the experts of the road infrastructure (own representation)

As a summary of the semi-structured interviews with experts in the road infrastructure sector, the following can be said. The experts who were interviewed were part of different groups regarding the whole construction process. The groups were split into the areas of building owners, experts in contracting, planning, building, operation, and people who also represent the interests of the public. This is visualised in the house that can be seen in Figure 5-11. Two of the participants of the public that have been interviewed do prefer full transparency and immutability. In the field of planning, building and operating most of the participants do like the idea of full transparency and immutability. But this is changing in the top of the house. The field contracting and the area of the building owner do not want to have full transparency as they do think that this kind of information is too confident and should not be shared with all stakeholders. The participants also mentioned the trust issue here. It is conspicuous that these who are working directly in the project every day, as in the building sector or later on in the operation sector, do want to have full transparency of the whole process. For them, it is really

important that the process and documents they work with are immutable. So a relation is established that, if processes are transparent, they are immutable. Immutable does not mean that it is not possible to change something, but if a procedure needs to be changed all the involved stakeholders can trace who did the changing and can understand why the changing was necessary. The motivation for this is that they have the feeling that, in the first steps of a project, as in the contracting or in the planning, information gets lost or is not shared very openly. This leads to the fact that the building and operation groups can be hindered thereby.

For the further research, it needs to be considered that, as #RI-6 and #RI-12 mentioned, the transparency for the whole process should start in the planning and in the design phase. When this phase is ended, the results of it should be presented to every further stakeholder.

After the conduction of the semi-structured interviews the researcher realised that the most mentioned challenge during the projects is the information exchange and the communication between the different participants and project managers. Because of this, the researcher started with a literature review in the field of information exchange and communication.

After the conduction of the semi-structured interviews with the experts in the field of road infrastructure, the researcher conducted semi-structured interviews with experts of the BT industry.

5.3.7 Blockchain experts

The conduction of the semi-structured interviews was parted into two parts. In the second part experts of the BT sector were interviewed. After the criteria have been set, they were compared with the existing contacts of the network of the researcher. The network is composed through previous studies and research projects they already have been conducted. The participants complying with the criteria were invited via email. With that email the potential participants were given information about the research. The selected participants were compared with the

criteria of the requirements of the semi-structured interviews to make sure that the most suitable participants were selected to answer the research question in the end.

5.3.8 Descriptive data

Semi-structured interviews in the field of BT were conducted with 8 participants. All of the participants were aged between 32 and 62 years during the study. Participants were based in Germany, the Netherlands and in the United Kingdom. All of the semi-structured interviews were conducted through the web, as it was not possible to do face to face meetings because of the Corona pandemic, that started at the beginning of 2020. All of the interviews were conducted in the year in 2020.

Every interview lasted between 45 and 95 minutes. Each interview was transcribed directly afterwards by the researcher.

As the interviews with the experts of the BT involved 8 participants, prior to the analysis they were classified as in the table below. To anonymise the number of participants the coding started with #BT-1 and ended with #BT-8.

Code	Area	Private / University	Total work experience (years)	Position
#BT-1	Blockchain Technology	Private	7	Consultant - IT
#BT-2	Blockchain Technology	Private	20	Lawyer
#BT-3	Blockchain Technology	Private	13	Project Manager
#BT-4	Blockchain Technology	Private	30	Project Manager
#BT-5	Blockchain Technology	Private	19	Project Manager
#BT-6	Blockchain Technology	Private	10	Project Manager IT
#BT-7	Blockchain Technology	Private	25	Project Manager
#BT-8	Blockchain Technology	Private	14	Project Manager

Table 5.3: Selected participants for the individual interviews (BT)

5.3.9   Questions in the semi-structured interviews (experts of Blockchain Technology)

Based on the findings that were gathered through the semi-structured interviews with experts in the road infrastructure sector, a new questionnaire was generated for the BT experts.

1. General information/description of yourself

- What is your positon within your company, what are your responsibilities?

- What is your total work experience?

- Please give a short overview about your organisation.

- What road infrastructure projects are you focusing on in your company? Highways, rail, bridges? Are you a public or a private company?

- How many projects does your organisation undertake per year?

2. Blockchain Technology

A big problem in road infrastructure projects is that a lot of different stakeholders are involved, with different interests. Some of the big advantages of Blockchain Technology are decentralisation, transparency and traceability.

- What is your experience with Blockchain Technology? What do you think about that technology in terms of the road infrastructure sector?

- Where do you see the focus in implementing Blockchain Technology between building and operating? What do you think will be an advantage of this?

- When is a Blockchain Technology needed in a road Infrastructure project? What do you think about the following parameters?

  i)   Automation

  ii) Repeatable process

  iii) Multiple stakeholders

  iv) Value transfer (not just monetary, e.g. information)

v) Immutability

vi) Transparency

vii) Trust

- What else do you think about the research? Any comments? (These questions are also shown in appendix F.)

The semi-structured interviews in the field of BT provided a large set of significant clusters to the research. The questions were structured similar to the semi-structured interviews of the road infrastructure projects. In the first part, general information was requested, such as the participant's experience, their profession, and where they work. The second part of the interview questions here started with talking about BT and where it can support and how it can support. These interviews with BT experts helped the researcher to obtain an understanding whether it is useful in road infrastructure project management and where it can be useful.

5.3.10 Analysis of the data to descriptive data (BT)

In total, 8 semi-structured interviews were conducted in part 2. Their transcription resulted in a total of more than 55,000 words. The researcher in the interviews talked also less than 10%, whichmeans, that the participants contributed in the interviews predominantly.

The semi-structured interviews were recorded through a mobile phone and a laptop. In the next step, the semi-structured interviews were transcribed. As the semi-structured interviews were also recorded through Microsoft Teams, and Microsoft Teams has a transcription function, the semi-structured interviews were transcribed with the help of Microsoft Teams. The transcription of the semi-structured interviews was checked paragraph by paragraph by the researcher, to make sure that every single semi-structured interview was transcribed correctly. The whole procedure is the same as it was for the semi-structured interviews in the field with road infrastructure experts see chapter 5.3.4.

Based on this, the researcher was able to optimise the conduction of the interviews. In order to participate in the semi-structured interviews, the participants needed to have specified criteria. The researcher was looking for individuals who held or had held a project management role in the private, public or voluntary sector. It also was mandatory that the participants were experts in the field of BT. If they did not have this relevant experience, potential participants were not allowed to participate. These semi-structured interviews were analysed and the results of these will be used for the further research in this thesis.

5.3.11 Results of the thematic analysis – general understanding (semi-structured interviews)

As described in the methodology chapter, the data analysis is based on the thematic analysis. To generate a clear structure for the main themes, the following coding structure was created. The coding structure with its several codes and sub-codes will be explained in more detail in the following sub-chapters.
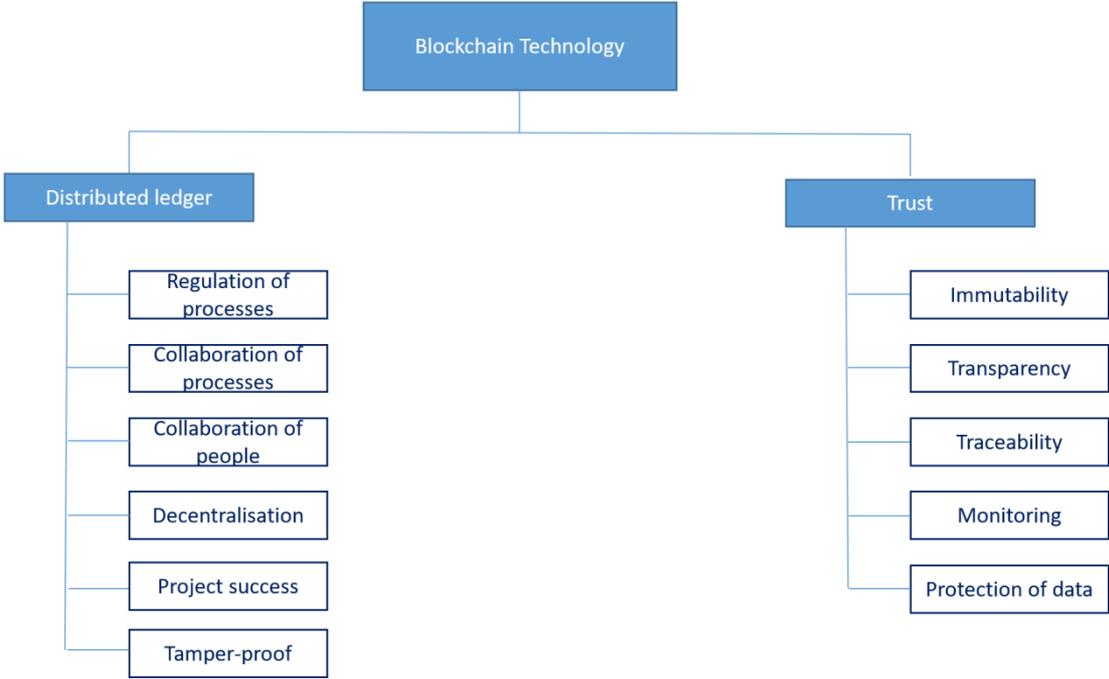
Figure 5-12: Coding structure for the category "principles of Blockchain Technology"

Prior to the data analysis, the first two levels of the coding structure of the principles of BT, see Figure 5-12, were defined. While analysing the data in detail, the sub-codes of the two main categories were developed. In total, two codes and 11 sub-codes were derived for the category principles of BT. The 11 sub-codes were developed through the thematic analysis.

Distributed ledger

The origin of BT is the decentralisation that is based on the distributed ledger. Based on the theme of the distributed ledger the following parameters were analysed through the thematic analysis decentralisation, regulation of processes, collaboration of processes, collaboration of people, project success and tamper-proof.

Regulation of processes

In terms of the regulation of processes, #BT-8 explained it with the help of the design stage, manufacturing stage, operational stage and the disassembly stage. In a current project he is working on, they use BT in the whole cycle. And he also mentioned what confirmed the importance of the planning phase in the life cycle of a road infrastructure project, that they use the BT from the design phase on, over the whole life cycle. He stated that the design phase is one of the most important phases, because in that phase all the information is gathered and a lot of documents are shared. Because of the BT it is possible that the whole process of a project can be regulated.

Collaboration of processes

One of the strengths of a distributed ledger technology can be seen in the information exchange. A distributed ledger is able to support in the collaboration of the different processes that appear in road infrastructure project management. This proposition was underpinned by #BT-4, #BT-5 and #BT-8.

Collaboration of people

#BT-6 mentioned that in their existing projects, between the design stage, the manufacturing stage, the operational stage and the disassembly stage, there is a lot of information exchange required and, for this, BT is the right technology, because of the given security of the data. Talking about the collaboration of people, #BT-7 supported this, stating that, "*with the help of the distributed ledger and the given security, the collaboration between people can increase, because of the safer method used to communicate with each other*".

Strong evidence for using the principles of BT was found when the BT experts were spoken to. #BT-4's attitude was that a technology like the BT only makes sense when a lot of different groups and companies are involved. It does not make sense to use a BT only in one company'. In such a case a public-permissioned blockchain would be recommended.

Decentralisation

The origin of the whole technology is the decentralisation. "*So the decentralisation does work in the finance industry, why should it not work in the field of road infrastructure projects?*" (#BT-8). As trust is a challenge in road infrastructure projects, the idea came up during the research that with the help of a decentralised system trust could be increases in these projects. But until now, there is no confirmation that trust is increasing because of the decentralisation; this was mentioned and confirmed by several participants (#BT-2, #BT-5 and #BT-7).

Project success

"*Whenever a step of success in a process is achieved, this becomes obvious for all participants*" (#BT-6). As there is no common confirmation the correlation with BT and road infrastructure projects, #BT-8 mentioned that, in terms of project success, he accepts that this would increase with the help of that technology. This statement was also underpinned by #BT-7: "*Using a technology that is based on a decentralised system would make projects more successful, as all involved stakeholders would trust each more than they do trust each other so far.*"

Tamper-proof

#BT-2 was a civil engineer but he changed career to be a lawyer. From his experience, one of the most important issues of the technology is that it is tamper-proof. But the question that arises together with that is if this huge technology really is needed for the road infrastructure sector.

Trust

A recurrent theme in the interviews was a sense amongst interviewees that the topic of trust was really important. This was also noted by #BT-4 at the beginning: "*The most important with the Blockchain Technology is that things can be fixed and thereby trust is created. So a blockchain can offer security through decentralisation and it is almost impossible to copy the system.*"

One aspect that supports the topic of trust in terms of the technology is the fact that there is a vast amount of data. This topic was brought up by #BT-3, who stated that in every project a lot of different groups are involved and every group has a lot of different data. But everybody has their own data and does not really share them. With the help of this technology, all these secret data can be brought together and be saved with the help of BT. This technology can also help in giving access to the right people.

#RI-11 mentioned that, for using a technology that is facing the principles of BT, a great deal of partnership and trust is required, and this is not common in the classic projects.

BT is known as a technology that is used when groups, for example that work together do not trust each other. The parameter of trust in the field of BT is composed by several different parameters. The main important parameters that were analysed through the thematic analysis are immutability, transparency, traceability, monitoring and the protection of the data.

Immutability

Namely, the principles of BT work well and do provide support in the field of immutability (#BT-1, #BT-2, #BT-3, #BT-5 and # BT-7). With the given transparency and traceability, documents can be made immutable and will be tamper-proof.

The theme of immutability that was discussed with the participants needs to be understood as follows, as #BT-2 confirmed: "*Immutability regarding the BT does not mean that it is not possible to change documents or processes. The advantage of that technology is that a detailed traceability is possible and a traceability [of] why something was changed.*"

Transparency

Talking to the experts in the field of BT, the view of the topic of transparency started from a different position.

#BT-2 stated that, when he started working with the technology, transparency was spoken about and that the technology is popular because of the transparency. But from his point of view, the technology is absolutely not transparent. He justified this with regard to the finance. Whenever it is not known who is behind a special process, this process or technology is not transparent. So it needs to be thought about in the whole study that a process can be made transparent with the help of the technology, but the transparency in terms of who is behind that process is not transparent.

This statement was confirmed by #BT-3 and #BT-4. But, at the same time, they also rebutted this statement because they argued with the fact that different BTs are around, for example a private or a public-permissioned one.

In terms of transparency, according to #BT-2, the principles of BT offer both a kind of transparency and a kind of lack of transparency. #BT-4 stated that: *"But in the early days of this whole blockchain world, the whole goal was basically to hide the actual owners of processes or operators."*

An attitude in terms of the transparency in the field of BT was mentioned by #BT-1. "*One is a blockchain that would be public facing that anybody could gain information from. And that would increase transparency overall, sort of thing. And then the other one is an internal sort of blockchain that would give you the things like traceability, immutability and all of those same sort of benefits. But then would not be external facing. So I think that the argument for the second one is really strong.*"

As transparency is one of the big advantages of BT, #BT-4 explained that it is to be expected that the industry is demanding transparency.

One aspect #BT-3 noted in relation to transparency is, that at the present time it needs to be kept in mind that people do not want to be transparent, because they do not want to share knowledge. From the perspective of #BT-3, this needs to be thought through more widely, because we are all dealing with the same problems and challenges. This statement can be supported by a comment from #RI-4, who also saw this from the view of the cultural change and different generations. #RI-4 stated that: "*The transparency we are in today is unescapable, we also need to think about the cultural change. We have to work transparently with each other; this means a thinking in the whole construction industry. In road infrastructure projects, different generations are involved and a project only can be successful if knowledge and information are shared.*"

In correlation with the BT, the term transparency needs to be explained very well. For some participants, the term transparency of the BT is sometimes conflicting; this was also supported by #BT-2, who mentioned that, *"At the beginning, I was struggling with that technology, because in correlation with the technology transparency is talked about all the time, but the technology is, from my point of view, absolutely not transparent. It is important that there are different understandings of transparency around. I am part of the finance sector and, whenever you do not understand who is behind a process, we do talk about a [complete lack of]*

transparency. Processes can be made transparent with the help of the BT and this is really useful."

"*So I think transparency will work both ways*" (#BT-1) is a common principle of BT that has been highlighted. When talking about the advantages of the principles of BT, the reaction of #BT-3 was "*transparency*!". "*The reason why we are using the BT is because of the transparency, and we use it in the field of the digital passport and especially in the first phase of the life cycle, in this phase where data are born*" (#BT-7).

Traceability

The attitude that the principles of BT can help regarding traceability was argued by #BT-1: "*BT can be built into software like that in the future and sort of thing. So, like you said, update, so things are traceable and things like that and any data you load. You know when it was loaded and by who and things like that.*" #BT-3 emphasised the importance of traceability in terms of data: *"The question that is coming up is where are all the data from we are working with? Are these real data or are they mathematically interpolated? Another argument in terms of traceability and the improvement of a process in a project is that it is traceable that an improvement in a project is not only working at the beginning, on day five, but also five years later as well."*

The discussion about traceability was also introduced by #BT-2, who related the traceability to the topic of evidence problems: "*We have many problems with proof, especially in the building industry, especially when it comes to warranty claims; a large part is then first to record where the problem is and who caused it. And if you really had a blockchain in construction projects that securely recorded all these processes, then you would have already solved an incredible number of problems and also reduced the costs. Because in a construction project, it is*

extremely problematic to determine who made the mistake, because simply no one wants to have made it."

#BT-7 mentioned that: "*We use the BT because of three reasons, transparency, traceability and collaboration*". #BT-6 stated that: "*Because of the traceability that can be guaranteed through the BT, for a bridge for example, every single parameter is well known, and everybody is up to date in terms of the quality of that bridge.*"

Monitoring

#BT-1 mentioned seeing a huge advantage in the field of monitoring when the principles of BT are used "…*but prove that they did it well and proved that they were monitoring and it wasn´t just tucked away in a filing cabinet somewhere*…." With this statement, the participant was relating to data that are normally paper-based and are stored in a filing cabinet. "*With the help of this technology, all complex projects can be monitored*" (#BT-6).

Protection of data

"*With the help of the unique object identity that can be given through the BT, the protection of the data is guaranteed*" (#BT-6). Regarding the complexity of BT and the practicability of the technology, #RI-2 stated the following: "*It needs to be thought about if such a complex technology will support in the challenges that are faced in the road infrastructure project management and it needs to be thought about if the protection of the data is the main issue in road infrastructure project management.*"

The question that arises in combination with the principles of BT and the information exchange is: *"Is it possible to use the principles of BT with its distributed ledger as a foundation for a proper information exchange system?"* (#BT-7). This was also considered by #BT-1: "*It would be great to have a proper information exchange system, for the whole communication through the whole life cycle of a road infrastructure project, that would be based on the tamper-proof*

principles of the BT." Therefore, the predicament between the information exchange and the

principles of BT lies in its environment, regarding trust, less digitisation and less transparency.

5.3.12 Results of the thematic analysis enabler / barrier (semi-structured interviews)
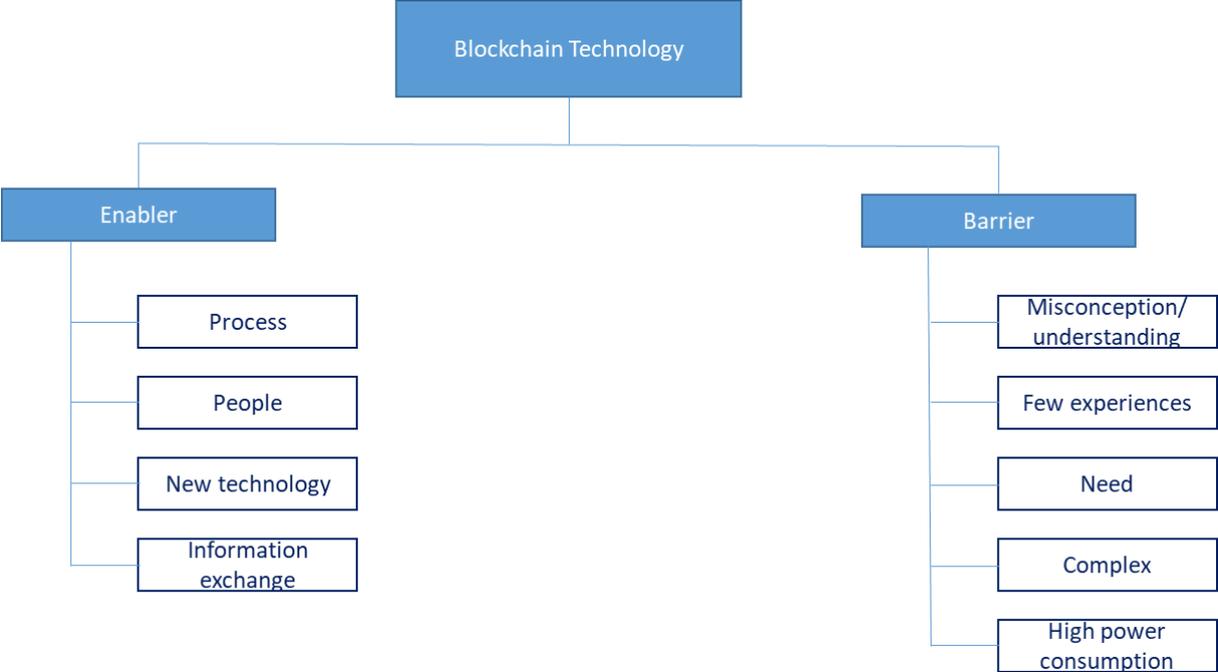
Figure 5-13: Coding structure for the category "principles of Blockchain Technology"
(enabler / barrier)

One part that needs to be answered in the study as well is to gain an understanding of what

the enablers of and barriers to the principles of BT in the context of road infrastructure projects

are. To understand the meaning of a barrier and an enabler, definitions from the Oxford

Dictionary were used. A barrier is an obstacle that prevents movement or access and to enable

means to make something possible for something.

