Data-driven enterprise risk management of critical infrastructures

The Dutch railway sector

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Preface

This master thesis that lies before you is the final hurrah of my academic career. It is the end result of a tough but above all educational process to complete the Engineering & Policy Analysis Master's program. The master thesis process is best compared with using the train. It was all fun and games until a disruption messes up the entire schedule. Fortunately, there was always the coffee machine at the TPM faculty or Cecile's home to give comfort. This master thesis is a co-production between hard work, perseverance, and caffeine and means the end of my stay at the Delft University of Technology as a student.

After high school, I was set to match my sister and also study at the TU Delft. But soon after starting at the TU Delft, this motivation disappeared and made room for a new intrinsic motivation: being part of TU Delft. The beginning of my student days was everything but easy, two times postponement of BSA and even switching to applied earth sciences for a year. In the end, however, I found my way at the TPM faculty, and everything started to fall into place. I felt at home at the TPM faculty. However, I decided to leave the faculty in Delft and do my master's in the Wijnhaven building in The Hague. After two and a half years in The Hague it is time to say goodbye to this trusted location.

The saying it takes a village to raise a child also applies to writing a thesis. Without the help of others, it was a mission impossible to write my thesis. I want to say a big thanks to everyone who has helped me with reading my thesis and checking my grammar skills. Without you guys, I would never have been able to deliver a quality master thesis with my dyslexia. Cecile, Sarah, and Nathalie, I am very grateful to you. Additionally, I would like to thank Cecile again for supporting me during this sometimes lonely thesis process with great advice and delicious coffee. I want to thank my family for their support during the last eight years. I also have to apologise to them for not visiting them because I was busy. Finally, I would like to thank my supervisors, Hans and Eleonora, for their support and feedback on my work. Although my planning was always seen as quite ambitious, you motivated me to go for it. I am very grateful to EY and the Enterprise Risk team that I was given the opportunity to do my graduation internship there. Thank you, Marco and Janoe for the guidance you provided during this period and for making me feel like I was part of the team while working from home.

I wish you lots of fun reading my final hurrah!

Jean-Paul Chün
Delft, September 7, 2021

Abstract

The Dutch rail sector is one of the most heavily used rail networks in Europe. It plays a critical role in the domestic transportation of passengers. The winter 2020 showed how vulnerable and complex the Dutch rail sector is. The snowfall in January disrupted the Dutch rail sector for almost a week. The disruption led to a reduced capacity of the passenger transport for the entire week. Disruptions do not only affect passenger transport it also impacts freight transport by rail. The port of Rotterdam is a gateway of cargo to the hinterland of Europe. One of the modes of transport to supply the hinterland is the railroads. Disruptions of the supply lines do not only impact the Netherlands but also European countries in the hinterland. The Dutch rail sector is a critical infrastructure for the Dutch society: 1) for its abilities to provide transporting service and 2) due to its economic value as a mode of transport for freight.

Preventing disruptions of the rail sector is key because the rail sector fulfils such a critical function within Dutch society. Risk management addresses possible threats that can disrupt the rail sector. The rail sector consists of multiple stakeholders, each responsible for its own risk management. However, all the organisations within the Dutch rail sector are intertwined with each other. Disruptions in the operation of one organisation can have a cascading effect on others within the sector. Risk management needs to identify and address these weaknesses to prevent large-scale disruptions. The risks a rail organisation faces are diverse, ranging from financial risks to strategic risks. The enterprise risk management methodology addresses all the risks of an organisation to reduce the negative effect and seize opportunities. Enterprise risk management assesses risks uniformly to compare and prioritise them. The prioritisation process determines the top risks of an organisation. These top risks support upper management with their strategic decision-making process. In recent years, there has been increased emphasis on data-driven work, including within the risk management domain. The Dutch rail sector is highly dependent on data, e.g. time schedules, planning maintenance and warning signals. This research explores the implementation of data-driven work in the enterprise risk management of the Dutch passenger transporting rail sector. The research question of this research is: “What is the added value of data-driven work on the enterprise risk management of passenger transporting rail organisations in the Netherlands?”