The findings are based on the data collection from focus groups and semi-structured interviews

and will be presented with the help of quotes. The tables and maps that will be illustrated are

also based on the quotes from the data collection. The results in the findings chapter will merely

be based on the focus groups and the semi-structured interviews. The comparison and the relationship to the literature review will be made in the discussion chapter.

Blockchain technology as an enabler

The focus groups and the semi-structured interviews showed that BT was seen as an enabler for managing road infrastructure projects. With the help of the structure of the technology processes, people and the technology are brought together (see Figure 5-14).
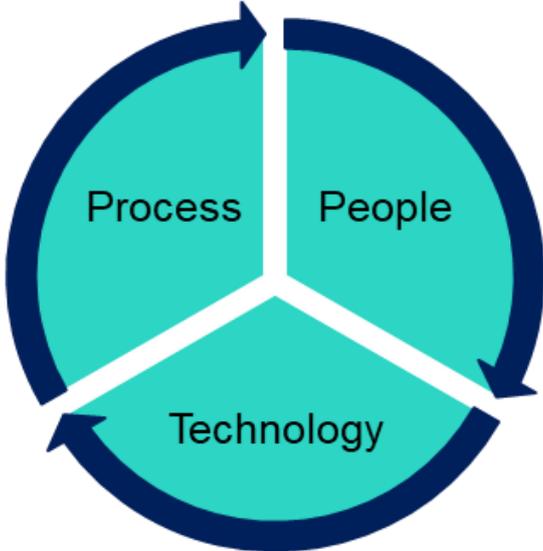
Figure 5-14: Blockchain Technology as an enabler

This adoption can be confirmed with the following statements from the conducted semi-structured interviews:

> *#BT-3: "With Blockchain Technology, the goal is to connect*
> *the different processes and make them transferable."*

> *#BT-5: "Blockchain Technology and the new technologies are*
> *a new-thinking model, in that collaboration is wanted."*

> *#RI-3: "The Blockchain Technology is definitely an enabler for*
> *the whole life cycle of the project management of road*
> *infrastructure projects from the first step on. Especially the*

> *planning phase is a critical phase in the whole life cycle. Lack of planning leads to a construction lack."*

> *#RI-1: "Such a technology is needed from the first step on, continuing in the whole life cycle of a road infrastructure project."*

To gain an understanding of why BT can be seen as an enabler, different topics that are included in the huge field of BT need to be categorised.

The topics in which participants saw BT as an enabler for the road infrastructure sector are the following:

- ➢ Information exchange

An example given by #RI-6 for what can go wrong is if there is a lack in the information exchange. The following scenario happened in an actual project:

An application for a full closure of a road in the subordinate network was made, because the road body still has to be adapted under the new bridge that was built – kerbs, new asphalt, etc. So, they submitted the application before Christmas and just now with the application mailing. They also informed the public in good conscience. They were obliged to do so, because supply chains, travel routes to work, school, etc., were also involved, and the information is passed on accordingly via their media. And this is then also published in the daily newspapers and on the internet. With the consequence that the person responsible for this traffic order was in self-isolation. And he had no access to this document and it was just today that they received the information that the application had been approved too late. As a consequence, they postponed the measure by one week. And the whole thing was rounded off in a sensible way by the fact that the mayor of the neighbouring municipality informed them by WhatsApp, "Mr XYZ, you have reported the closure of the road. I drove through this morning, what's going on? Stupid." This is actually about pure information, but if such a system will not be misused. It is worth thinking how much easier it would be if you could set the processes once and then have

them run through almost automatically, right up to the press spokesperson. It would then be possible that Mr XY had not accepted the application and would know the consequences, which would be a huge advantage.

> ➢ Technology itself

#BT-3 stated that: *"With Blockchain Technology the goal is to connect the different processes and make them transferable."*

Information exchange

#RI-1 highlighted the issue of when a project goes wrong, stating that *"A project goes wrong when information gets lost or does not even arrive at all. This is the reason why the topic of information distribution is really important for us and where we do need a solution."*

> *#BT -2 "It is simply the case that information is always distributed and in this respect the blockchain is at least something quite realistic, because, even with all the efforts to create huge data platforms, if information is passed on from one person to the next, it will deteriorate, i.e. it will become older and older. In the worst case, it will be falsified. And there is no longer any guarantee that the third or fourth person who receives it actually has the current version. Yes, so the distribution of information is a huge issue. And, from my point of view, the blockchain can really be a central infrastructural component in the construction industry and in the entire circular economy and supply chain and whatever else plays a role there."*

#BT-2 also highlighted, "*Whenever we do give information from one to another, information does get lost."*

Planning phase/Design phase

What was discussed during the semi-structured interview with #RI-13 is that the planning phase is split into a lot of different phases. Hence, from the perspective of #RI-13, the principles of BT with its given possibility of transparent processes could be a huge enabler in that phase. #RI-1 also saw that the principles could help as an enabler in the design/planning phase. It was mentioned that it could bring a huge additional value as his experience is that a lot of things go wrong in the planning phase and with incorrect tenders. A lot of a project depends on the planning phase, and this is also related to the information exchange, how everything is prepared and set up. This statement was underpinned by #RI-3, "*The technology definitely can be used as an enabler in the planning phase, because it is the most critical phase. Lack of planning leads to a construction lack.*" From the perspective of a BT expert, #BT-3, this can be seen as the following: "*Everything starts before building what for materials where used, what about the supply chain management; at the beginning, everything is a product and can have an ID*".

Traceability

Based on the transparency, the traceability can be spoken about at the same time. For participant #RI-1, it is really important, that: "*It needs to be highlighted, what did change during the whole lifetime in the design phase and from this phase on to the whole process. A technology with the introduced principles is needed from the first step on and would bring an additional value to every project. We need to plan realistically, we have a realistic cost estimate and what can we add for contingencies.*"

Talking about traceability as an enabler, according to #RI-2 this is a "*basic need in a building process, in the planning, controlling and in the release. In terms of the traceability, it will not help regarding the different interests of the different stakeholders, because this will never change.*"

From the perspective of interviewee #RI-7, BT is not really a new technology. From the idea itself, the idea has been the same for a lot of years, everybody wants to have access to all data, but until now no proper solution has been found. So the idea is not new, the idea of the implementation is new. So this can be a huge enabler for the BT.

Even though the technology is hard to understand and is not that greatly used so far, participant #BT-2 expected that a time would come when everybody was using it, like the internet. And not everybody who uses the internet understands how it works. The participant also explained: "*It is simply the case that information is always distributed and in this respect the blockchain is at least something quite realistic, because, even with all the efforts to create huge data platforms, if information is passed on from one person to the next, it will deteriorate, i.e. it will become older and older. In the worst case, it will be falsified. And there is no longer any guarantee that the third or fourth person who receives it actually has the current version. Yes, so the distribution of information is a huge issue. And, from my point of view, the blockchain can really be a central infrastructural component in the construction industry and in the entire circular economy and supply chain and whatever else plays a role there.*" #BT-2.

In combination with the traceability, the information exchange was a more important theme. #BT-2 spoke about the information exchange and the value transfer: *"If you can reliably record certain information on a blockchain, that is simply a prerequisite for digitally mapping a value transfer, as long as you can't really trust the information if it says that and the material with that and that value has been delivered there and then."*

#BT-3 saw the enablement of that technology also from a different perspective, namely, "*Enablers for the Blockchain Technology are the following parameters: automation, repeatable process, multiple stakeholders, transparency, trust, immutability, value transfer.*" It was also mentioned the incentive, which is given a huge advantage for the technology.

Barriers to blockchain technology

The next set of questions aimed to find out if there are barriers to the implementation of BT in road infrastructure project management. It also needed to be found what the fundamental barriers to the BT are detached from the road infrastructure. To distinguish if there are barriers is mandatory for thinking about the utilisation of the technology. This is a basic step for the understanding of the collaboration between the technology and the road infrastructure project management. In view of this, it was not surprising that the participants mentioned a number of barriers they associated with that technology.
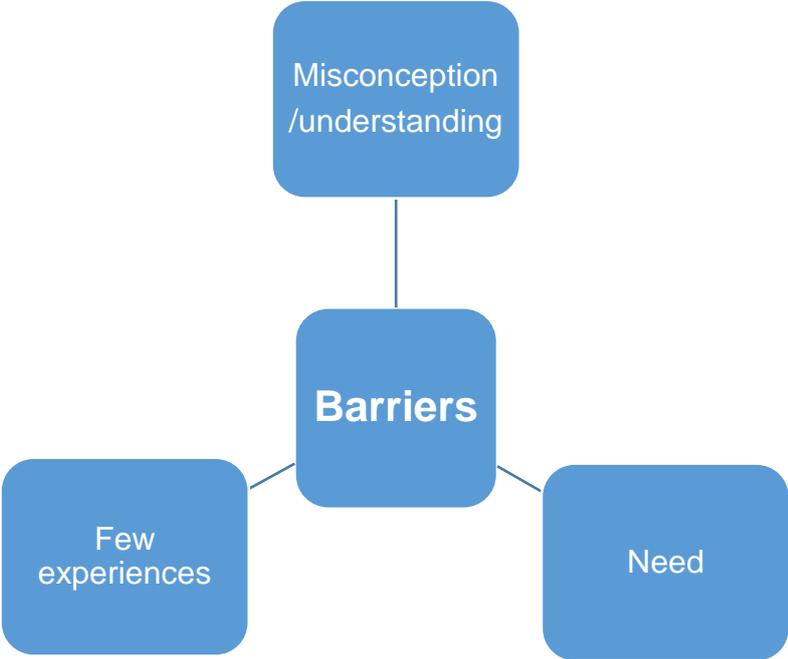
Figure 5-15: Barriers of Blockchain Technology for managing road infrastructure project management

Figure 5-15 highlights the three most mentioned barriers the participants named during the data collection.

One of the most stated barriers in the semi-structured interviews was the misconception or the misunderstanding of BT. Overall, an obvious misunderstanding appeared when the researcher started with the data collection. As explained in the earlier chapters, the explanation of the principles of BT was really important, as most of the participants had an understanding that BT

was the cryptocurrency bitcoin. To overcome the first challenge, the researcher explained the technology regarding the issue that the BT is not bitcoin. To explain this, the researcher used the example of a road and a car. It is known that a road and a car are two different assets. To drive a car and to get safely from A to B, a road is mandatory. But a road can exist without having cars on it, as we can use roads for different actions as well, like riding a bike or walking on it, for instance. This can be compared to the BT and the cryptocurrency bitcoin. The BT can exist on its own, but, so that the cryptocurrency bitcoin can be used safely, the BT needs to run in the background.

This explanation leads to the first barrier in the context of BT: the misunderstanding with the technology.

A number of participants, mainly the road infrastructure experts, mentioned that they are afraid of the technology because they think that it is an expensive technology with regard the energy costs. They had this opinion because of the comparison of a Bitcoin Blockchain with other blockchains. So it needs to be highlighted that these are statements from participants who are not experts in the field of BT.

This view surfaced mainly in relation to the "not knowing" about the technology. Most of the people bring the BT in connection with the Bitcoin Blockchain. The Bitcoin Blockchain is actually facing the mentioned problem but the Bitcoin Blockchain is different from other blockchains, so it has to be careful, when it is talked about BT. This is something that can be confirmed by #BT-2: "*The old Bitcoin-Blockchain is an energy guzzler for sure, but the new Blockchain Technologies that are used are no more energy guzzlers.*"

This statement also highlights the misunderstanding of the technology; it demonstrates that groups do not know that there are different blockchains or BT? around. This also leads to the fact that the researcher is focusing on the principles of BT and not on the technology itself.

This proposition, with the misconception and the misunderstanding, was also confirmed by #BT-1 and #BT-4, who explained the circumstances as follows. Vast computing landscapes are necessary for generating the cryptocurrency bitcoin. But, for using the principles of the blockchain in a common project, fewer databases are necessary to obtain the same effect than in a Bitcoin Blockchain. Blockchains used in this correlation are Ethereum Blockchains. This was also the experience of #RI-12. #RI-12 wanted to implement the technology in an existing project, but was not allowed to because of the expected costs in terms of energy.

This misunderstanding appears because a lot of participants know BT only because of the cryptocurrency bitcoin and think that this technology is only useful in the finance sector. Thus, from their perspective, it does not make sense to use this technology in a different sector.

In a summary, it can be said that the *misunderstanding* of BT is the wrong understanding of the technology, because it is related to the Bitcoin Blockchain.

Closer inspection of the data collection demonstrated a second barrier in correlation with that technology. Several participants mentioned the need together with new technologies or especially the BT.

For example, #RI-2 wondered if, through new technology, needs are arising in an industry that are not necessary. "The technology is discussing needs, which were not necessary years ago."

A number of participants (6) related to the need in terms of the principles of BT. This was predominantly mentioned by #BT-3 and #RI-2. #BT-3 noted that, prior to such a technology being used, the following question needed to be answered: "*In which areas can such a technology be used?*" From his perspective, the biggest challenge was the wait until such a technology was working and where it could be useful for the user. He explained this with the help of a car and a road: "*Now let's use the analogy to the road infrastructure. If I build a road now, it will be expensive and will only bring nothing as a road for the time being. But if cars can drive on this road and transport can be made, people can earn money with it and the road has*

a financial benefit." #RI-2 wondered if such a technology was thinking about needs that were not required before'. Similar to #BT-3, he also supported that it needs to be thought about "*in which areas can such a technology be used and is this really needed*?" He explained it with the help of the following example: "*Twenty years ago, when there was no WhatsApp, I was sending Christmas cards to my family and friends, but I was only sending Christmas wishes to a fraction of people I do send Christmas wishes today. WhatsApp offered me the* ability to send *Christmas wishes to so many people, but, compared to the earlier days, I do not have more friends now.*" The participant was wondering if such a technology is thinking about actual needs and will maybe not really change something in present times.

Another interesting finding from the collected data is the third barrier, which is related to less experience with that technology. As it is used successfully in the finance sector and in the supply chain field, no experiences are developed in the field of project management of road infrastructure projects, which was investigated by the researcher. This is a fact that was mentioned by #BT-2 and #BT-6: that there are a lot of pilot projects around in the construction industry, but the problem is that at the moment these are only pilot projects and there are no implemented projects.

But prior to starting with the principles of BT, it needs to be started holistically in terms of the digitisation. This is something that #RI-7 stated: "*In terms of the acceptance in the construction industry, there is still a lack. In terms of digitisation, I see a problem with new technologies in principle.*"

#BT-2 mentioned that the whole topic with the BT is really hard, the fear of contact is large, because not a lot of people really do understand the technology.

Another challenge that was mentioned by #BT-3 was that his fear with this technology was that, from his point of view, people are not willing to share data and their servers. But this thinking needs to be changed.

Namely, it is obvious that there are some challenges related to that technology; some more of them are listed in the following:

> "Until now, there have been only little experiences with the technology in the field of road infrastructure projects" #BT-2.

> "People do not understand that we have more options than using a public unpermissioned blockchain" #BT-5.

> "Everybody wants to understand the BT, but the more important is, what is possible with that technology? (For example, everybody is writing e-mails, but nobody is asking for the TCP IP protocol, which is behind the function of writing e-mails.)" #BT-3

> "Nobody is talking about the application and what would be the advantages of the technology, why is this so interesting in this technology?" #BT-2

> "What are the applications we want to use the principles of BT for?" #BT-3

> "It is important not to think from an IT perspective; it is more important to think from a conceptual view." #BT-4

> "When transparency is talked about, it does not mean the whole transparency." #BT-4

> #BT-2 mentioned that, from his perspective, groups and people need to be careful when talking about the transparency. Normally, the understanding of transparency is that every step of every communication and every process is transparent for everybody in:

- ➢ Fear of contact with that technology – #BT-2

- ➢ Not every blockchain is taking so much energy – #BT-2

- ➢ #BT-3 observed that BT and the new technologies are a new-thinking model, where we do want to work together, and this does not fit into the old thinking.

5.3.13 Summary semi-structured interviews of the blockchain technology experts

The individual interviews with the BT experts were conducted to develop the understanding of the principles of BT further. Talking to the experts in this field helped in generating an in-depth understanding of the phenomenon of that technology. Furthermore, the conduction of the interviews helped in achieving the second and third objectives in the research, and these objectives are also mandatory for developing the framework at the end.

Basically, the main advantage of the BT is, that it is built on a decentralised system. This decentralised system works with the help of distributed ledger. BT was developed for processes in which the participants did not trust each other. For this reason, the distributed ledger is the correct system. Based on this system, data are not stored on a central system; this system supports the idea of having all documents stored on different servers.

Figure 5-16: Understanding Blockchain Technology

Figure 5-16 helps in understanding what the principles of BT are. In this correlation, it is significant that these are the terms that were mentioned the most during the data collection. When the principles of BT were discussed, the most important terms were trust, transparency and traceability.

5.4 Chapter summary

What was found out is that in road infrastructure projects a lot of different stakeholders are involved, which makes it hard to obtain transparency and traceability in the whole process of a project regarding the life time and every phases in the project management. Hence, the focus now needed to be on these advantages of the BT with regard to road infrastructure projects. What also needed to be investigated with the help of the interviews was how the socio-political,

structural and uncertainty complexity are applicable in mega, large and small projects. It needed to be found out in which types of projects and which fields of project management BT could be used. The world is changing very fast in the era of digitisation and it is also worth having a deeper look into the field.

#RI-1 observed that: *"A lot of building owners do not have the data of the planning phase; transparency would help in here."*

The researcher conducted focus groups in two different companies and semi-structured interviews are operating in the field of road infrastructure projects and in the field of BT, to get to know the status of the companies in the road infrastructure sector in terms of the digitisation.

The results of the focus groups and the semi-structured interviews were that the project managers in the field of road infrastructure projects felt they were only little digitised, and compared to other industries it can be said that this industry is less digitised.

The result of the data collection is not that companies are not using tools for their support, but they do use digital aids for specific tasks and processes in a specific workflow. So it does happen that a company has a lot of different tools for a lot of different operating workflows.

This was one of the reasons why the researcher asked the question about what tools the companies are using, and what the need behind them is.

Although the companies are not really digitised, that does not mean that they are not willing to use new technologies; the reason why they are not using new technologies is more that they are afraid and really sceptical of them. In the current research, the new focus of the new technology was the BT.

Within the research, the whole life cycle of the project management was analysed. Starting with the planning phase, it needs to be considered that a planning phase takes over several years until the building phase starts. The challenge is to involve all circumstances in that project, but this is hard, as sometimes it is not clear what will happen in the future. One example

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for this is Berlin's airport. When the planning of the airport started, nobody was even thinking about the airplane A 380. Suddenly, the A 380 needed to be involved in that airport. That meant a lot of changes to the airport itself. And now the A 380 no longer exists, which means that the planning needs to change again.

This provides an understanding for all involved stakeholders that the planning phase needs to be flexible in terms of changing plans and transactions. This means that, for a short-term period, it needs to be possible that the planning can be changed, shifted or planned differently.

However, flexible planning also requires a flexible planning tool that can be quickly ready for use and which leads to a rapid adaptation of the plan. Unsuitable tools are inefficient because they slow down the work and they slow down the work process, because they require a lot of manual work. This is the last thing what a project manager needs on his/her way.

Close to the planning is the planning uncertainty. This can have effects in terms of logistics and finance. In such situations, rapid actions are necessary. And what will happen to the other stakeholders and to the other processes also needs to be considered. For these scenarios, it is essential to have a solid database. With the help of data, risks can be estimated and situations can be evaluated.