The research field of data-driven enterprise risk management is novel and underdeveloped. Hence, exploratory research is needed to add knowledge to this new research field. The exploratory research approach is adopted for this research. For more specific insights into the use of data-driven ERM in the Dutch rail sector, this approach is complemented with a comparative case study. The case study looks into the added value of data-driven enterprise risk management to three Dutch rail organisations: the NS, Connexxion, and ProRail. The data collection methods for the case study are semi-structured interviews and desk research. The desk research looks into annual reports and financial statements of the cases. The interviews are held with experts that are involved with Dutch rail organisations regarding risk management. In addition, per case, at least one employee is interviewed who is involved with the risk management of the organisation. Besides the case study, this research reviews the academic literature about data-driven work and enterprise risk management. To put this research into, an overview of the Dutch rail sector is also provided.

This study found that a state-of-the-art review of the literature was difficult. Data-driven work is a concept that has not been researched in abundance in the academic literature. In addition, during the review of the Dutch rail sector, it emerged that the historical context of the sector still has its influences today. Two former state-owned rail organisations, the NS and ProRail, are still the dominant powers within the sector and are still owned by the Dutch State. The last observation of this research is that smaller rail organisations are not likely to invest in new systems or work processes. Therefore, they are less likely to adopt data-driven work or enterprise risk management, even when it would be beneficial for them in the long run.

This research concludes that data-driven work adds value to the enterprise risk management of Dutch rail organisations. Data-driven enterprise risk management improves the predictive capabilities of rail organisations. In addition, it enables real-time monitoring of risks. Hence, it supports the

decision-making process more precisely and accurately. Data-driven enterprise risk management has already found its place within the Dutch rail sector. Larger rail organisations already use enterprise risk management and developed strategies to become data-driven organisations. However, the investments in data-driven work and enterprise risk management are still too high for smaller passenger rail operators in the Netherlands.

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Introduction

At the end of the nineteenth century, during the first showing of the silent film, L'Arrivée d'un train en gare de La Ciotat, panic broke out and people jumped into the aisles. According to the urban legend, the public was sincerely terrified of the imminent danger of the steam locomotive. In this anecdote about the beginnings of cinematic arts, the train takes the lead role. Back then, the railway sector was of great importance for people. The invention of the steam engine and the resulting steam locomotive and ship have started the age of globalisation, which led to increasing economic growth (C. Zhang and Yang, 2020). The steam locomotive made it possible to travel faster on land and increased the transport capacity between places. A study of Swedish rural areas in the second half of the nineteenth century showed that areas that accommodated railroad infrastructure, were more industrially developed than those that were not in close proximity of railroad infrastructure (Berger, 2019). Urban areas also benefitted from the construction of railroads. Prussian cities with a rail connection experienced a significant increase in their industrial activities. Factories within these cities were twice as big (Hornung, 2015). The increasing industrial activities encouraged migration to these industrial areas. The railway sector provided a cheaper and faster mode of transport for the supplies of cities, delivering the mains for cities to flourish (Jedwab and Vollrath, 2015). The construction of the railroads is one of the enables of the globalisation and industrial revolution.

The rail sector has not only left its mark on history by contributing to the industrial revolution but it also was involved in some historical events. The rail sector played several roles during both world wars, some of them controversial. The end of the First World War came when the armistice of 11 November 2018 was signed in a train carriage. The same train carriage, Compiègne Wagon, was used by Nazi Germany for the armistice of 22 June 1940 when the French surrender to Germany. This train carriage became a symbol of defeat and humiliation. The rail sector kept playing a gruesome role during the remainder of the Second World War. The rail infrastructure facilitated the deportations to the concentration and death camps of Nazi Germany. The Germans also used the rail infrastructure to transport material for their war effort in massive quantities (Vallejo et al., 2012a). They also used the railroads to transport the largest gun ever used in combat: the Schwerer Gustav. On the other side of the globe, the Imperial Japanese Army forced prisoners of war to build the Thai-Burma Railway during the Pacific war. This construction project has cost the lives of almost twelve thousand Allied prisoners of war, amongst them 2490 Dutch citizens from the Indies (Sturma, 2020). More recently, a train played a leading role during the 2019 North Korea-United States Hanoi Summit. The leader of the Democratic People's Republic of Korea, Kim Jong-un, travelled from North Korea to Vietnam by train for a historical meeting with former U.S. President Donald Trump (Nah, 2019). The events mentioned above are not direct consequences of the existence of the rail sector, but they show the role the rail sector played during these moments.