All the results and findings that were found are based on a well working information exchange system. This is a fact that nearly all participants supported, without a proper information exchange, it is not possible to work in the different phases with each other.

5.5 Summary of complex relationships and outlook for the discussion

To get a better understanding of the complex relationships that were identified during the literature review and the collection of the data the following diagram see Figure 5-17 was created to give an overview.

First of all, it is started with the challenges in road infrastructure projects, identified from data analysis, that can be divided into two areas. The first area is the topic of "sharing strategic intent" which includes the different stakeholder expectations generated within a project and the second area is the challenge of the cultural change with big projects as it is common in the road infrastructure. The second area is the area of trust, which is the main topic of the whole research within the scope of this thesis. The theme of trust can be divided into transparency, traceability and immutability. These topics can be related to the principles of the Blockchain Technology. This fact is bringing us to the second part of the diagram, that were identified in literature review, the benefits. The Blockchain Technology consists of the fields of decentralisation and trust. Decentralisation is useful in the areas of "regulation of processes between different groups" and the "collaboration of processes and people." The field of trust involves themes such as "enable transparent processes", "possibility of controls" and "protection of data". Looking at these two areas the first assumption can be made. It becomes visible that the decentralisation of the Blockchain Technology can support in the challenge of sharing strategic intent in road infrastructure projects. The second assumption is that the decentralisation has the possibility to offer a higher level of trust because it effects the areas of transparency, traceability and immutability. Putting all these information and advantages together this is leading to the outcome – which is the information exchange. As it was found out that communication is playing a big role in the success of road infrastructure projects the third link can be made. Using the advantages of the Blockchain Technology for the challenges that the different stakeholders face in road infrastructure projects a shared understanding will be enabled. This gives an opportunity of better information sharing along the whole life-cycle, better knowledge transfer, up to date information and a better collaboration of people, processes and technology.

1. Challenges -
Road Infrastructure Projects

- Different stakeholders expectation
- Cultural change
- Sharing of strategic intent
- Transparency
- Traceability
- Trust
- Immutability
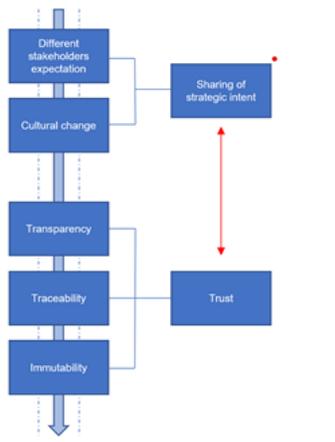
2. Benefits –
Blockchain Technology

- Decentralisation
- Regulation of processes between different groups
- Collaboration of processes and people
- Enable transparent processes
- Trust
- Possibility of controls
- Protection of data

3. Outcome –
Information Exchange

- Information sharing over a life cycle
- Collaboration of people, processes, technology
- Enable shared understanding
- Better knowledge transfer
- Up to date information
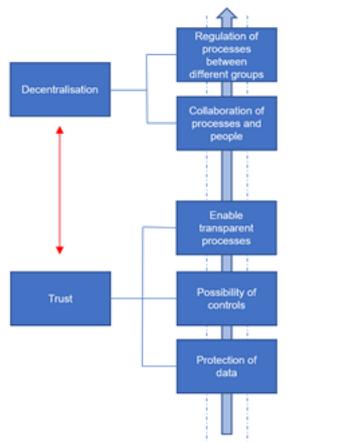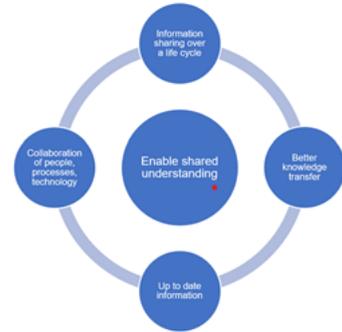
Figure 5-17: Explanation of the complex relationships between the three areas (own representation)

6 Discussion and framework development

6.1	Introduction
6.2	Procedure in the discussion chapter
6.3	Reasons for developing the holistic framework
6.4	Reasons for using the principles of BT for the development of the framework
5.5	The key attributes of the framework
6.6	The Framework in the whole project management life cycle
6.7	Content of the framework
6.8	Development of the framework
6.9	Chapter summary

Figure 6-1: Overview of chapter 6 – discussion and framework development

6.1 Introduction

The aim of the discussion chapter is to bring together the findings of the different data collection methods conducted for this work (Chapter 5). It is also the goal to reflect the findings against the existing literature theory that was introduced in Chapter 2. Based on the reflection on the findings and the comparison of those to the literature review, the overall outcomes of this research will be presented.

This chapter on the discussion and framework development is fundamental to the whole study. Next to the discussion about the findings, in this chapter the aim is to discuss and develop a holistic framework that enables the road infrastructure project management to manage in terms

of an information exchange in correlation with the principles of BT. In the current chapter, the outcome of the conducted focus groups and the conducted semi-structured interviews is discussed. For the discussion, the findings of the collected data and the literature review are compared with each other. Based on this discussion, the framework is developed that enables us "*to utilise the principles of Blockchain Technology for managing road infrastructure projects*". The framework contains the findings of RO 1 to RO 3. With the results of the first three research objectives, the research aim is defined:

> "*To develop a framework for the utilisation of BT to support the management of Road Infrastructure Projects*"

A discussion will take place in this chapter referring to the conducted data collection and the literature review. Constitutive on these findings, the chapter guides the reader through the development of the framework and explains the needs for developing this special framework for this study. The aim of the framework in the research is that the structure of the framework supports the theory of the research study. At the same time, with the help of the framework, it will be described why the research problem under the study exists. In one of the last steps, the developed framework is presented and it is elaborated how this framework can be used in theory. Finally, the research question of the whole study will be answered.

6.2 Procedure in the discussion chapter

Figure 6-2 shows that Chapter 6 is based on the data collection and the literature review. As the findings of the data collection were presented in detail in Chapter 5, the literature review will be investigated as a comparison in the current chapter. The results of the data collection will be viewed in that way, to gain an understanding of how the literature review supports the data collection. The diagram visualises that the circle in terms of the literature review needs to be closed around the data collection to support the results. To understand the context of the whole research, every parameter of the different themes will be explained in detail.
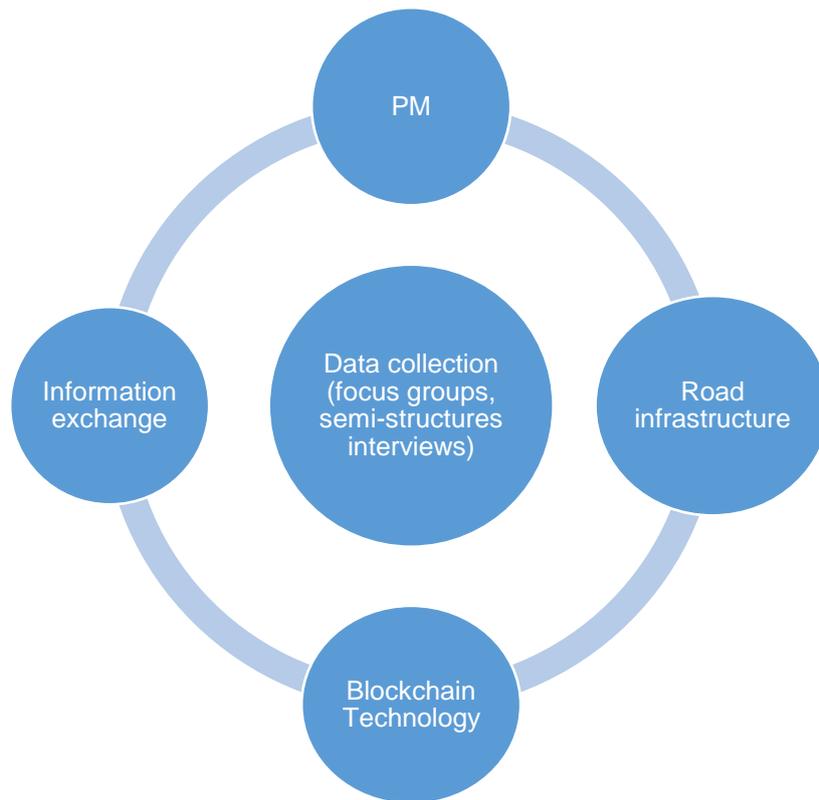
Figure 6-2: Consolidate the literature review and the data collection (own representation)

6.3 Reasons for developing this framework

Different frameworks and platforms of BT were created in the last decade. Based on these frameworks and platforms different issues in manifold areas were able to be addressed with the help of the BT. The main blockchain frameworks that were created so far are Ethereum, Hyperledgers, Bitcoin and Ripple (Hames, 2022). And these are only a few examples for already created frameworks based on the BT. With this research another framework will be created.

The whole study started with the statement by McKinsey (Strube, 2021) that the productivity in the construction industry had not grown in the last 40 years compared to the other industries such as the manufacturing, engineering or the automobile industry. It is a big discussion in the construction industry that an improvement is required in here. In the first chapters it was shown

that, since the year 1960, there has been no improvement regarding productivity. Since the 20th century, we have been living in the age of industry 4.0. One big part of industry 4.0 is new technologies and digitisation. In the past decade, BT has become more popular and more industries are using it successfully. A central role in the whole road infrastructure sector is the different cultures, different generations, long life cycles and requirements for a proper information exchange. For this purpose, there is a need for a management between road infrastructure project management groups, digitisation (in the current research the principles of BT were investigated) and information exchange. Little attention has been paid to the principles of BT in the road infrastructure sector so far. Thus, it is essential that organisations are supported in the field of new technologies and that organisations and companies understand what the meaning of the term "new technology" is. The literature research and the data collection supported the need to develop a framework to support the management of road infrastructure projects in terms of the existing challenges.

So far, the BT has been applied in a lot of different industries and sectors such as the finance sector, in the supply chain or in the health sector (Hames, 2022). Within the road infrastructure sector, the technology has only been applied in a few disciplines as pilot projects. The idea in the current study is to apply the principles of BT in project management, change management and process management related to information exchange. An application that is already used in the construction industry and can be compared to the principles of BT is the use of Building Information Modelling (BIM) (Aziz, Riaz and Arslan, 2017). The difference between BIM and the principles of BT was discussed in detail in the literature review chapter.

At the beginning of the study, a literature review was conducted in the field of road infrastructure projects, BT and information exchange. One result from the literature review was that when a new technology is utilised in the road infrastructure project management regarding the information exchange, three factors play an important role. These are the factors people, processes and technologies (see Figure 6-3).
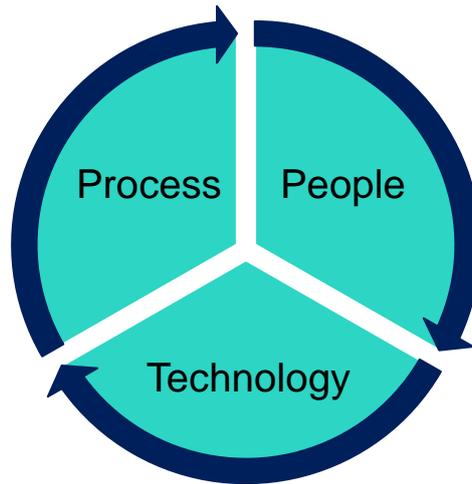
Figure 6-3: Important factors for utilising a new technology (own representation)

For developing a framework and utilising a new technology in a first step the attention was on where the industry is in terms of digitisation and how it is handling new technologies. This step is important to gain an understanding of what are the industry's fears regarding new technologies. The literature review, the focus groups and the semi-structured interviews support an understanding of the need for such a framework.

The challenge in developing this framework is that, in the area of road infrastructure project management examined by the researcher, there are few experiences in the field of the principles of BT so far. During the research, the term BIM was discussed several times. Inasmuch, BIM and BT have an interface, experiences of the so far developed BIM projects can be used for developing the framework. Challenges the industry is facing can be found in the following key elements:

> ➢ Different stakeholders need to trust each other → How can trust be generated?

> ➢ For working more efficiently, transparent processes are needed → How can processes be generated that are more transparent?

- ➢ Processes need to be traceable and immutable → With which tool can this be ensured?

- ➢ As a lot of different stakeholders are involved, collaboration is a really important parameter →How can a proper collaboration be ensured?

- ➢ Processes needs to be transparent from the first step on until the last step → In which phase will the framework be used and why?

In order to answer the above questions and statements, the framework is developed based on the literature review and the data collection in the next section.

6.4 Reasons for using the principles of blockchain technology for the development of the framework

One of the goals of the conduction of the focus groups and the semi-structured interviews was to find out if the principles of BT are the correct procedure. The evidence can be given now that these principles are the right approach, as this can be supported by statements from focus group and the semi-structured interview participants, for example: #RI-11 mentioned, that for using a technology, that is facing the principles of BT a great deal of partnership and trust is required, and this is not common in the classic projects.

6.4.1 Blockchain technology as an enabler

The expectation is that the procedure of the understanding of BT can be compared to the procedure of the web and of writing e-mails. #BT-3 explained this with the help of the following example.

He thinks that one of the special things about BT is that, for a lot of people, the focus is that they want to understand how this technology works. Sometimes, people even think "How does it work?" before they think "What is this technology able to do?" This can be compared with the

TCP (Transmission Control Protocol) IP protocol. This is the protocol that is responsible for the data transfer of e-mails. Nobody is interested in that protocol and how it works, but everybody is writing e-mails every day. And it seems like this is not that important anymore. This was different when the internet and writing e-mails came into our lives. At the beginning, people were critical about that technology and how it worked and people were really sceptical about using it. Participant #BT-3 expected that the same would happen with the BT in the future. The time will come when the technology is running in the background and nobody is asking how it is running and what is running in the background.

The history of e-mails shows how long it takes us to use new technologies in our lives. The first e-mail was sent in 1971, but it took 13 years until the first e-mail arrived in Germany, in 1984. And it took even more years until it was used by everybody and fitted into our daily lives (Samoriski, 2009).

6.4.2 Advantages of the blockchain technology

The question that arose during the whole research was why is BT so different from other technologies.

As a basic principle, the BT is based on a decentralised system. Because of the decentralisation, no intermediary is necessary (Gordon, 2018; Hames, 2022). Another argument for the speciality with the technology is the immutability, the distributed ledger and the peer-to-peer thinking, and a huge advantage is that an incentive can be brought into a process with the help of the technology (#BT-3). This is a usual procedure that makes the technology that special and efficient (Cowden and Tang, 2022).

6.5 The key attributes of the framework

6.5.1 Key attribute – trust

One of the most important key attribute in the interviews and focus groups was stated to be the field of trust. Additionally, it was stated by #RI-6 that the problem in the current projects is that partners they are working within the actual project can be competitors in the next project. This statement supports the belief that the BT is the right technology because of the trust age (Mazzella et al., 2016, p. 31). As noted by Hames (2022) is the system of the BT the system that can be successfully used if different parties do not trust each other. This technology can bring security to transactions because it uses a distributed method that is not tied to a trusted party. The feature decentralisation does bring the quality of trust and immutability.

6.6 The framework in the whole project management life cycle

The first phases of the project management as the planning phase and the design phase play a central role in a road infrastructure project (Spang, 2016), the framework needs to involve the whole project management life cycle from the first step on. It is said that it is only possible to start with the construction process when the planning phase is finished. Changes in the planning phase during the process of the construction can have the consequence that projects are not in time and the costs are increasing (Spang, 2016). This prediction by Spang highlights the challenges in transportation projects, and was also supported by #RI-13: "*A transparent and traceable procedure is mandatory for the whole life cycle of a project. But if there is no traceable completed planning phase in a project, from my perspective, the planning phase is the most important phase, the whole project will meet the timing, the budget and the quality.*"

6.6.1 Positive feedback in terms of developing the framework starting from the planning phase

That the planning phase has a central role during the whole project management can be underlined by one of the statements from the semi-structured interviews: #RI-2 "The quality of a project is made through the planning phase. This means that, if we do not have a proper planning phase, we do not have to discuss about cost and timing."

On the basis of the statement, #RI-2 is expecting that the principles of BT can deliver a huge number of advantages in the planning phase.

It also needs to be considered that the different groups in a construction project have different interest (Bartsch, 2013). This was also mentioned by #RI-2, who gave the following example: the planner wants to plan as long as possible, the entrepreneur wants that the planning phase to be as short as possible, and the building owner wants the plan to be finished as soon as possible to the best quality and for it to get to the implementation team as soon as possible. What can help is if the building owner agrees with the plan, that the planner can release the plan, the planner gets the agreement, and from that point on the plan is immutable and traceable. And this process brings transparency with it (Samset, 2014). #RI-2 Basic needs in a building process are: planning, controlling and release. A result of the literature review in the field of road infrastructure project that can be confirmed through the findings of the semi-structured interviews is that the planning is the central role in the management of a road infrastructure project (Spang, 2016). Therefore, it needs to be recognised that it is only possible to start with the building phase, when a proper planning and design phase is finished. In terms of the relationship of costs, timing, quality and risk (see Figure 6-4), the consequences of changing the planning in the building phase lead to the fact that costs are increasing and time schedules are not in time. This was also stated by #RI-9:

> *"In my opinion, the most important building block is the*
> *planning phase. If, for example, a soil survey is not carried*

out or is incomplete, we need additional information

afterwards. And here there are simply a lot of input

parameters where it can really be decisive whether a project

works at all or not."

Being successful in a project and talking about the principles of BT in a project, the main question all the time was "Where does the data come from?" (#BI-4). #BI-4 also mentioned that this also leads to the idea of having all the data, starting from the planning phase in a blockchain. #BI-4 is asking: "*Why should we start using a blockchain after the planning phase and how will be confirmed, that the data which are in the process of a blockchain are the real data*?"

Figure 6-4: Relationship costs, timing, quality and risk (Spang, 2016)

Based on the gathered data and statements, it is obvious to generate a holistic framework for the whole life cycle of road infrastructure project management.

For generating the holistic framework for the present study, a general literature review in the field of stakeholder management was performed (Freeman, 1994). Additional to this, an actual project was used for generating the framework.

As mentioned by #RI-14, it generally makes sense that the different groups are working together. For example, the ecologists of the forest and the flora. It also is recommended that groups that investigate the field of noise/pollution reports and in the traffic study. Both, for instance, need to count the traffic. If two groups count the traffic, the likelihood that two different results will be generated is really high.

6.6.2 Critical feedback in terms of developing the holistic framework for the whole life cycle

The aim of the research is to develop a framework for the whole life cycle. This idea was to develop this framework based on the research findings. But, next to the development of a framework for the whole life cycle, some critical notifications were also made during the data collection: #RI-3: *"Transparency from the first step on would make sense, but is it allowed that all data are available for everybody all the time?"*

#RI-4 observed that what was getting lost was that the building owner and the building contractors have the same goal (Bartsch, 2013). #RI-4 mentioned a project in which a tool was developed with the goal that it is possible that in one model the building owner does not see what the constructor is doing and the other way round. This is similar to the fact that companies are trying to find a solution for how SharePoint is used in a way that not everybody can see what the others are doing. This is not the goal of transparency. If this is the need for the different stakeholders, the use of BT would be a great advantage as with the help of BT different types of technology can be used: permissioned BT, private blockchain and public blockchain (Lemieux, 2016).

#BT-4 stated: *"But, in the early days of this whole blockchain world, the whole goal was basically to hide the actual owners of processes or operators."* This statement underlines what #RI-6 mentioned in terms of that different stakeholders do not want to share their strategic alignment.

6.7 Content of the framework

The development and completion process of the framework was identified through decoding and understanding themes in the literature research and the thematic analysis of the data collection. During the data collection, important themes and subthemes were identified and opposed. The framework consists of three themes and relates to the project management of Road Infrastructure, the principles of BT and how this technology can provide support based on the third theme, the IET.

The first topic in developing the framework sought to determine the term stakeholder in detail, as has been mentioned in the research so far several times.

Based on Freeman (1994), two questions need to be thought of in general:

> ➢ What is the purpose of a particular company/project?

> ➢ What responsibilities do managers have towards stakeholders?

What Freeman is focusing on is that the goal of a project should not only lie on the financial aspect; he mentioned that it is important that different groups of interests are involved. Freeman's general idea of stakeholder understanding is as shown in the following.

The project is in the middle of everything and the stakeholders are put around the project.
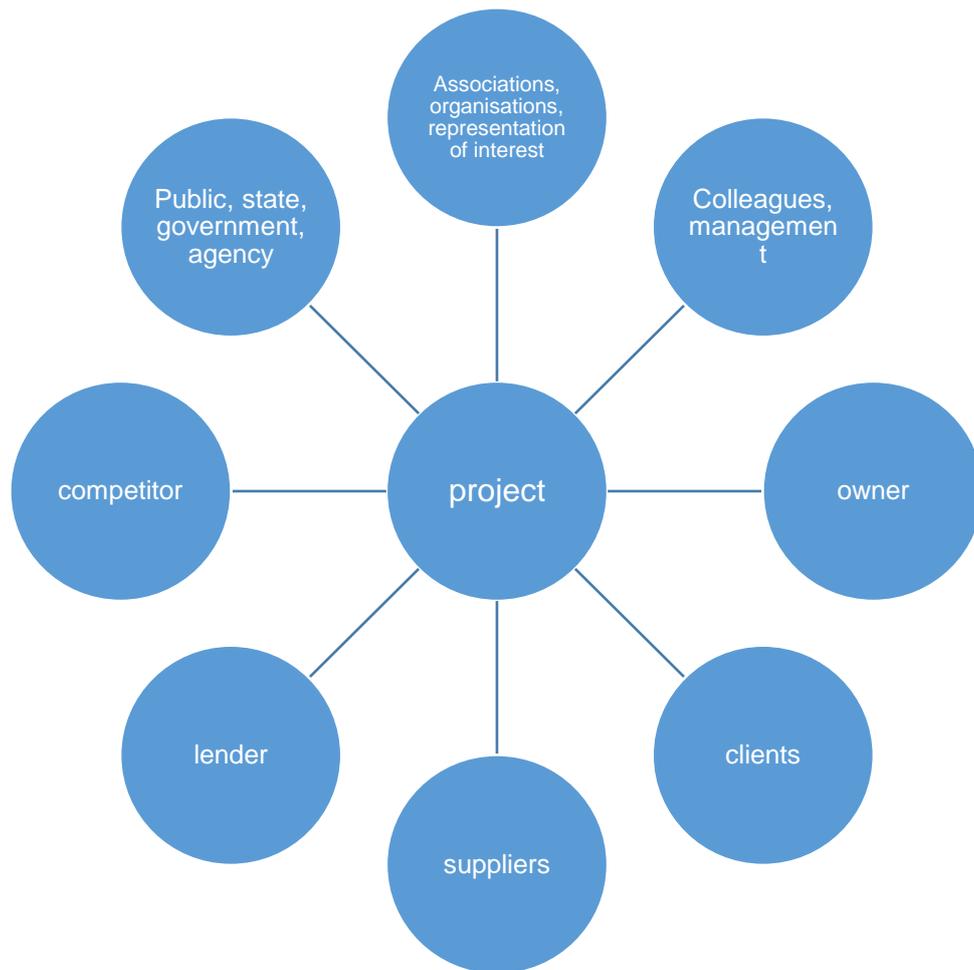
Figure 6-5: Understanding of the term stakeholder by Freeman, 1994

According to this model, there is no connection between the stakeholders. This refers to the thought that every group is acting in its silo. The idea of the framework in the current research is to develop a model that brings all the silos together (Freeman, 1994).

The framework generated for the road infrastructure sector facilitates several different parameters and one of these parameters is transparency. With the help of the decentralised system of a BT, the transparency will be provided because processes are traceable and immutable. Based on this, the trust level between multiple stakeholders is increasing. This will work because of an open value transfer that can give an incentive, from a long-term perspective, in terms of information exchange, communication, saving time and saving costs.

Thus, finally the framework is streamlining the whole life cycle of the project management of road infrastructure projects regarding the information exchange.

The starting point for the generation of the framework is the question of how the different stakeholders communicate with each other and how they share their knowledge. It seems like every group is working in their silo and not sharing knowledge with each other, with those who could use the information as well (#RI-15). So the question arises concerning how the different groups' information can be shared with other groups as well.

The idea of this is working with a distributed ledger database. All different groups have access to this database. In the case where they are afraid of sharing competitive alignment, every group is given a key identity with different permission rules, which will be organised with the help of different types of blockchain. The access to the database will be managed with different permissions, so that the groups who need to work together receive the same information and have the same access (Cowden and Tang, 2022). It needs to be discussed what information will be shared with other groups and have to be shared.

The big advantage of a decentralised network is that these data servers are safe and cannot be manipulated.

For a general understanding, the project management in road infrastructure projects includes five phases in total and four of them are the main phases.
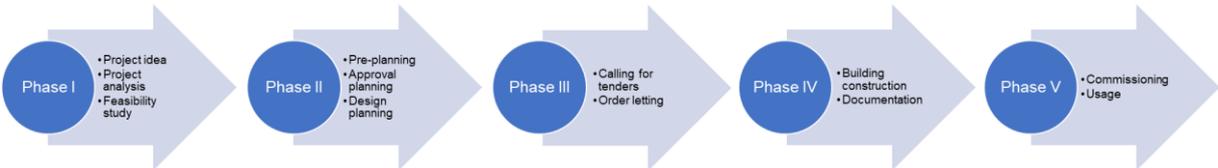
Figure 6-6: Main phases of the project management in road infrastructure projects (Spang, 2016)

The framework will be based on the whole life cycle of project management in road infrastructure projects.

Figure 6-7: Life cycle of the framework (Spang, 2016)
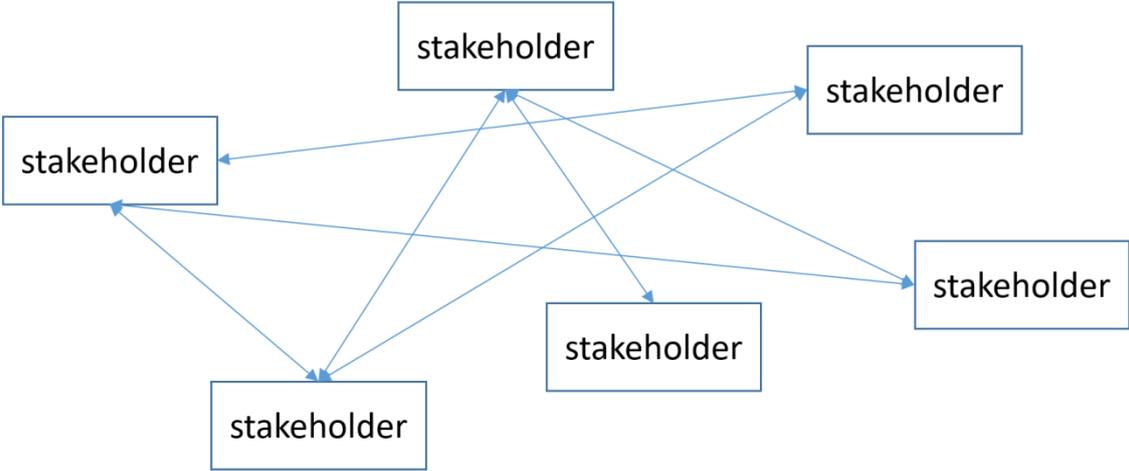
Figure 6-8:Collaboration between the different stakeholders in a project (own representation)

The challenge in a road infrastructure project is that a lot of different stakeholders are working together in one project. But in traditional projects the sharing of data between these stakeholders can be supported by optimised systems and tools, but often every stakeholder is working in its silo. This is happening because groups do not trust each other and normally a tool with a transparent process is not provided. The idea of the available framework is that all participants have access to the same database that will be stored on a distributed ledger, which is based on the principles of BT. The database will be secured with a key, and at the start of

the project the project manager will decide which group will have access to which data. But the basic idea should be that the transparency of the whole process is available for everybody, only decisions made within a silo will not be shared (Fabbri, 2019). But the final result will be transparent for all groups and stakeholders (see Figure 6-9).
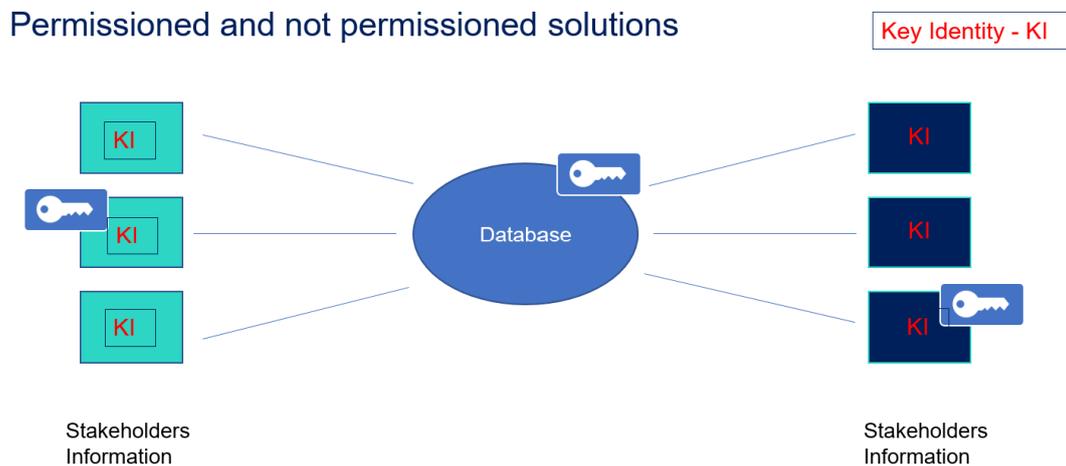
Figure 6-9: All information in one database (own representation)

The idea with BT is to use it from an internal perspective for the traceability and immutability and from an external perspective for the transparency, as #BT- 1 proposed:

> *"One thing is a blockchain that would be public facing that anybody could gain information from. And that would increase transparency overall, sort of thing. And then the other one is an internal sort of blockchain that would give you the things like the traceability, immutability and all of those same sort of benefits."*

> *#RI-7: "In my opinion, that makes no sense. So, in my opinion, every work step that is, let's say, completed trade-wise should be transparent, but to make the intermediate steps transparent, in my opinion, makes no sense."*

#BT-3: "*All objects have an ID, signature, time stamp and are decentralised and because of this they are verified. With the help of this, you do have a continuous cycle.*"

The statements of #BT-1, #RI-7 and #BT-3 were supported by a study conducted through Cowden B. and Tang J. (2022).

These examples help to explain what the special argument of this technology is. With all the information gathered so far, the researcher was able to develop the holistic framework for the research.

6.8 Development of the framework

The three main themes that are appearing in all modules of the framework are transparency, traceability and immutability. In the following sections these parameters will be explained in more detail in correlation to the modules as a preparation for the explanation of the development of the framework.

Transparency

To work in a successful project, *transparency* is an important element. That the element "transparency" is a key element in the whole construction of road infrastructure projects can be seen in the successful infrastructure project of the Gotthard Base Tunnel. This project was in time, in cost and of the required quality. Fabbri (2019) explained why it can be defined as a successful project. All stakeholders involved in the project were included in the whole organisation of the project all the time. On the basis of this, it was possible to have simplified contacts and links to each other. Also, lean organisation was used so the whole project had a better transparency, governance and efficiency. With respect to this finding, it can be related to a statement by #RI-1, who mentioned that transparency and also traceability help in their systems in the field of the digital construction file. And, since they have been using this procedure, communication has been working much better. This is of particular importance as the previous research has shown and transparency can be coordinated through the principles of the BT (Hawlitschek, 2016).

Traceability

The element of traceability is another element that is affecting projects in the field of road infrastructure. Prior studies that have noted the importance of traceability were mentioned in section 2.3.5. Samset (2014) argued that it is hard to conduct a detailed planning in terms of the time schedule. This is due to the fact that, for instance, the soil, rock and weathering are not predictable. This leads to the fact that it is important that all changes and steps need to be documented, so that changes and unpredictable occurrences are traceable for all relevant and involved groups. This assumption was also supported by the data collection. #RI-11 made the following statement related to traceability:

> *"[The] discrepancy of the status of the information between building owner and employees, for instance, needs to get smaller. The idea should be that all participants have the same information and, in terms of a change, all participants will be informed or will have access to a tool to get to the information of the change."*

That traceability is one of the advantages of the BT is supported by a study of Loukil et al. (2021).

Immutability

Immutability as an element of the challenges in the road infrastructure sector was predominantly identified in the interviews. An important issue in terms of the immutability appears in the planning phase. #RI-2 argued that, "*When a plan is released, all groups should be informed about the release that are working on the implementation of the plan, for instance, in the construction phase. This can also be seen as a need, so that from this phase on, plans have to be immutable.*" The interview with #RI-12 confirms that BT is associated with immutability and would give a huge advantage in the road infrastructure sector. #RI-12 mentioned that, in road infrastructure projects, a lot of steps and documents are manipulated.

With help of the principles of BT the interviewee imagined that the manipulation could be brought under control (Shrier, 2020; Zmani, 2018)..

In order to achieve immutability within a project the principles of the BT are a method to be used (Pu, 2020).
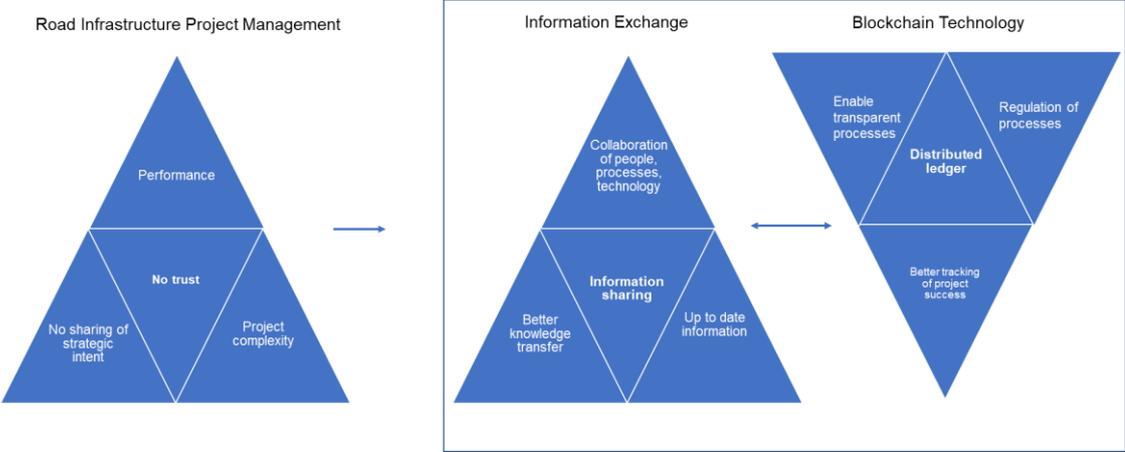
Figure 6-10: Framework for implementing the Blockchain Technology for managing road infrastructure projects

Figure 6-10 visualises the holistic framework of the research. One the left-hand side of the framework, the themes of the road infrastructure project management are visualised. These are the main themes of the current study that were analysed through the literature review and the data collection. What was found was that trust is the most important challenge that is faced during the life cycle. This is the reason why "no trust" is in the middle of the triangle and why it is highlighted in bold. Around the theme of trust, the key factors mentioned are performance, no sharing of strategic intent and project complexity. The researcher's idea is to visualise it as a triangle, so it has corners and the other half needs to be searched for to have a completed thing, and from the researcher's perspective a complete thing is a square (right hand side). Following the arrow of the challenges of the road infrastructure project management, the

framework leads to a box that contains a triangle with the themes of information exchange and an upside-down triangle with the principles of BT. These two triangles are connected to each other with two arrows. Putting them together, the result is a square. The two triangles of the box show that they have to communicate with each other to give an answer to the challenges of the road infrastructure project management.

A detailed explanation of the framework will be given in the next sub-chapters.

6.8.1 Key parameters of the road infrastructure project management

In the first part of the framework, the topic of road infrastructure is discussed. Within this discussion, the challenges that are faced through the life cycle of the road infrastructure project management will be mentioned. Involved in the framework are four different parameters that are related to each other. These parameters were identified in the literature review and in the data collection. The results of the challenging parameters are illustrated in Figure 6-11: Road infrastructure . To obtain a better understanding of all four key parameters, they will be discussed individually in the following text.
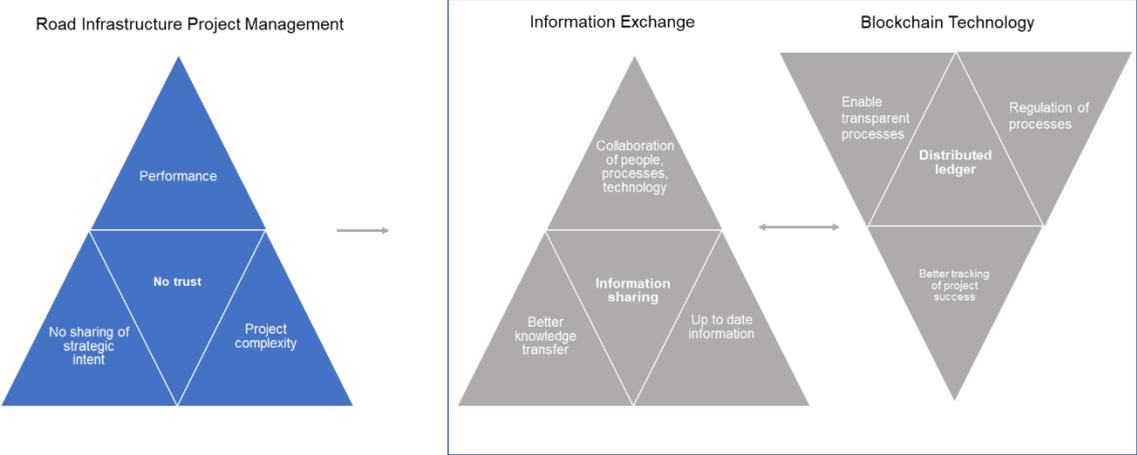
Figure 6-11: Road infrastructure project management

Figure 6-11 presents the breakdown of the challenges of the road infrastructure according to the literature review and the data collection. This assembly gives an overview and understanding of the first module of the framework.

The importance of the key parameters of the road infrastructure project management was stated in the semi-structured interviews and was supported by the undertaken literature review. As a result of the research, several themes were identified that need to be managed through the whole life cycle of a road infrastructure project. In the current study, four topics were distinguished as the main challenges in the life cycle of a road infrastructure project management regarding the communication that is part of the information exchange. These are *performance, project complexity* and *no sharing of strategic intent.* Three of these parameters are related to the main topic, trust.

Performance

As mentioned in section 2.3.7 Performance and success of road infrastructure projects, it is essential for a successful project to have a combination of critical success factors and key performance indicators. Every project is measured in terms of the performance and normally the measurement is made through the key factors – if the project is in time, if it is in budget and if it is to the required quality. So the performance of a project is an essential thing.

Project complexity

The theme *project complexity* is mentioned in the triangle as it is one of the main topics that need to be managed. Spang (2016) supported the statement about project complexity with the explanation that the number of stakeholders is growing and that the distribution of their tasks has become more complex in the past years (Geraldi at al., 2011).

One part of project complexity is the different stakeholder expectations. The element of the different stakeholders is crucial to the next steps and the structure of the development of the framework. The parameter of the different stakeholders is one of the elements that were

mentioned most in the focus groups and in the individual interviews. One statement regarding the different stakeholders was made by #RI-6: "*One of the most interesting and challenging issues in the road infrastructure sector is that a lot of different groups of interest are involved in such a project. And with the groups of interest I do not only mean the people that are directly involved in such a project; I also mean these groups that are having an interest from the outstanding view, such as the public and the tax payers, for instance."* This statement from #RI-6 is supported by the theory of Edward Freeman (1984). In his theory, he mentioned that, in an interconnected relationship, different groups are involved such as the customers, investors, communities and others who are involved in the whole project. If different stakeholders are involved, this leads to the fact that all stakeholders have different expectations.

The challenge that arises if different stakeholders with different expectations are involved, is not only dealing with different expectations, but also managing different attitudes and different conceptions of aims and goals through the project management.

No sharing of strategic intent

Regarding the parameter of *no sharing of strategic intent*, the theme arises that mentions the fear of transparency in a project. This fear is supported by a statement by #RI-4, who mentioned the fear of transparency and the fear of sharing of information and knowledge. What he was talking about is that, in earlier days, it often happened that knowledge was treated like "domination knowledge". And the critical thing that #RI-4 mentioned was that this behaviour is not only appearing between different companies, it is also appearing within own companies. From his perspective, this was one of the reasons why systems were developed with different folder systems. And, during the timing of the digitisation, digital folder systems were developed. What is very important for those involved in such a system is the different available access rights. #RI-4 mentioned in this correlation SharePoint. From his perspective, SharePoint is a great example of the understanding of "SharePoint" of a majority of people. From his

experience, one of the first questions that arise is: "How can I use SharePoint, that only I do have access to the documents, that the information is not visible for everybody". This demonstrates that people do not understand what the meaning of sharing information is.