Both the involvement in historical moments and the contribution to the industrial revolution show the impact that the invention of the steam locomotive and the railroads had on the course of history. The transporting capabilities of the rail sector also left their mark on the further development of the global economy and our society. Even nowadays, the rail sector is a vital mode of transport for commodities, goods, and people (Baldini et al., 2010). The rail sector, therefore, is classified as critical infrastructure (Becherová and Hošková-Mayerová, 2017; NCTV, n.d.). An infrastructure is deemed to be critical

when it contributes to the following three aspects of society: national security, economic wealth, and life quality (Busch-Geertsema et al., 2021; Karabacak et al., 2016). The transport sector, and the rail sector covered by it, is one of these infrastructures that provide an essential service to society (Cedergren et al., 2019; Dunlap et al., 2016). Disruptions of critical infrastructure can have severe consequences for the stability of society because they can affect the economy and the population (Brem, 2015). Failure of these infrastructures can result in "... a serious impact on health, safety, security or well-being of the society or effective functioning of governments and/or economies ..." (Bialas, 2016, p.240, p.240). In the case of the rail sector, it affects both. The economy suffers when supply chains are interrupted due to disruptions in the rail transport of goods and commodities. The population is affected when public transport by train is not available. In the Netherlands, the train is the largest mode of transport for public transportation (CBS, n.d.-b). The consequences of large-scale disruptions in the rail sector are a real threat to society because hindering both freight and passenger transport leads to large economic damages (Dekker and Panja, 2021). Therefore, risk management of critical infrastructures, such as the rail sector, is important to minimalise the chances of disruptions. However, the risks rail organisations face are not always a matter of life or death or impact an entire nation. Most of the risks of a rail organisation relate to business continuity and strategy. This research looks into how rail organisations can shape their risk management function in such a way that it considers all the risks the organisation faces. In the end, these organisations must manage their risks properly to ensure a stable rail transport infrastructure.

1.1. Research topic

This research focuses on the risk management of the rail sector as part of the critical infrastructure of society. The rail sector is a complex socio-technical system that faces challenges and risks (Kline and Hutchins, 2017; Siegel and Schraagen, 2017; Wilson et al., 2007). The rail sector can be seen as a socio-technical system because "... it is a purposeful system that is open to influences from, and in turn influences, the environment (technical, social, economic, demographic, political, legal, etc. [8]); the people within it must collaborate to make it work properly; and success in implementation of change and in its operation depends upon as near as possible jointly optimising its technical, social, and economic factors" (Wilson et al., 2007), p.102). To react to risks or grasp opportunities, rail organisations need to successfully implement changes to their operation to adapt to disruptions (Siegel and Schraagen, 2017). Risk management of socio-technical systems requires analysis of all the aspects of the organisation, such as "... social, organizational, commercial or political factors" (Morel and Chauvin, 2006, p.601). Furthermore, the risks in a complex socio-technical system cannot be assigned to a sole party. Usually, it involves several stakeholders to manage the risks and prevent incidents (Årstad and Engen, 2018). The organisation of the rail infrastructure is complex, with many different stakeholders and interests. On the one hand, there are the passenger-carrying operators, and on the other hand, there are cargo transporting operators. Both use the same railroad network for their core business but compete for access rights to the railroads. However, both have the same interest regarding the safety of the railroads and the maintenance of the infrastructure. The complexity is increased due to high security and safety standards within the sector. Altogether, zooming in on one risk area limits the overview and the interconnectedness of this complex sector. A method to find a comprehensive overview of the risk landscape is enterprise risk management (ERM). This methodology strives for a holistic risk managing approach. Instead of managing risks within business units or silos, it centralises the risk management of an entire organisation. The risk assessment is directly communicated to the managing or executive level of the organisation Fraser and Simkins, 2010. This research focuses on the implementation of the ERM method by rail organisations.