Another example #RI-4 gave in terms of the not understanding of sharing knowledge and transparency was one that happened in a university of applied science in Germany. A professor was very interested in the topic of BIM and in generating a BIM model. But what he and his team were researching during that project was how it is possible that the building owner and the contractor see two different perspectives. The goal of the project was that the building owner should not see what the contractors are developing. At the end, the team achieved the goal and such a BIM tool was developed. But again, this is not the understanding of a BIM model.

These two examples confirm that transparency is also associated with fear and with the topic of no trust between stakeholders and even no trust within a company (Freeman, 2016).

Trust

Putting the parameter from the beginning of the chapter transparency, traceability and immutability together, the big topic of trust can be discussed. Relating this to the framework, performance, no sharing of strategic intent and project complexity have the foundation of trust (Gordon, 2018; Laurence, 2017).

The above results are in line with those of the literature review (Schoorman et al., 2007; Zhang et al., 2011). The elements traceability, transparency and immutability are a possible explanation for the challenge with the lack of trust in the transportation projects. #RI-8 explained that the order letting in such projects is really secret. And traceability and transparency need to be treated secret as well, because of the high level of trust in these projects. #RI-4 mentioned that it can be therefore assumed that a lack of trust exists, because of the fact that the partners that are worked with today may have been competitors in the past

and will be competitors in one of the next projects. So it is clear that, what one company is able to do today, the other company is able to do tomorrow.

6.8.2 Key parameters of information exchange

The whole framework involves three parts; one of them was already explained in the previous chapters. The part in the middle of the framework, the outcome, is the pillar of the information exchange. As a result of combining the challenges of road infrastructure projects and the solution of the principles of BT, the outcome information exchange appears. In the middle of the inverted triangle, "information sharing" is highlighted. The principles of BT as a solution will bring a huge advantage in the field of information exchange, which is demonstrated in the middle of the triangle. That the idea of the BT can support in the information exchange is also supported by a research conducted through Vadgama (2021). With the transparency, the traceability and immutability, the technology will bring a proper information exchange; also, this will bring a huge benefit in the field of communication. The word *people* means the different groups, stakeholders and all participants involved in a project or a process. There is no differentiation made about if these are the people in internal or in external procedures. As there is a secure technology behind it, the people's trust will increase, as they understand that a safe technology is behind it that was not hacked before. Within the data collection and the creation of the framework, the researcher realised that the people are the foundation for every step. This leads to the parameter of processes. The meaning of the word *processes* is contracts and documents that are substituted between the different groups. Processes are meetings and procedures within a project. Furthermore, a process is the improvement that is made in a project procedure. Because the people work in a transparent way with each other, all processes are more transparent and traceable. That people can rely in these processes, there are different options in using a blockchain This leads to the fact that the processes in terms of the information exchange are also becoming more transparent and traceable. Another advantage in the processes itself is that with that technology the data that are involved are

protected; this protection also leads to higher trust within the whole project. Last but not least is the *technology*. The technology is the key for the whole framework. The technology is given the possibilities of transparency and traceability that solve the trust theme in the project and process and within the organisations. Given these three options and opportunities, the whole collaboration between people and processes and technologies is optimised.

As these three parameters are at the top of the triangle information exchange, this ensures that all information is up to date all the time and is accessible for all participants. This up-to-date information option causes an information sharing over a life cycle with the result of a better knowledge transfer (Röttger, 2013).

On the other hand, it needs to be considered that, regarding the *information sharing*, the challenges in road infrastructure project management might change. It should not be assumed that the challenges that are faced currently will be the same challenges in five, 10 or 15 years, for example. So it needs to be considered that this derivation of the framework is only related to the current state.

When the outcomes are discussed, it needs to be thought about that the whole derivation of the framework started with the outcome. At the beginning of the study, the researcher was thinking about what challenges are faced in road infrastructure project management. And, as it did start with the outcome in terms of the communication, it is obvious that, with the BT as a solution, there can be a solution for the challenges.
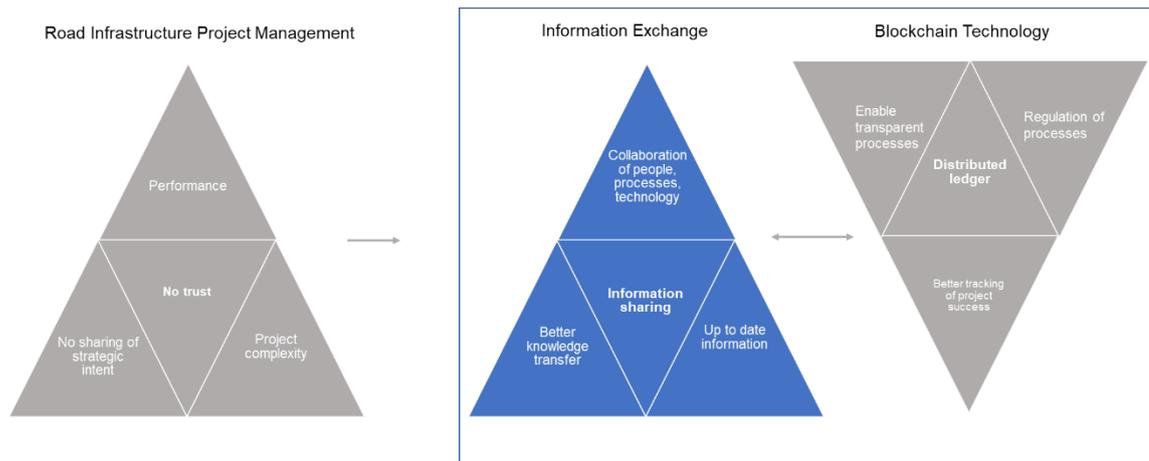
Figure 6-12: Information exchange

As a result of the findings of the semi-structured interviews is that communication plays an important role in a project, the researcher focused on the field of information exchange (Deekeling, 2017). As the key parameters were already explained in the introduction of this chapter, the next section will summarise the framework in detail and it will be compared to the principles of BT.

In the middle of the triangle, information sharing is highlighted in bold, which is the essential component of the whole triangle.

Collaboration of people, processes and technology

Considering the collaboration of people, processes and technology, a proper information exchange guarantees that these factors can communicate with each other in a transparent and traceable way (Zmani, 2018). The decentralisation of the BT will also enable the interaction between the processes as well. Correspondingly, the collaboration of processes, people and technology is growing .

Up-to-date information

One of the reasons why a proper information exchange system is essential is so that all involved stakeholders have up-to-date information during the whole life cycle.

When information in a project or a process is mentioned, it means all information from the beginning to the end. This information flow starts with the feasibility study that is made before a project starts. After the feasibility study, the project has to go through different phases. In these phases, different modules of the planning phase are included, based on the planning phase the building phase follows. Through all these phases, it is mandatory that all stakeholders are able to have a proper system for the communication and the information exchange.

Better knowledge transfer

Constitutive on the up-to-date information, better knowledge transfer can be discussed. When groups and stakeholders have a system that provides the possibility for the sharing of up-to-date information, this will lead to the fact that, within the whole life cycle, a better knowledge transfer is guaranteed.

One of the challenges that stakeholders face in their projects is that the actual knowledge transfer contains a lack of trust and sometimes no possibilities to share information (Gordon, 2018). This is not only because the technology is not around; it is also because a lot of information is paper-based, so there is not even the possibility to share information.

6.8.3 Key parameters of the blockchain technology

As in an earlier section, the challenges of road infrastructure project management were discussed, a solution for these challenges was also presented. The outcome of the research is that the principles of BT can be that potential solution (Cowden and Tang, 2022). In the framework, all dependencies of the different parameters of this solution are visualised.
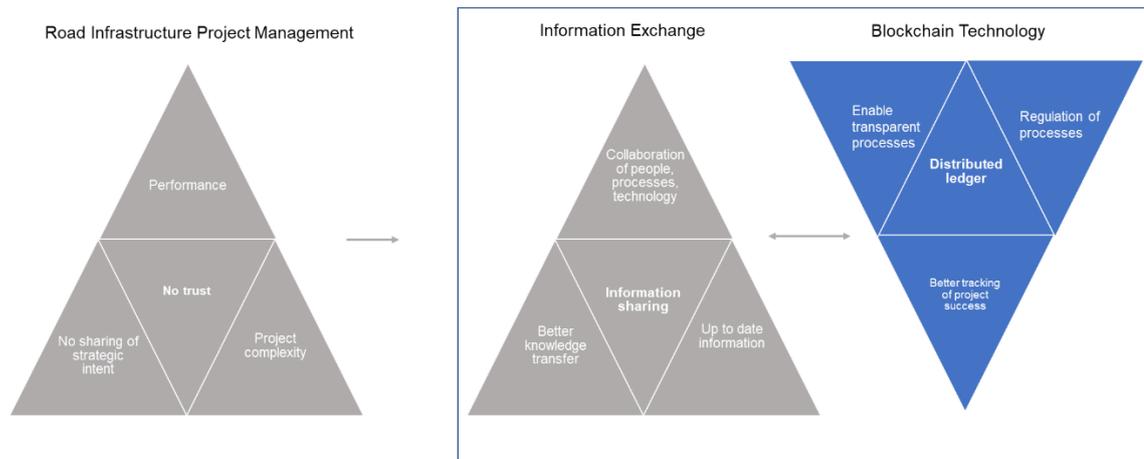
Figure 6-13: Blockchain Technology

Comparison of the findings of the semi-structured interviews with the road infrastructure experts, with those of the semi-structured interviews with the BT experts, confirms that the topic of trust is required in processes and projects. The themes of the key parameters of the road infrastructure demonstrated that having no transparency and no traceability leads to the topic of not trusting each other.

The reason why the BT was developed in 2008 was because of the topic of the theme *trust*. The idea, with its distributed ledger, is that the technology can be used in projects and processes in which the stakeholders and the different participants do not trust each other (Cowden and Tang, 2022). This is the main reason why the principles of this special technology are used in the current study.

Enable transparent processes

As #BT-3 explained, the transparency of the BT can be seen in two different ways. When the transparency within the BT is talked about, it does not mean that everything is transparent. This is also supported by the statement that transparency can be seen from two different stages. With the help of BT, it is possible to make only the processes transparent. But, with the help of the encryption, it is possible to make the groups behind a process invisible. Thus,

this gives the people who are working in a project the security that it is not visible for everybody, just in case a mistake occurs. This is the most mentioned problem regarding why people are afraid of control, but, with the help of the technology, a solution can be found regarding how the control of processes can be managed (Nakasumi, 2017). This possibility of control is related to the enablement of the transparent processes. Because the opportunity is given to make the process transparent, it is possible to have a kind of control over the processes and the performances that are made behind these processes and decisions (Cowden and Tang, 2022).. If we now turn to the negative aspect of it, it can be assumed that, from the point of view of a building owner, it does not make sense to not have full control in terms of full visibility. From the view of a building owner, only full transparency will work for the full possibility of control.

Regulation of processes

One of the topics of the decentralisation as a BT solution is the theme of the "regulation of processes between different groups". As has been mentioned several times so far, different stakeholders with different interests are involved in these huge projects (Bratsch, 2013). The findings show that decentralisation can help in terms of the regulation of processes between the groups. A decentralised system can help all groups have access to all data and nobody is responsible for the data. The suspicion of data misuse is thus eliminated. As with the help of the idea of the regulation of processes between groups, the topic of trust is growing; this leads to the fact that the distributed ledger also will enable transparent processes (Shrier, 2020).

Better tracking of project success

A positive correlation was found during the study between the standard protocol of BT and the possibility of controls. As the participants are afraid of being controlled in a project or a process, the result in terms of the control in the course of the BT is somewhat counterintuitive. It is explained that it is possible to think in every system about the different rights of the participants and groups that are involved. It is possible to define different rights for different groups in a

project, who will have access to which information (Ma, 2020). And, because of these rights that can be given to different groups, the actions of all groups can be tracked in a more secure way. When all these aspects are taken together, it can be defined that, with the help of these principles, the project process can be tracked in a better way (Ionescu, 2015).

Distributed ledger

The mentioned factors related to the BT are all linked to the distributed ledger. The distributed ledger is the procedure of decentralisation and is delivering all the advantages a blockchain is delivering. The distributed ledger is the foundation for a BT, so that it can work.

6.8.4   Final holistic framework

Now that the three main themes in the thesis, road infrastructure project management, the BT and the IET have been compared to the data collection, the final framework can be generated.
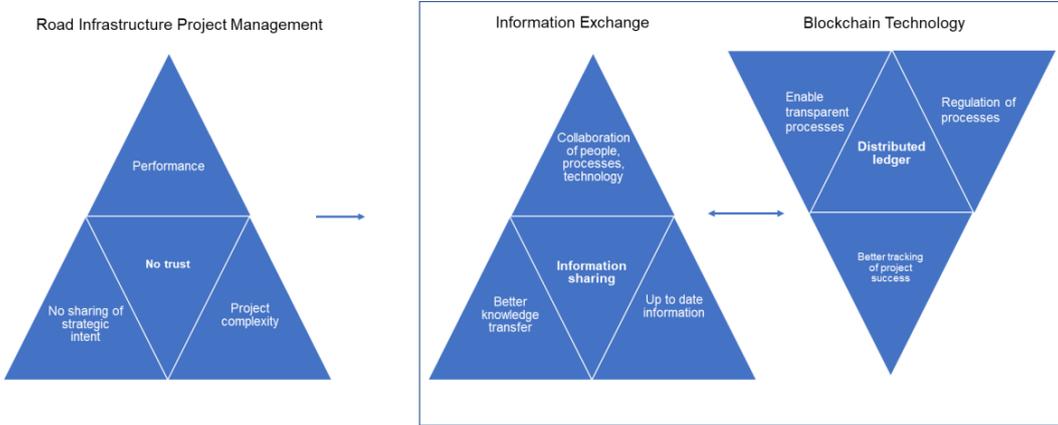
Figure 6-14: Final holistic framework

To obtain an understanding of what the researcher wanted to achieve, it needs to be thought about that everything started with the golden triangle of project management. The previous chapters explained that a project is called successful if it is in cost, in time and if the expected quality has been delivered. Examples of successful projects that are mentioned in the thesis

are the Gotthard Base tunnel (Fabbri, 2019) in Switzerland and the Morandi Bridge in Genoa. These are examples of projects which were in time, in cost and also the expected quality was delivered. After this step, the researcher conducted research in the wide field of road infrastructure projects. The aim of this research was to find out what the main themes are that the stakeholders in road infrastructure projects have to deal with. These themes were separated into two main themes, "no sharing of strategic intent" and "no trust". Parameters that were mentioned through the data collection and what were analysed during the literature research were the topics of quality management, data management, the complexity of road infrastructure projects and the information exchange. As one of the results of the data collection was that communication plays a mandatory role in the project management, because of the vast number of stakeholders that are involved, so the researcher analysed the information exchange in more detail and thought about what was the meaning behind trust and how this can be solved. As was mentioned many times during the data collection, an issue in projects is that there is no trust between the different stakeholders. The known technology that can be used if there is no trust between different parties is BT. Because of its decentralisation, no intermediaries are necessary any more.

6.9 Chapter summary

In the above chapter, the consolidation of the literature review and the data collection has been presented. On the basis of this, the development of the framework to support the management of road infrastructure projects with the help of the principles of BT was elaborated. This developed framework is supporting organisations and companies in managing road infrastructure projects. For developing this framework, the findings of the data collection in Chapter 5 and Chapter 6 have been linked to the literature research. Basically, the parameters that were analysed during the literature review and the data collection have been used for the development of the framework. In particular, it was linked to 10 main parameters. Based on

the literature review, the framework was structured into three parts, the road infrastructure, the

principles of BT and the information exchange.

7 Conclusion and recommendations

7.1	Introduction

7.2	Summary of the research

7.3	Contribution to knowledge

7.4	Limitations

7.5	Recommendations for further works

7.6	Chapter summary

Figure 7-1: Overview of chapter 7 – conclusion and recommendations

7.1 Introduction

This last chapter summarises the research with its main findings, implications, limitations and recommendations for further work. In the next sub-chapter, a brief summary of the whole study, "*Utilising the Principles of Blockchain Technology for Managing Road Infrastructure Projects*", is provided. This summary is separated into the different research objectives and the research aim of the thesis. This is assembled by conclusions of the holistic research and how the objectives and aim were achieved. Finally, at the end of the summary, the research question will be answered. This is followed by the conclusion, the contribution of theory and practice, the limitations of the study and the recommendations for further work.

7.2 Summary of the research

This thesis in total is divided into seven chapters. This first chapter provided an introduction to the research, and explained the research question, and the research aim and objectives. It also highlighted the background and problems of the construction industry, especially the road infrastructure industry. As an ending to the chapter, an overview of the whole thesis was provided, and the link between the different chapters was presented.

In order to provide a comprehensive understanding of the current "state of knowledge", in Chapter 2 a critical literature review, focusing on road infrastructure projects, the principles of BT and the information exchange, was presented. With the help of this literature review, a theoretical background for the further research was laid and an understanding was established regarding the need for this research. In the literature review, the gap in the literature was also identified. During the literature review, the researcher learned from previous studies, experiences and studies. The chapter is an important chapter as well as it supported the development of the framework that is mandatory for the whole research.

The third chapter examined the philosophical perspectives, the research philosophies, research approaches and the methodological choices in order to gain an understanding of those. These are required for the research as they provide support in answering the research question and in achieving the aim with its objectives.

In Chapter 4, the chosen methods for the current research were presented. The motivation for the initiation in this research was explained and the chapter defined how the methods would be implemented. How the data after data collection were structured and analysed was also presented. This step is essential for the development and validation of the research strategy.

In Chapter 5, the data collection from the two focus groups and the semi-structured interviews was presented. The findings were presented based on the thematic analysis decided in

Chapter 4. In this chapter, information was collected for answering research objective 1 based only on the data collection.

For the development of the framework in Chapter 6, the findings of research objectives 1-3 were analysed with the help of the literature review chapter. As a result of this analysis, the research aim, "the development of the framework", was implemented and generated. In this chapter, the framework is presented with its expected implications. Finally, the current chapter presents the summary of the main findings, implications, limitations and recommendations for further work and the original contribution to knowledge made through this research.

7.2.1   The research objectives and aim

The aim of this research is to develop a framework for the utilisation of BT to support the management of road infrastructure projects.

In order to achieve this aim, several research objectives were created at the beginning of the research. A summary and an overview of these research objectives are given in Figure 7-3.

Research objectives / research aim	Methods to meet the aim/objectives	Relevant chapters
1. Research objective To identify in which aspects of managing projects the principles of Blockchain Technology can be effectively utilised.	➢ Literature review ➢ Qualitative data from focus groups	➢ Chapter 2 ➢ Chapter 5 ➢ Chapter 6
2. Research objective To explore the interrelation between the principles of Blockchain Technology and the performance of managing road infrastructure projects.	➢ Literature review ➢ Qualitative data from semi-structured interviews	➢ Chapter 2 ➢ Chapter 5 ➢ Chapter 6
3. Research objective To appraise the barriers and the enablers to the utilisation of Blockchain Technology in the context of road infrastructure projects.	➢ Literature review ➢ Qualitative data from semi-structured interviews	➢ Chapter 2 ➢ Chapter 5 ➢ Chapter 6
4. Research aim To develop a framework for the utilisation of Blockchain Technology to support the management of road infrastructure projects.	Validation through ➢ Literature review ➢ Focus groups ➢ Semi-structured interviews	➢ Chapter 2 ➢ Chapter 6

Figure 7-2: Overview of the research objectives

The illustrated figure introduces the following section in relation to the approach of answering the research objectives and a link to the relevant chapters in the thesis. This approach is the derivation for the mentioned research question described in Chapter 1, the introduction chapter.

7.2.1.1 Research objective 1: To identify in which aspects of managing projects the principles of Blockchain Technology can be effectively utilised

As is demonstrated in section 7.2.1, research objective 1 was achieved through the conduction of the two focus groups and the literature review. With the help of the literature review, it was possible to define the principles of BT. Based on the literature review and the focus groups, it became clear that, in the era of industry 4.0, development in the construction industry is essential. The transformation to digitisation and new technologies in road infrastructure projects is limited, so an organisational support through pilot projects, frameworks and case studies is mandatory. One goal of the thesis is to deliver this support through a framework.
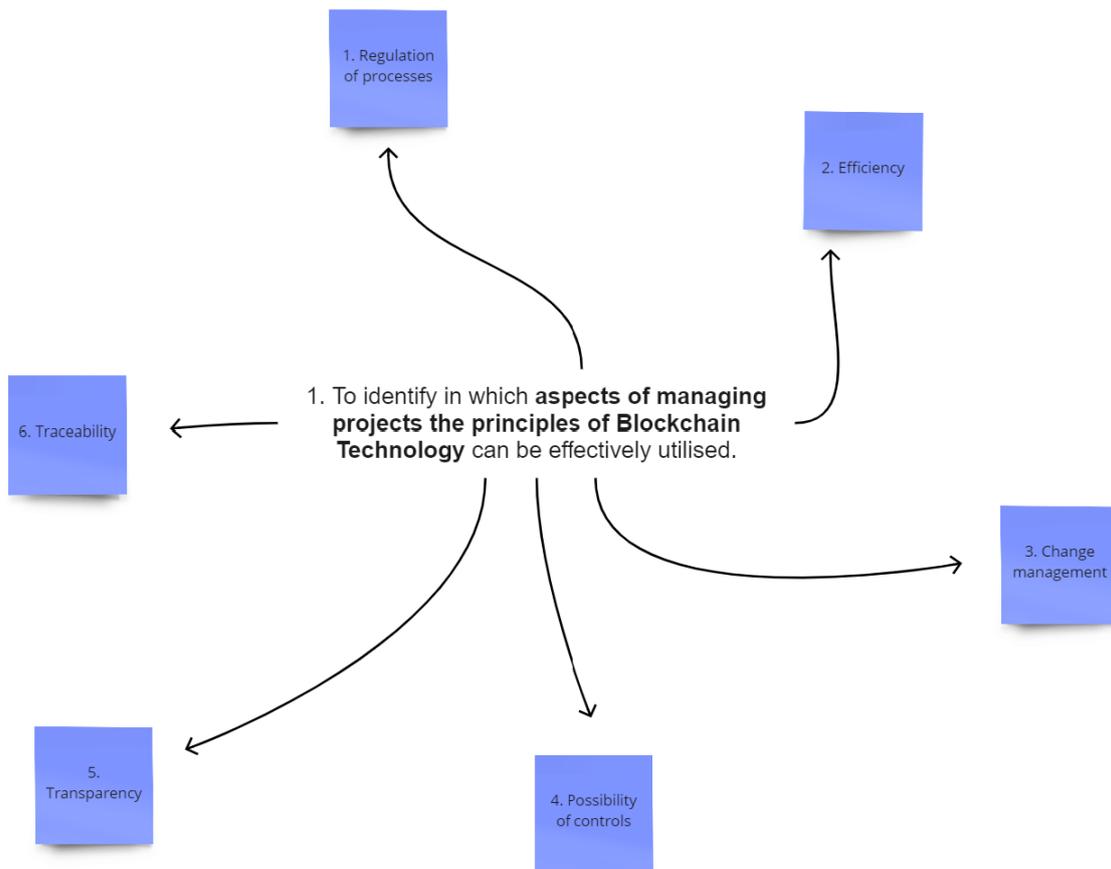
Figure 7-3: Answering research objective 1

The result of the first research objective showed that the principles of BT provide a lot of use in managing projects. The result of the focus groups offered the suggestion that the principles of BT can support the processes, as is shown in Figure 7-3, in terms of 1. Regulation of processes, 2. Efficiency, 3. Change management, 4. Possibility of controls, 5. Transparency and 6. Traceability. These results facilitate a foundation for the conduction of the semi-structured interviews to gain a more detailed understanding of the research problem. Constitutive on these results, the basis for the whole research was laid.

7.2.1.2 Research objective 2: To explore the interrelation between the principles of Blockchain Technology and the performance of managing road infrastructure projects

Research Objective 2 was achieved through a qualitative method, semi-structured individual interviews. Through the different interviews with different participants with different backgrounds, themes and fields of the performance of road infrastructure project management were identified. The main results in terms of the performance of road infrastructure projects and their issues are listed below:

- ➢ Not sufficient information exchange between the different groups

- ➢ Every stakeholder is working in its silo

- ➢ Little transparency within the processes

- ➢ Afraid of transparency → Fear of control

- ➢ Reservation with new technologies

In order to overcome these issues, an investigation was made through the interviews of if there is a relationship between them and the principles of BT. The advantages and disadvantages are visualised in Figure 7.3.

By comparing the challenges in road infrastructure projects and the advantages and disadvantages of BT, the researcher was able to define the relationships between these two themes.

> *"To explore the interrelation between the Mechanism of the Principles of Blockchain Technology and the Performance of Managing Road Infrastructure Projects"*

To understand the interrelation between road infrastructure projects and the principles of BT in the previous chapters the parameters transparency, different stakeholders, new technologies, traceability and immutability have been investigated in the different areas. As a

first result it was found that, that the advantages the BT is bringing can help in the challenges that are faced in road infrastructure projects. This can be supported by the following.

The relationship between the principles of BT and the road infrastructure projects can be confirmed with the statement of #BI-4, who mentioned that, with his experience in the construction industry, a big problem is the lack of transparency in every project and that nobody trusts each other. It is obvious that this is not helping anyone. From a long-term perspective, #BI-4 believes that even in this industry there needs to be transparency. He was also convinced that the industry does need such technology, which works on the basis of decentralisation, to work with transparent processes. With this technology, it will be possible to share things or not.

#BT-4 confirmed that the biggest and most important advantages of BT is in the field of trust, transparency, immutability and in the field of the value transfer. #RI-1 observed that transparency is really important in the process of the planning phase.

7.2.1.3 Research objective 3: To appraise the barriers and the enablers to the utilisation of Blockchain Technology in the context of road infrastructure projects

Through the data collection and the analysis of the findings, the barriers to and the enablers of the utilisation of BT in the context to the road infrastructure projects were defined. The barriers in that context are the less experience that is available in the combination of the road infrastructure and the BT and that it is questioned if this technology is necessary in that industry. The huge enabler that is given through that technology is that trust is a big problem in the road infrastructure field and, as the technology is known to be used when people do not trust each other, it would be a huge enabler in that field. Together with the theme of trust, parameters like transparency, traceability and immutability are listed again.
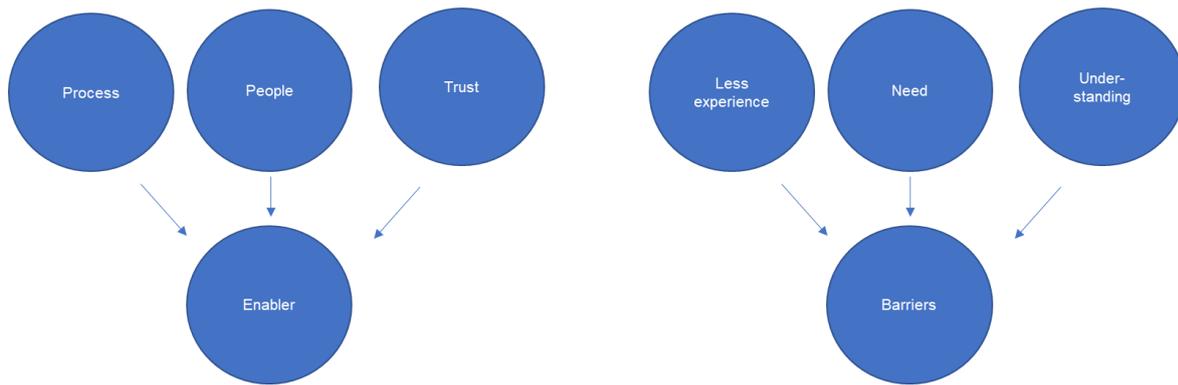
Figure 7-4: Enabler and barrier

7.2.1.4 Research aim: To develop a framework for the utilisation of Blockchain Technology to support the management of road infrastructure projects

Bringing the outputs of the first three objectives together, the development of the research aim, the development of the holistic framework, could be executed. Essentially, the development of the holistic framework is presented in Chapter 6, the discussion chapter. The development of the holistic framework is based on a detailed literature review and is linked to the findings of the data collection that was conducted through executive focus groups and several semi-structured interviews with experts from the road infrastructure sector and experts from the area of BT.

In the framework, the challenges of road infrastructure project management and the principles of BT were presented and classified into two core themes each. This framework supports the processes in road infrastructure project management in the context of information exchange and communication.

7.2.2 The research question

As a multi-method approach was chosen and the systematic application of this approach through a literature research + focus groups + semi-structured individual interviews is used, the research question:

can be answered as follows.

Through the study, it was identified that the Principles of BT together with an information exchange can be applied to the project management of road infrastructure projects. This result was achieved through the development of the framework with the classification into three themes with particular sub-themes. Hence, the research question is answered through the development of the holistic framework combining the challenges of the road infrastructure sector with the information exchange and the principles of the BT as a solution. The developed framework shows that the challenges that are faced in the project management of roads can be answered through a combination of the information exchange and the usage of the principles of BT.

7.3 Contribution to knowledge

The contribution to knowledge in this study on "*Utilising the Principles of Blockchain Technology for Managing Road Infrastructure Projects*" is separated into the contribution of theory and the contribution of practice, which will be presented in the next two sub-chapters.

7.3.1 Contribution to theory

Prior to the literature review, it was addressed that, for effective information exchange (Milne, 2015), transparency is required (Jacob and Varghese, 2018). To deliver that transparency in an information exchange, it was highlighted that trust is the foundation. As intensive research in the field of BT was conducted, see Chapter 2, it was found out that BT is built on a distributed ledger and through this decentralisation, transparency, traceability and immutability are facilitated. Because these parameters can be guaranteed through the decentralisation, the trust level is very high and consequently the transparent processes. To implement the principles of BT into an information exchange system, trust would need to be resilient.

Specifically, the current research provides new insights into the definition and characteristics of information exchange in the field of the principles of BT. The theory is also highlighting the critical connection in terms of the topic of trust within road infrastructure project management and between road infrastructure projects and new technologies.

The outcomes of the findings of the research provide a new contribution to theory in the balance of the information exchange and the principles of BT.

Throughout the findings and the discussion of the research, the obligation of a transparent and traceable process is introduced. In particular, it is presented that trust is increasing in the case of a transparent and traceable process. It is also highlighted that these two areas of "trust" and "transparency and traceability" are dependent on each other.

Expanding upon this, within the research it was possible to reach a first consensus that presumed that the design of the framework between road infrastructure project management, information exchange and the Principles of BT needs to meet a balance in terms of a transparent information exchange between the different stakeholders involved in road infrastructure project management.

The most notable effect on an imbalanced information exchange falls under the representation of the limits of information sharing between the stakeholders. This leads to a lack of information and, because of the fear of control and transparency.

As a summary the contribution to theory is the following:

> ➢ This thesis identified and characterised specific elements of the principles of the Blockchain Technology across the information exchange.

> ➢ The thesis provided support of underpinning the topic trust in processes of road infrastructure project management.

- ➢ The thesis demonstrated importance and influence of underpinning the principles of the Blockchain Technology in the process of information exchange.

- ➢ The framework provided a new understanding of using the principles of the Blockchain Technology as a solution for the challenges of road infrastructure projects.

7.3.2 Contribution to practice

As outlined in the first chapter of the thesis, over the last four years the researcher developed a strong link to particular organisations in the private sector in the field of road infrastructure project management. Because of the strong involvement of the participants through the data collection, the researcher is able to make a contribution to practice at the end of the research.

From the view of the practical perspective of the contribution to knowledge, the thesis has contributed to the support for using new technologies, especially the principles of BT, in complex road infrastructure projects. With the help of the framework, this work has contributed to make the information exchange in the field of road infrastructure projects more transparent and thus to support processes related to traceability and immutability. This framework is an advanced method, if properly applied, to support road infrastructure projects in terms of transparency in internal and external processes. The interaction of the parameters of the information exchange (the information sharing) and the parameters of the BT that are related to the distributed ledger, are supporting in handling with the challenges of road infrastructure project management. If the tool for the information exchange would be set up based on the principles of the BT the road infrastructure project management could be optimised in terms of transparency and traceability that would lead to more trust. Furthermore, it is expected that this framework will be used by project managers, clients and in supply chains, especially in long-term projects. Another important aspect of the framework is to use it in discussions and

basically in information exchange topics to provide stakeholders with a better awareness and understanding of processes in a project. Ultimately, the framework provides an exceptional opportunity to apply the skills of the principles of BT to a project and thus improve processes. This contribution to practice will help to improve processes in terms of information exchange in the field of road infrastructure project management and, if properly applied, the framework can increase the use of new technologies in terms of the principles of BT in the field of road infrastructure project management. So that the framework can be properly applied, the users need to understand how to manage the project and do need a holistic overview of the whole project.

The core application of this holistic framework within road infrastructure project management is expected through the whole process of the project management. The framework is made for the use of clients, contractors, sub-contractors, project management, planners and builders. Through the utilisation of the framework it is also expected that organisations, architects and engineers will benefit. The main applicability of this framework is expected through project managers having an overview of the whole project.

The result of the current research is that, with the use of the framework, the different stakeholders involved in a project are able to understand the internal and external processes with the help of transparency between all the different groups. The given transparency in the framework offers traceability and immutability and that leads to the fact that groups and participants do trust each other.

An important task of the framework is that all parameters of all three core themes are simplified and all kinds of users are able to understand the idea and the meaning of the framework.

7.4 Limitations

As is known, all research projects are accompanied by limitations. The relevant limitations for the current research that need to be considered are the following:

> ➢ The research was only focused on the road infrastructure sector; it was not conducted in other projects. Thus, the research cannot be generalised to other industries.

> ➢ As the BT itself is normally known in context with the currency Bitcoin, the researcher needed to be really careful in the research that the participants were not afraid and biased from the very beginning. The feeling arose that the BT itself could be a too big technology and too complicated.

The generated framework has not been tested in a real project. With a case study in a project, or the implementation in a long-term project, further results and a further improvement of the framework are expected. Although the themes of the framework are simplified, the framework auditors do need to understand the framework and it is necessary to understand the challenges of the road infrastructure and to understand the principles of the BT.

However, when applying this framework, it needs to be considered that the project manager using this framework needs to understand the idea of the framework very well to achieve the results. A reasonable approach to overcome this could be in-depth trainings of the use of the framework. Since the framework seeks to establish trust the framework should not be used to blame stakeholders or to make accusations of guilt.

7.5 Recommendation for further works

As was mentioned in the introduction chapter, there is a huge margin in terms of the productivity in the different industries compared to the construction industry. So that the

productivity in the field of road infrastructure can also grow, there needs to be a deeper investigation of new technologies and digitisation in this field.

The findings of the current thesis provide a respectable foundation to conduct deeper investigations in the field of BT. Further research also needs to consider investigating the implementation of the framework in a project environment with different durations to explicitly identify the limits of the suitability of this framework within projects. It also needs to be thought about that participants need to be trained on how the principles can be adopted into the project environment. For this adoption, a training programme should be developed.

7.6 Chapter summary

In the last chapter of the thesis, "Utilising the Principles of Blockchain Technology for Managing Road Infrastructure Projects", the efforts of the researcher are summarised, with the thesis findings, its implications and its limitations. In this research, the research question has been met and the research aim has been conducted. The framework developed in this thesis was developed through focus groups, semi-structured interviews and a very detailed literature review.

Furthermore, the thesis has invigorated the knowledge and the existing experience about challenges in road infrastructure projects and principles of BT. Moreover, a correlation between the road infrastructure, the information exchange and the principles of BT has been recognised.

This last chapter in the study also supports the understanding of how this research and the holistic framework present a contribution to knowledge in the areas of theory in practice. With the help of the limitations of this work, it is demonstrated how this field can be developed to gain acceptance.

Closing the thesis, the way in which this thesis and the developed framework could promote the principles of BT in the field of road infrastructure projects was well defined.

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APPENDICES

APPENDIX A: Example of the consent form (focus groups)

LIVERPOOL JOHN MOORES UNIVERSITY
CONSENT FORM

Utilising Blockchain Technology to Infrastructure Project Management

Lena Pauli, Liverpool Business School

1. I confirm that I have read and understand the information provided for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and that this will not affect my legal rights.

3. I understand that any personal information collected during the study will be anonymised and remain confidential

4. I agree to take part in the above study
   I.

5. I understand that the focus group will be audio recorded and I am happy to proceed

   II.
6. I understand that parts of our conversation may be used verbatim in future publications or presentations but that such quotes will be anonymised.

Name of Participant   Date   Signature

Name of Researcher   Date   Signature

Name of Person taking consent   Date   Signature
(if different from researcher)

Note: When completed 1 copy for participant and 1 copy for researcher

APPENDIX B: Example of the participant information sheet (focus groups)

LIVERPOOL JOHN MOORES UNIVERSITY

Title of Study Utilising the Principles of Blockchain Technology for Managing Road Infrastructure Projects

You are being invited to take part in a study. Before you decide it is important for you to understand why the study is being done and what the participation will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for taking the time to read this.

1. Who will conduct the study?

Study Team

Supervision: Professor David Bryde Phd (LJMU), Professor Dr. Hans Peter Schelkle (HTWG)

Researcher: Lena Pauli

School/Faculty within LJMU: Liverpool Business School

School/Faculty within HTWG: University of Applied Science in Konstanz, Department of Civil

Engineer

2. What is the purpose of the study?
This study hopes to answer the following questions "How can the principles of Blockchain Technology be utilized for Managing Road Infrastructure Projects?"
To answer this question, the following terms, have to be investigated:

1. To identify in which aspects of managing projects the principles of Blockchain Technology can be effectively utilized.
2. To analyze the potential relationships between the mechanisms of the principles of Blockchain Technology and the performance of Managing Road Infrastructure Projects.
3. To appraise the barriers and the enablers to the utilization of Blockchain Technology in the context of Road Infrastructure projects.
4. To develop a framework for the utilisation of Blockchain Technology to support the management of Road Infrastructure projects.

The first term was already investigated with the help of Focus Groups. Based on the results

of the focus groups, interviews will be conducted to find a solution for the terms 2 and 3.

3. Why have I been invited you to participate?

You have been invited, because you are an experienced engineer in the field of road infrastructure projects. The exclusion/inclusion criteria for participating in the interviews are that you have extensive experience in the field of road infrastructure projects, which is involving the areas of municipalities, highways, the rail sector, bridges or airports in this research. Your work experience should be typically at least 3 years and you should be employed as a project manager, an engineer a consultant or you should have experience in the field of project monitoring. Your experience should be in public and /or private sector organisations. You have been identified as a potential participant through researchers and professional partners´ professional networks.

4. Do I have to take part?
No. It is up to you to decide whether or not to take part. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a consent form. You can withdraw at any time by informing the investigators without giving a reason and without it affecting your rights.

5. What will happen to me if I take part?

If you will take part and will attend in the interview, it will take around 30 minutes. The findings of the survey will be essential for the discussion and answer of the above mentioned topic in the framework of a PhD thesis.

All data will be treated with anonymity and confidentiality.

6. Will I be recorded and how will the recorded media be used?
The audio recordings of your activities made during this study will be used only for analysis. No other use will be made of them without your written permission.
The interview will be audio recorded on an encrypted audio recording device and as soon as possible the recording will be transferred to secure storage and deleted from the recording device.

7. Are there any possible disadvantages or risks from taking part?
There are no risks or possible disadvantages involved. In taking part, your opinions and your current experience in managing mega projects, large projects or small project in the field of Road Infrastructure Projects can provide useful insights about the development of the principles of Blockchain Technology in the field of Road Infrastructure Projects.

8. What are the possible benefits of taking part?

The benefits for you taking part in the study is, that it is hoped that this work will contribute to a clear understanding of the process of the principles of Blockchain Technology in terms of Road Infrastructure Projects. Your experience and perceptions may reveal new insights and knowledge, extending and adapting traditional project management together with Blockchain Technology.

At the end of the study you will get a summary of the survey.

9. **What will happen to the data provided and how will my taking part in this project be kept confidential?**

The information you provide as part of the study is the study data. Any study data from which you can be identified (e.g. from identifiers such as your name, date of birth, audio recording etc.), is known as personal data. This includes more sensitive categories of personal data (sensitive data) such as your race; ethnic origin; politics; religion; trade union membership; genetics; biometrics (where used for ID purposes); health; sex life; or sexual orientation.

When you agree to take part in a study, we will use your personal data in the ways needed to conduct and analyse the study and if necessary, to verify and defend, when required, the process and outcomes of the study. Personal data will be accessible to the study team. In addition, responsible members of Liverpool John Moores may be given access to personal data for monitoring and/or audit of the study to ensure that the study is complying with applicable regulations.

When we do not need to use personal data, it will be deleted or identifiers will be removed. Personal data does not include data that cannot be identified to an individual (e.g. data collected anonymously or where identifiers have been removed). However, your consent form, contact details, audio recordings etc. will be retained for 5 years.

Personal data collected from you will be recorded using a linked code – the link from the code to your identity will be stored securely and separately from the coded data

We will not tell anyone that you have taken part in the Interviews. We will also not name you in any of our reports or publications.

We will use pseudonyms in transcripts and reports to help protect the identity of individuals and organisations unless you tell us that you would like to be attributed to information/direct quotes etc. with your consent, we would like to store your contact details so that we may contact you about future opportunities to participate in studies.

10. **What will happen to the results of the study?**

The results of that study will be essential for the discussion and answer for the above mentioned topic of a PhD thesis.

11. **Who has reviewed this study?**

This study has been reviewed by, and received ethics clearance through, the Liverpool John Moores University Research Ethics Committee.

12. **What if something goes wrong?**

If you have a concern about any aspect of this study, please contact the relevant investigator who will do their best to answer your query. The investigator should acknowledge your concern within 10 working days and give you an indication of how they intend to deal with it. If you wish to make a complaint, please contact the chair of the Liverpool John Moores University Research Ethics

Committee (researchethics@ljmu.ac.uk) and your communication will be re-directed to an independent person as appropriate.

13. Data Protection Notice

Liverpool John Moores University is the sponsor for this study based in the United Kingdom and Germany. We will be using information from you in order to undertake this study and will act as the data controller for this study.This means that we are responsible for looking after your information and using it properly. Liverpool John Moores University will process your personal data for the purpose of research. Research is a task that we perform in the public interest. Liverpool John Moores University will keep identifiable information about you for 5 years after the study has finished/ until X.

Your rights to access, change or move your information are limited, as we need to manage your information in specific ways in order for the study to be reliable and accurate. If you withdraw from the study, we will keep the information about you that we have already obtained. To safeguard your rights, we will use the minimum personally-identifiable information possible.

You can find out more about how we use your information or by contacting secretariat@ljmu.ac.uk.

If you are concerned about how your personal data is being processed, please contact LJMU in the first instance at [secretariat@ljmu.ac.uk. If you remain unsatisfied,](mailto:secretariat@ljmu.ac.uk) you may wish to contact the Information Commissioner's Office (ICO). Contact details, and details of data subject rights, are available on the ICO website at: https://ico.org.uk/for-organisations/data-protection-reform/overview-of-the-gdpr/individuals-rights/

14. Contact for further information

Contact details researcher

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Thank you for reading this information sheet and for considering to take part in this study.

Note: A copy of the participant information sheet should be retained by the participant with a copy of the signed consent form

APPENDIX C: Example of the consent form (semi-structured interviews)

LIVERPOOL JOHN MOORES UNIVERSITY

CONSENT FORM

Utilising the Principles of Blockchain Technology for Managing Road Infrastructure Projects

Lena Pauli, Liverpool Business School

7. I confirm that I have read and understand the information provided for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily

8. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and that this will not affect my legal rights.

9. I understand that any personal information collected during the study will be anonymised and remain confidential.

10. I agree to take part in the above study.

11. I understand that the interview will be audio recorded and I am happy to proceed   .

12. I understand that parts of our conversation may be used verbatim in future publications or presentations but that such quotes will be anonymised.

Name of Participant   Date   Signature

Name of Researcher   Date   Signature

Name of Person taking consent   Date   Signature
(if different from researcher)

Note: When completed 1 copy for participant and 1 copy for researcher

APPENDIX D: Example of the participant information sheet (semi-structured interviews)

LIVERPOOL JOHN MOORES UNIVERSITY Participant Information Sheet – Semi-Structured interviews

Title of Study Utilising the Principles of Blockchain Technology for Managing Road Infrastructure Projects

You are being invited to take part in a study. Before you decide it is important for you to understand why the study is being done and what the participation will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for taking the time to read this.

15. Who will conduct the study?

Study Team
Supervision: Professor David Bryde Phd(LJMU), Professor Dr. Hans Peter Schelkle (HTWG)
Researcher: Lena Pauli

School/Faculty within LJMU: Liverpool Business School
School/Faculty within HTWG: University of Applied Science in Konstanz, Department of Civil

Engineer

16. What is the purpose of the study?
This study hopes to answer the following questions "How can the principles of Blockchain

Technology be utilized for Managing Road Infrastructure Projects?"

To answer this question, the following terms, have to be investigated:

5. To identify in which aspects of managing projects the principles of Blockchain Technology can be effectively utilized.
6. To analyze the potential relationships between the mechanisms of the principles of Blockchain Technology and the performance of Managing Road Infrastructure Projects.

7. To appraise the barriers and the enablers to the utilization of Blockchain Technology in the context of Road Infrastructure projects.

8. To develop a framework for the utilisation of Blockchain Technology to support the management of Road Infrastructure projects.

The first term was already investigated with the help of Focus Groups. Based on the results

of the focus groups, interviews will be conducted to find a solution for the terms 2 and 3.

17. Why have I been invited you to participate?

You have been invited, because you are an experienced engineer in the field of road infrastructure projects. The exclusion/inclusion criteria for participating in the interviews are that you have extensive experience in the field of road infrastructure projects, which is involving the areas of municipalities, highways, the rail sector, bridges or airports in this research. Your work experience should be typically at least 3 years and you should be employed as a project manager, an engineer a consultant or you should have experience in the field of project monitoring. Your experience should be in public and /or private sector organisations. You have been identified as a potential participant through researchers and professional partners´ professional networks.

18. Do I have to take part?

No. It is up to you to decide whether or not to take part. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a consent form. You can withdraw at any time by informing the investigators without giving a reason and without it affecting your rights.

19. What will happen to me if I take part?

If you will take part and will attend in the interview, it will take around 30 minutes. The findings of the survey will be essential for the discussion and answer of the above mentioned topic in the framework of a PhD thesis.

All data will be treated with anonymity and confidentiality.

20. Will I be recorded and how will the recorded media be used?

The audio recordings of your activities made during this study will be used only for analysis. No other use will be made of them without your written permission.
The interview will be audio recorded on an encrypted audio recording device and as soon as possible the recording will be transferred to secure storage and deleted from the recording device.

21. Are there any possible disadvantages or risks from taking part?

There are no risks or possible disadvantages involved. In taking part, your opinions and your current experience in managing mega projects, large projects or small project in the field of Road Infrastructure Projects can provide useful insights about the development of the principles of Blockchain Technology in the field of Road Infrastructure Projects.

22. What are the possible benefits of taking part?

The benefits for you taking part in the study is, that it is hoped that this work will contribute to a clear understanding of the process of the principles of Blockchain Technology in terms of Road Infrastructure Projects. Your experience and perceptions may reveal new insights and knowledge, extending and adapting traditional project management together with Blockchain Technology.

At the end of the study you will get a summary of the survey.

23. What will happen to the data provided and how will my taking part in this project be kept confidential?

The information you provide as part of the study is the study data. Any study data from which you can be identified (e.g. from identifiers such as your name, date of birth, audio recording etc.), is known as personal data. This includes more sensitive categories of personal data (sensitive data) such as your race; ethnic origin; politics; religion; trade union membership; genetics; biometrics (where used for ID purposes); health; sex life; or sexual orientation.

When you agree to take part in a study, we will use your personal data in the ways needed to conduct and analyse the study and if necessary, to verify and defend, when required, the process and outcomes of the study. Personal data will be accessible to the study team. In addition, responsible members of Liverpool John Moores may be given access to personal data for monitoring and/or audit of the study to ensure that the study is complying with applicable regulations.

When we do not need to use personal data, it will be deleted or identifiers will be removed. Personal data does not include data that cannot be identified to an individual (e.g. data collected anonymously or where identifiers have been removed). However, your consent form, contact details, audio recordings etc. will be retained for 5 years.

Personal data collected from you will be recorded using a linked code – the link from the code to your identity will be stored securely and separately from the coded data

We will not tell anyone that you have taken part in the Interviews. We will also not name you in any of our reports or publications.

We will use pseudonyms in transcripts and reports to help protect the identity of individuals and organisations unless you tell us that you would like to be attributed to information/direct quotes etc. with your consent, we would like to store your contact details so that we may contact you about future opportunities to participate in studies.

24. What will happen to the results of the study?
The results of that study will be essential for the discussion and answer for the above mentioned topic of a PhD thesis.

25. Who has reviewed this study?

This study has been reviewed by, and received ethics clearance through, the Liverpool John Moores University Research Ethics Committee.

26. What if something goes wrong?

If you have a concern about any aspect of this study, please contact the relevant investigator who will do their best to answer your query. The investigator should acknowledge your concern within 10 working days and give you an indication of how they intend to deal with it. If you wish to make a complaint, please contact the chair of the Liverpool John Moores University Research Ethics Committee (researchethics@ljmu.ac.uk) and your communication will be re-directed to an independent person as appropriate.

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Liverpool John Moores University is the sponsor for this study based in the United Kingdom and Germany. We will be using information from you in order to undertake this study and will act as the data controller for this study.This means that we are responsible for looking after your information and using it properly. Liverpool John Moores University will process your personal data for the purpose of research. Research is a task that we perform in the public interest. Liverpool John Moores University will keep identifiable information about you for 5 years after the study has finished/ until X.

Your rights to access, change or move your information are limited, as we need to manage your information in specific ways in order for the study to be reliable and accurate. If you withdraw from the study, we will keep the information about you that we have already obtained. To safeguard your rights, we will use the minimum personally-identifiable information possible.

You can find out more about how we use your information or by contacting secretariat@ljmu.ac.uk.

If you are concerned about how your personal data is being processed, please contact LJMU in the first instance at secretariat@ljmu.ac.uk. If you remain unsatisfied, you may wish to contact the Information Commissioner's Office (ICO). Contact details, and details of data subject rights, are available on the ICO website at: https://ico.org.uk/for-organisations/data-protection-reform/overview-of-the-gdpr/individuals-rights/

28. Contact for further information

Contact details researcher

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t: +497531206402 e: hp.schelkle@htwg-konstanz.de

Thank you for reading this information sheet and for considering to take part in this study.

Note: A copy of the participant information sheet should be retained by the participant with a copy of

the signed consent form.

APPENDIX E: Questions for the experts of the road

infrastructure sector (semi-structured interviews)

Utilising the Principles of the Principles of Blockchain Technology for Managing Roads for Managing Road Infrastructure Projects

3) <u>General Information / Description of yourself</u>

- What is your positon within your company, what are your responsibilities?

- What is your total work experience?

- Please give a short overview about your organization.

- What for Road Infrastructure Projects are you focusing on in your company? Highways, Rail, Bridges? Are you a public or a private company?

- How many projects does your organization undertake per year?

4) <u>Size and Structures of a new technology / experiences in the past</u>

- Does your company support new technologies (Industry 4.0)? What for experience do you have with new technologies / What for technologies do you use? How do you handle with the digitisation?

- Have you ever used Blockchain Technology?

  i)   If yes, what is your experience with it?

- Do you think with the help of new technologies, especially Blockchain Technology there is a bigger security and immutability with projects?

- In which fields do you think can Blockchain Technology be recognised?

  i)   Planning

  ii) Implementation

  iii) Anything else

- One of the big advantages of Blockchain Technology are decentralisation, transparency and traceability. Using these advantages, it would be great to use them in the following fields

  i)   In the field of contracts.

  ii) In the visibility of processes.

iii) In the supply chain management.

- A big problem in road infrastructure projects is, that a lot of different stakeholders are involved, with different interests. Do you think the technology can help in solving this problems, if yes in which fields?

- What else do you think about the research? Any comments?

APPENDIX F: Questions for the experts of Blockchain

Technology (semi-structured interviews)

Utilising the Principles of the Principles of Blockchain Technology for Managing Roads for Managing Road Infrastructure Projects

1) General information / description of yourself

- What is your positon within your company, what are your responsibilities?

- What is your total work experience?

- Please give a short overview about your organization.

- What for Road Infrastructure Projects are you focusing on in your company? Highways, Rail, Bridges? Are you a public or a private company?

- How many projects does your organization undertake per year?

2) Blockchain Technology

A big problem in road infrastructure projects is, that a lot of different stakeholders are involved, with different interests. One of the big advantages of Blockchain Technology are decentralisation, transparency and traceability.

- What is your experience with the Blockchain Technology? What do you think about that technology in terms of the Road Infrastructure Sector?

- Where do you see the focus in implementing Blockchain Technology between building and operating? What do you think will be an advantage of this?

- When is a Blockchain needed in a Road Infrastructure Project? What do you think about the following parameters and why do you think yes or no?4

    i) Automation

    ii) Repeatable process

    iii) Multiple Stakeholders

    iv) Value transfer (not just monetary, f.e. information)

    v) Immutability

    vi) Transparency

    vii) Trust

- What else do you think about the research? Any comments?

APPENDIX G: Example of one transcript of an interview

PhD: Utilising the Principles of Blockchain Technology for Managing Road Infrastructure Projects (Focus onf Blockchain Technology)

Interview: 1 (*#BT-1*)

Date: 30th April 2021

Time: 1600 – 1702. Recording duration 62 minutes.

Location: Teams.

Led by: Lena Pauli

Sector: Construction.

> *#BT-1: Would it be OK if I had a copy of the recording as well, just for… I don't know if it will be useful for me in the future, but just …*

LCP: I can send it over to you when you want. Now you should have a message that it's recorded. And then I can send you that video as well. OK, perfect.

> *#BT-1: Thank you.*

LCP: I can share some slides there. So now you should see a presentation.

> *#BT-1: Yes.*

LCP: OK, so I think the problem is when I make full screen then it's on my other screen, but I think it's fine like this. So, what I'm doing in my whole study is, that I was starting to talk about the path of industry from 1.0 to 4 and what I have realized during that path that one of the most problems, what we are facing in the road infrastructure is the problem, Trust. So in the in the huge projects we

do not really trust each other. Because it can happen that the partners we are working together today, are our competitor's tomorrow. And because of the trust issue, which is coming up, I also did a research in information exchange theory. So and this is in regards to how do we communicate with each other, what for systems are we using for communicating with each other? And what is the information exchange theory behind it? And then when I did the research in the information exchange, I realized that the communication is also a big problem, we are having all in of our projects and I think maybe this is something what was appearing when we were working together in Yotta, that our customers sometimes told us different things that they meant or something like this so. And this is the problem that we are having a problem with communication and with trust. And what I'm trying to find out is how can blockchain technology help with these topics. And Blockchain Technology is also known, because it's a system you can use when you do not trust each other. So this is the background or this is what I'm researching at the moment. And yeah, and this is what I said, was the path of industry 1.0 to 4.0. Everything started in the year 1784 when we were in the age where we talking about mechanization or when something were developed in terms of the water power. And after that I think we all know Henry Ford. We have all the mass productions. And now since this it's getting more fast in the Industry with cars and everything, but the problem is and this is what already starts here that all industries are growing and the productivity is growing. But the industry of the construction and the industry of the road construction is not really growing. So and yeah this is one of the problems. I'm also I'm trying to do a research in. Then in the industry and 1969 everything starts with the computers, we were used to have computers and now I think it's not possible to have a life without computers and now we're in the industry 4.0 and what we are dealing with every day, is that we are having a lot of data and we are having a lot of data which are online and this is what I just mentioned. And because of this, a lot of data we are having. With the Internet, we are having the problem with trust and communication, because we know everything can be available for everybody, everything can be visible. It's also now more easy to manipulate some data or just to hack some things. And I think when we're just

in a group of different stakeholders, then we do not really know what we should trust. And I think this is what we're having in the road infrastructure sector. We are having a lot of different stakeholders. We're having the building owner. They are in the hierarchy on the top and they are only just responsible for all the financing thing. But we also have in road infrastructure project stakeholders, for example the public, the public and they are the taxpayers. And all the infrastructure road projects. I think they are financed by the taxes. So the public is having the feeling that it's my money, what we're spending in this road infrastructure projects and what is the problem in the projects? They're not in time? Not in costs and not in quality. And then what I try to find out is, if we could have a better system in how to communicate with each other and a system where we can prove that we can trust each other, and if it would help in that whole group with the different stakeholders. And what I have done in my interview so far.

I was just talking, what they do think about transparency. What they do think, for example, about the traceability and for example in the transparency… so half of the group said, I think transparency is really useful in a project and when we were talking about the transparency, we were talking about the whole project. That every stakeholder knows from each other what the other stakeholders doing. Is it from the top level? Or is it maybe only the public? Or is it the planners or the builders. But half of them said that they do not want to have a transparency in these projects, and the reason for, the we do not want to have the transparency, is because they do not trust each other. And this was the result that they said because the people we are working together today, they can be a competition tomorrow. And why should I give them my strategic alignment for the next 30 years? So because this can damage me, but I think if, when everybody would trust each other. And everybody would share everything. Then life would be more easy. But this is a philosophical question. So yeah, but I will not solve this.

#BT-1: Yes, I fully agree with that.

LCP: But, the thing is, the transparency would help. And then that's the same thing with the traceability or the immutability. Everybody said it would be great, if everything would be traceable. And when the data we would work with are immutable. So if we would have in the whole system, we would know what the planners had said at the beginning. And then it's just in a blockchain for example. And then we know what the planner said finally and then we can build the whole thing, but I think the data are not immutable at the moment and we're changing them all the time. Sometimes we have to change it, because it's in the road infrastructure like this, but sometimes I think in this, it was really interesting, because most of the people said we have to manipulate in the in construction sector, otherwise we would never be successful. So this is something we really…we can't solve. And what I have done with the new ideas, this was more like, where can we use the blockchain technology. And maybe the blockchain technology would make sense if we would use it in the quality management or it in the feasibility study. So there is really a huge field where we can use the blockchain technology. But the problem is, my PhD is so small I can't go in all of these topics. So I was more gathering it and all these new ideas will be a topic for somebody else who will do a research. But what I am focusing on is really that, why do they do not want to have the transparency and… That it is really important, that the data are immutable. And how can we work on the no trust thing. And how can we work on the competitive advantage. And blockchain technology can help with it. And I'm thinking about a few parameters, where I do think when we're having these parameters in our system, then it would be worth having a blockchain, because blockchain is a really hard technique and I think it does not make sense use it all the time because it's so complex and I think it's really expensive. So just in case you and me would work together. It would not make sense, if we would use a blockchain around all of our communications because we trust each other and I think it's a too huge technology. And then I'm thinking about a few parameters, where I think when all these parameters would fit together then it would make sense to use like them a blockchain. But I will come to this later.

#BT-1: And do you think that maybe that would get easier with time sort of thing, as it becomes if it was built into sort of day-to-day tools that we would use for contracts and things. So I know Ethereum, is like a cryptocurrency, that sort of set up for contracts and I feel like… You're right, I think it would be an investment and in time and effort to do it for small things currently, but do you see that changing over time?
And then in the next few years, do you think that there would be this sort of software that makes it less of overtime and cost investment to use blockchain technology?

LCP: I do not think in the next years, it will be used. I think they're not willing to use it at the moment, so they see the advantages of it, so this is my feeling. So everybody sees the advantages of it, but they are afraid of. They're afraid that, when we're using a blockchain, that everything can be traceable, and then they do not want to share what they're doing, because they're afraid that they're losing their jobs at the end. So this is the strange thing with it, but as you said in the contracting and all these fields, it would make so much sense. But at the moment we are not there, so hopefully we are slowly getting there. But I'm not having good feeling at the moment.

#BT-1: So do you see it more of a social barrier than a technological one?

LCP: Ja.

#BT-1: OK. Yeah.

LCP: But this is only my view. So I have no idea. So I think maybe when you would talk to somebody else, this person would say something different. But I really do think this is a social thing and this is the big trust thing and trust is something you can't measure. So and in this House what I am, what I did here is, I wanted to show, but this is just yeah really simple, who is involved in such a road infrastructure project. And normally when I talk about a Road infrastructure Project, I do talk about the airport in Berlin. I think you know about this airport. I think it took 8 years longer to build it. The costs were doubled and

it went not really well. And the problem is, why are all these projects are going so slow and why are they having so many mistakes? And I think the problem is and this is what I mentioned at the beginning, we are having so many stakeholders involved. We are having the building owner and I was talking to some people from the European Investment Bank and they are part of the building owner and they are only responsible for the financing thing. They have no idea about asphalt or concrete for example. They do not even know the difference between concrete or asphalt, but they're not interested in that. They are only interested in, how the whole financing will work. And I think they're spending a lot of money in it. And the only thing that they want is that the money is spending the right way. And these people do not want to have a transparency and these people, the building owner, do not want to have a blockchain because, they want to have their data secret, they do not want to share it. But then my idea was, maybe for this people (build and operate) blockchain would make sense, because they are dealing with so much money. And if all their communications would be in a blockchain and all of this would be secrets that nobody can hack it. So maybe it would make sense for them but they are… They're afraid. And this is the same with the people who are working in the in the field of contracting. So I think they said maybe they want to have a blockchain, but only in their group, so they do not want to share the contracting with the planners, the builders, the operators. And this is my idea, or this is what I do, what my understanding of a transparency is that everybody knows from each other what they're doing, so even the public. So because the public is important. And if we would use the public… For example, the builders when they're building the projects and if they would involve the public Just give them all the information what's happening. Why sometimes the project takes longer… or what's the problem. I think they would have a better understanding and then we would not have all these protests.

#BT-1: And yeah, I think you're right. I think there's a real social barrier to being the first person to take this step and say we're going to make all of it public, because as soon as you do that, people will jump on it and start poking holes in it and saying, why

did this job take this much longer or cost this much more, but I think you're right, the world would be a better place for it. If we decided to do that, and I think that the same is probably true of those other revolutions that you were talking about. There's probably a few companies that took the first step and put their neck out and those companies would become places like Google and Amazon. And yeah, and I think it takes guts, I think to adopt new technology like this, especially when the public is funding the projects, that that it would make more transparent. But I do think as a general theme, we've gone further and further and further into transparency, rather than privacy, especially with companies. I think this would be really valuable.

LCP: "Yeah, this is what I think as well. So this is the reason why, I've put the blockchain technology around the whole process, but the thing is, what you can see... the building owner or the people who are working in the contracts, they do not want to have a transparency, but the people who are building a project or the people who are working in the operation phase. They want to have a full transparency. They want to know what the others are doing. They want to have an understanding what was in the contract, so this is really interesting, it depends in which group you are. If you want to have a transparency or if you do not want to have a transparency. And what I'm thinking about focusing on now, is just thinking about between building and operation. So, I'm thinking about if it makes sense, if I will focus on this interface between building and operation, and if a blockchain technology would make sense here... between building and operation. This is what my idea is, because I think this is the work where we are working every day. And. I have no experience in the contract, so I thought in building and operation. This is what we are having in in all the projects, so I'm thinking if it makes sense having them... and what I should mention, so it's it's not... I'm talking about the blockchain technology, but what I want to do is I want to talk about the principles of blockchain technology. So what are our big advantages of the blockchain technology so it's the decentralization, and because of the decentralisation, it helps us in transparency, traceability and trust. And I have spoken about the trust. And when I've done these interviews and the feedback of them was when we were talking about the transparency and

then they said OK, I do not want to have it, because of the trust issue. And then I was thinking, but when we have a clear information sharing policies so when we are all in a system and we know when somebody else is something sharing, I have to share my knowledge as well. That would be maybe sometimes be more easy, but I think this is sometimes it's just happening in the projects. We're not really sharing our knowledge, so there are so many people involved and so many people are having so much experience from the last years. But we're not sharing our knowledge, because I think everybody is just afraid that somebody stealing their knowledge from the other person and is using it for other projects. It's a problem."

#BT-1: Before that, I really agree with, is that there's almost two sort of types of it. One is a blockchain that would be public facing that anybody could gain information from. And that would increase transparency overall sort of thing. And then the other one is an internal sort of blockchain that would give you the things like the traceability, immutability and all of those same sort of benefits. But then wouldn't be external facing. So I think that the argument for the second one is really strong, because…. There's no reason that we shouldn't use the technology internally even if each company had their own set of blockchain that there's no, there's not… I can't see an argument against that because there seems to be a lot of benefits for blockchain technology. And implementing, it doesn't necessarily mean that you have to be completely transparent. I would argue for the first one. I agree with you. I think true complete transparency would be awesome. Would improve the world information sharing in general. I think, just on a philosophical, I think is one of the biggest advantages that humans have. One of the best things that we've done is just general information sharing, making information free. Making data open so I always would advocate for that, but I guess when it comes to blockchain you could… You don't necessarily have to have that transparency along with it. It would give you transparency along within everyone in the blockchain, but you can determine who you want to be in your chain or not.

LCP: "And the good thing with it. So when we're talking about the transparency in the blockchain, I think that this is the transparency of the processes, so we

can when we want, we can put a code behind all the groups and stakeholders that we do not really know, who told something or who agreed something. So we know the process. So what A&B were talking about and this is transparent for everybody. But we can make it in transparent who really said it. So because I think maybe, this would also help that we can have… only the process is transparent, which the technology can provide so."

#BT-1: Definitely.

LCP: "So these were the things of trust and the problems, that we're having is that we're having many stakeholders in the project. But every stakeholders is using a different tool, so for them it's hard that they do not want to put…they have the feeling that they have to use all the same tool, but this is not the idea behind it. So I think it's everybody can use their own tools anyway, but the results of what's coming out from this, if from a different tool can be in the blockchain so. And if we would have these tools for, I think everybody is talking about BIM for example. And everybody thinks now BIM is just solving our life and BIM is solving the construction sector. But BIM is at the end, it's just a software and you have to feed it with information and you have to start with the project from zero on and at the beginning there's nothing in, and then you have to put a lot of information in and then at the end BIM can help you. But you have to put all information and otherwise, it's not working. And the problem is that information do get lost in in all these systems. We need to solve this."

#BT-1: BT can be built into software like that in the future and sort of thing. So like you say update so things are traceable and things like that and an any data that you load. You know when it was loaded and by who and things like that is I think you're right that people wouldn't have to abandon the tools that they've learned. It would probably go the other way around and the tools could integrate blockchain technology.

LCP: "When I've done the interviews, I started the research in the information exchange management and where are we in terms of information exchange in

the road infrastructure. And I think everything is around people, that technology and the processes. And when we're not having these three parameters combined, then the whole thing is not really working and I think the thing is what we're having in this big project is that we are having a concurrency, we're having these lots of different stakeholders and we're having really complex projects. So because every project is different. So I think we will never have a project, which is similar to another project. Every project is different we are having so much data and so much data are produced in every project. And yeah, these are one of the things where I think, so much data are produced and even we are still working with paper. I think there is the trend that we have to work with the digitisation that we have to... not work with paper. BIM can help, but maybe just put a blockchain around BIM or using BIM and put a blockchain in some parts of the BIM right? This is this is my idea. This is where I am at the moment and with the information I have with this. So yeah, I want to focus now on this small thing of that whole house. So I called this the house of my road infrastructure project management. And what I am, what I am thinking and I was talking with you about the parameters. If a blockchain really does make sense or if it's really, really necessary. So because I think when we're having a really, really small project, we do not need that huge technology, where we need a lot of different databases, where we need a coding. And then I was thinking about these 7 parameters. If maybe a blockchain only is necessary and when we are having an old automation in our processes, when we are having a lot of processes which are repeatable and they're not appearing all four years, when they are appearing several times in a year and when we're having multiple stakeholders. So at least three. So when we're having at least three different stakeholders. Or maybe, yeah, maybe two. I'm not sure with that at the moment, when we're having two different stakeholders, at least then maybe a blockchain would make sense. And when we are talking about value transfer and I'm not only talking about a transfer in terms of the money. I think it runs where can also be the communication, the whole information which needs to be exchanged, all the documents. Then it would make sense from my perspective when we need a process, which is immutable in when documents need to be immutable and we should not change

it, and when we changed it, a blockchain would help in terms of because we know when it was changed and then we can explain why it was changed. A Blockchain would make sense from my perspective, when the process needs to be transparent and when we are having in that whole project a trust problem. So what do you think about these parameters?"

#BT-1: I agree completely. I think I yeah, definitely the value transfer as well, like I would add as well if it was monetary, then there's the benefit of blockchain from being independent of… you can use obviously, as you know cryptocurrency, and things which would be independent of banks, independent of governments and things like that. So it would mean that for international projects you would all be using the same currency you would, I see some benefits around that, but yeah, completely the immutability transparency interest. I think when it comes to like contracts and things like that and it, you would have a way of hosting a contract and knowing that that contract was the latest version of it and the that's what the one that everybody had agreed to. And if it was updated you would see when and by who. And I think all of those things. So when you say not just monetary value transfer as well, I think definitely when it comes to services you could very clearly in theory put together a proposal in the contract and say this is what we will deliver, and there's no… At least there's less room for ambiguity about versioning and about promises made to people and things like that, because you could have for all parties they can access the same in the same location. This is the latest version of whatever document we're looking at and not just contracts but just everything. final deliverables….and things like that and then just general data. I think, yeah, completely. There's not anything on this list I disagree with, and I wouldn't add anything more to it.

LCP: "OK, so that would have been my next question. And what do you think… Do we need all these parameters together, so would a Blockchain only makes sense when we're having all these seven point. Or would it also make sense when we have for example only having multiple stakeholders, or when we're only having a repeatable processes? Or do we really need all seven parameters together to use it? "

#BT-1: So I see it like, matches like, a value is saying in one of your sides about the progression of technology. So I say very much as an addition and like and like another not quite as big as the Internet, but another massive step in terms of technology. And personally I see it eventually being integrated into all sorts of things and I think with any technology like that I take your point definitely about the social barrier to it, but I think personally, I think it as it becomes more popular, the investment in, in requirements in time and cost and whatever of implementing it, will be lower and lower and it might become integrated into more and more software. And you know that if it, I guess, whether you need all of them or not. It's like a cost benefit way up? And if the cost is very low and the only benefit you would get from it is that is transparency, it may, it may be worth for just for the transparency of the cost is nearly zero, or if that's, you know if that's the way things are done by that point. If that's the norm, so I think it would be, whether you need all of them or not. Is just a what the what is the net benefit of it versus what is the cost of it. And I see the cost of implementing blockchain technologies into things as I would imagine it will go down in the future. So I think right now it's kind of like a cumbersome technology that you would have to set up your own, so I think it would be a little bit like setting up like an Internet or something. I would see it as like some companies would at some point in time would be asking is it worth setting up an internal network with all of our computers? And for some companies that would be true because you know there be real benefits from having an internal network and so it wouldn't be. And now it's kind of just common practice that you have an internal network because the cost of doing so is so low and the benefit so you know whether you. You just use it for sharing files. Even then, don't use it for communication or publishing news in the company or any of the other things you could do with an internal network. If you only use it for one purpose, you could still say yes it's worth using it, 'cause the cost of implementing it is not very high at all. And standard practices have been developed as to how to use it and what the benefits have been justified. In other case studies and things. And I think once you have all of that sort of stuff going on. And it's easier to take that leap and say, yeah, we'll have an internal blockchain networks or thing. And even if we only use it to share files and keep track of who said

what to who at one point, then you know it would be worth it. Still, depending on how cheap and how easy to implement it was at the time.

LCP: "OK, this is this is a good point. I was talking about these seven parameters between building and operating."

#BT-1: Yes, I was going to ask what would fit under the buildings of umbrella of this. Would this be the operations is the people on the ground creating and doing the construction.

LCP: "For example, when we are building a Road. Then there is the phase, where we are just building the road and then there is a time where the road is finished. So it's just built and it's done. But then we need to operate the road, which means for example, the road is having a lifetime. I think a bridge is a better example. When a bridge is built then you need to operate the bridge in the next years, so you have just to make sure and do some surfing's. You have to do some treatments you have to make sure that it's not breaking down and this is the operation part."

#BT-1: Right, then definitely, I do see these parameters in them. There was a case in the UK awhile back that the people that had put down the road, the road within about seven years or something was falling apart and it was a massive motorway project. Multiple billions of pounds spent on it, and run the name afterwards. But then the Council had paid for this to be put down and was left with a road that was falling apart and the operational cost of maintaining the road was very high and they had a job on them to go back and prove that the road was laid correctly in the 1st place. And that turned out to be quite a tricky thing without sort of having access to that data of what was the roller temperature, how many roller passes did you do? At which point of the road you know, how hot was the material when you put the material down on the road? What was the temperature at the time? What was the weather condition? And things like that. And as the one thing we've looked at in the past is sort of using the as built data sort of thing to make predictions about where Road defects will occur in the future.

But that's definitely something that. That comes up fairly often is having that transparency. I mean I know there's standard procedure for that at the moment, is that they'll take all of the recordings and basically print them out as the spreadsheets, but on printed paper and they say they were saying to us at the standard is that you end up with a stack of paper. This I guess put into like a folder somewhere, put into a filing cabinet and never looked at again. So I think as to all of those details about how a Road as an example, was laid in the 1st place, and so I think for blockchain coming out would it would be brilliant for that, that data to be transparent and for it to be traceable. So when you you're in that position as a whoever the operational person responsible for the operational cost is. If you've got your road or your bill or any construction projects, what does performing less well than you would expect it to? You can go back and say these are the positions where we're finding these are the coordinates were finding defects. Was it laid down correctly, you know, is what is the reason that is not performing as, as expected and then I think the benefit from the building side of it, when we first thought about using this as built data, a lot of people that we went to were worried about the transparency, because they were thinking it would just be giving whoever were born in the road for a stick to hit us with this sort of thing. If we if we make all of that open but the benefit for them was they would be the only company that could come forward and say not only will we do this project for you, but will make open and all of these visualizations of how well the work was done, and so it's almost like a guarantee that goes along with that work. You know, without the only ones that can not only do the job, but prove that they did it well and proved that they were monitoring that they did it well and it wasn't just tucked away in a filing cabinet somewhere. And prove that they were that confident is that. Signing off your own work and putting your name to it and you know. And saying it's so good that we know we can hand this over to you, you know. And as I think, that was an advertising thing was good for them as well. So I think the transparency worked both ways for that and definitely immutability as well. Like you say, it's very good to be able to hand it over and know that this was the record as it was taken on site and all of a sudden, sure, you know, like the, rollers and a lot of the and the trucks and things like that. They all have sensors on the that has sense things like the weather and the compaction rate and the temperature of the material and things like that. So you know that if you put

that into a blockchain 'cause at the moment is put into a spreadsheet sent to a date around the list or a third party company analysed, turned into visualization sent back to you, there's you know, I don't think you have that happens necessarily, but there's nothing stopping that data from being edited at any point in that chain. And there's nothing to stop the person who's visualizing it, from visualizing it in a way if they're working for that company from visualizing it in a way that suits them. So if you had access to the raw data and you knew that it was completely unchanged from collection, you have the freedom to visualize it yourself and draw your own conclusions. So yeah, I think definitely between those in the interface between those two things, there's quite a few places where blockchain technology I think would be really good.

LCP: You had some great examples. So this is just, confirming now. I think this is really the part where we are having our daily work. So this is where we are working every day. So in it, it would make life so much easier for all the stakeholders and groups who are involved that they know what they have done each. And yeah, so OK good. OK so let's just stop sharing.

OK so am I just need some general information about you that I can put you in my special groups. I know what your name is, but can you just give a small introduction about you. What are you doing? How long are you working in the company? In which company are you working?

#BT-1: Yes, I work for company called Yotta and I do work as a data science consultant. So my main set of responsibilities would be well, I guess the company is like an infrastructure asset management company and they're also a software company that helps manage assets. So my role within that would be visualizing data and working on innovation projects primarily. So looking at new technology and how we could use that for infrastructure projects, whether it was strategic or operational management of those projects. So the data analysis and data visualization mostly, but also so if you're looking into new technologies and where we could best use data coming from things like LIDAR or when we were looking at is a gravimeter which measures gravity to look at voids and surface and things like that. Accelerometers and

sadly not blockchain yet, but definitely an interesting sort of an interesting topic to investigate. I've been with the company for almost 3 1/2 years now. My background is in environmental science and I started the company as a data technician and then became a graduate infrastructure asset management consultant, which I think is the longest job title that will ever have, probably. And then yeah, then moved into the data science consultant.

LCP: OK, good thank you. So what is your experience with blockchain?

#BT-1: So I trade crypto currencies quite frequently and I'm really interested in that sort of side of it. The thing that got me interested in trading them though, was the underlying technology and so I've got no professional experience with Blockchain, but definitely like a strong personal interest in it and then professional experience in infrastructure management so. And with applying new technologies to infrastructure projects. But yeah, in terms of my experience with blockchain, this is entirely just an interest sort of thing. I think. I see it is quite a revolutionary technology for lots of different spaces. And yeah, I can see it changing the way in the way that you were talking about in traceability and transparency and immutability as I see it, changing the way a lot of different things work

LCP: "What do you think? Do I miss something in my research?"

#BT-1: No, I think it's really interesting. This social part of it, like you say, 'cause I think the it's true of cryptocurrency as well. I think that it's a taking cryptocurrency as an example of a blockchain technology that's kind of proven to work and proven to be useful. There's lots of reasons that cryptocurrency is better than normal money. There's no technological barrier for swapping pounds to Bitcoin or etherium or something like that and just moving forward and getting rid of normal Fiat currency altogether. I think it's the same problem is, is people catching up to the technology and putting trust in the technology too, especially when they don't understand it. I think the same was true of the Internet, and the same is true of a lot of different things. It kind of. You know when the Internet came along, it was just clearly better when Microsoft Word came

along, it was clearly better than using paper like they were for a number of reasons. And you know it was more cost efficient and similar to blockchain. You know you could send a file and know that you were looking at the same file rather than copying a bit of paper somehow and sending that and you didn't have to physically send things, so there are 1,000,000 reasons why you would use a computer versus a filing cabinet. But I think it was the same thing like the technology was there. And then society had to catch up with it and the decision makers in particular had to catch up with it and not generalizing. But I think decision makers tend to be at an advanced stage of their career and that means tends to mean that they were of a certain age and that tends to mean that they've grown up with technology that's is older than the most recent technology, and so I think, and so I think sometimes, and that's changing a little bit. I think the average age of like CEOs is changing and stuff like that, but I think there is a bit of like between, the people who would be able to make the decision to make the switch in an organization and the absolute because blockchain is a fairly cutting edge technology. And you need to put a lot of trust into something before you can make that that initial step and take that jump. But yeah, I do look at companies like Google, you know, making that jump in, seeing the value of the Internet before other companies did and investing incredible amounts of money into our see it as a similar thing. This is if somebody's got to take the first step, but for me it's a technologically speaking. It's a clearly superior thing to not using it. There's not very many disadvantages to it, to using blockchain. That is, I think the disadvantages at the moment are the investment. And like you say, there's social trust in it, and the understanding of it. I think a lot of the time I think even people that have heard of cryptocurrency and they've heard of Bitcoin and things like that. And I think that's only really it doesn't really recent thing that it's become widely known about Bitcoin and I think even people that have heard of Bitcoin don't necessarily understand why it's why it would be a good thing to implement it. What are the advantages of it over money and and then I think blockchain is a step further from that again. 'cause it's not had the same publicity that something like Bitcoin has had. So people when you say blockchain people probably in general wouldn't even associate with Bitcoin or something like that. It is probably far away from the sort of Public and the general understanding of something is sort of the general working. Trying to look for is not in the vocabulary of the average sort of person to talk about

blockchain at the moment, and I think that would be the real turning point where you know, when you go from when everybody that you know when you go down the shops and they understand what blockchain technology is. I think that that would be the turning point when it would be implemented in a lot of different places.

LCP: "Sometimes I do think maybe it will be the time where we are using it and we do not even know that we are using it. So this is and this is what you said at the beginning. We were afraid of the Internet. What is it? We have no idea how it's working. I still have no idea how it's really working. I use it. Yeah, that we're using it, it makes life more easy and I think this is what… with blockchain and this is and I think because of the digitization more.., we're having more and more data and more data are in the Internet and we just have to make sure that it cannot be manipulated."

#BT-1: Yeah so. Technologies that would sit behind normal software. I don't think I think you're right, we wouldn't necessarily see that you were using it at all. You would make a payment on your card or whatever you're paying with your phone or whatever, and it might just be that the transaction is recorded by a blockchain. But you know the user experience probably wouldn't change very much. You might, you know we already have software where you might upload a contract so everybody can see it in the same place you know there's nothing to stop that being based on blockchain and then the user. The user is, you know, has no change to the way they using it. And I think blockchain is kind of one of those technologies. I don't think it would. Yeah it wouldn't be at the forefront of people's thought, but it's probably just something that changes in the background and most people don't notice or care. To begin with, but I think the repercussions of it would be would be immense.

LCP: "So, in the first companies, they should start working with it, and then I think it's our future. I believe in it, but we will see."

#BT-1: I don't see any good arguments against using it. It is kind of like the Internet for me. It is, it is just all Microsoft Word or whatever you know. Just feel like one of those

little technological revolutions where it's just you know, the cost of it at the moment is high. But just like with all of the technology, it would go down and how to implement it is a bit of an unknown at the moment. If you were trying to set up a blockchain system within your own company for instance. But again that's. The same as a lot of other technology that's just been in, and once at the thing.

LCP: "Yeah, when somebody just test done in the first time, then you know how to implement blockchain into your company and then again when it needs transparent that you can talk with each other that you know. This is how you should do it, and then it will work."