Risk management has evolved in recent years. Previously the experiences and expertise of professionals were the basis of risk management decisions. Nowadays, more decisions are approached with systematic processes and data (Kobayashi and Kaito, 2017). The advantage of data-based decision-making is the objectivity and reproducibility nature of the approach (Alemayehu et al., 2013). However, the data-driven approach to risk management is still in development. The problem occurring is that 30% of the decision-makers decide based on their intuition when facing uncertainty and not on data (Vahlne et al., 2017). The use of data safeguards the risk management decision-making process from being blindsided by gray rhino events. Gray rhino events are likely to happen, and their impact is significant, but decision-makers ignore the warning signals (Wucker, 2016). Unlike a black swan event, which is

very unlikely to happen and has not occurred previously (Andersona et al., 2013). An example of a black swan event is the 9/11 terrorist attack (Fishman, 2020). Such an attack was deemed very unlikely and did not have precedent in history. An example of a gray rhino event is the COVID-19 pandemic (Ibikunle and Rzayev, 2020). Multiple contagious diseases have spread in the last century around the globe, e.g. the Spanish flu, the swine flu and COVID-19. The use of data can provide insights into unconsciously overlooked early warning signals. Although the experiences and intuitions of experts cannot be brushed aside, it is a less systematic and reliable approach for decision-making. It is highly dependable on the competence and the availability of these experts. It is even more important when the decisions influence the risk management of a vital societal sector, such as the rail sector. Therefore, this research focuses on what the effect will be when ERM uses data-driven work processes.

The scope of this research is the Dutch rail sector. Firstly, this research is conducted in the Netherlands, and the connections with several rail organisations are already established due to the thesis internship at EY Netherlands. Secondly, the Dutch rail infrastructure is the busiest in Europe (ACM, 2019a). The Netherlands has per capita the least amount of rail kilometres of Western Europe (CBS, 2008). So, the Netherlands has relatively a small rail infrastructure compared to the population. The Dutch rail network is used both for passenger and freight transport. This research further demarcates by focusing only on the passenger transportation part of the Dutch rail sector. Passenger transport is interesting to research due to the complicated distribution of concession rights. The Netherlands has one dominant passenger operator, the Dutch Railways (NS). Chapter 3 discusses the Dutch rail sector in more detail. Another reason for the demarcation is that the lion's share of the rail activity can be attributed to passenger transport (CBS, 2008). Demarcating the research brings focus and ensures that this thesis is delivered within the predetermined time limits.

1.2. Academic knowledge gap

The research problem is the available academic knowledge about data-driven ERM in the rail sector, especially the Dutch rail sector. Case examples from the financial sector dominate the current ERM body of knowledge. An explanation can be found in the origin of ERM. Initially, ERM was used to manage the financial impacts of organisational risks (McShane, 2018; Schillera and Prpich, 2014). The risks of an organisation are addressed comprehensively to limit financial losses. Although a reputational risk is not a financial risk, it affects the financial performance of an organisation. As the rail sector, the financial sector is also a critical infrastructure (NCTV, n.d.). The body of knowledge does not support a generalisation of the effectiveness of ERM for other critical infrastructures than the financial sector. This research aims to add knowledge of the usefulness of ERM in the Dutch rail sector. In addition, this research also looks into the use of data-driven ERM. Both focus points are currently not part of the academic literature. The search results of two scientific search engines, the TU Delft library website and ScienceDirect, highlights this. Both search engines could not find a large amount of literature in the research area of ERM applications in critical infrastructure is, respectively 12 and 27 search results. None of which are related to the rail sector.

As mentioned above, risk management, and therefore ERM, needs to be adaptive and innovative to deal with changing threat environments (Miyamoto et al., 2017). The risks that organisations face are continuously evolving. Therefore, research into the newest developments of ERM is needed. The aforementioned data-driven work processes are an example of an adaptation into which more research is lacking. The innovation of ERM needs further researching because it currently does not suffice (da Silva Etges et al., 2018; Patra, 2017). The academic literature about ERM and working with a data-driven approach is not more extensive than ERM applications in critical infrastructures. The search results of the two scientific search engines of this research illustrate this again. The search results were 13 in the TU Delft search engine and 34 in the engine of ScienceDirect. The current body of knowledge requires more research into the use of ERM amongst sectors and organisations other than finance and accounting (Hameed et al., 2017). This research aims to explore the uncultivated research field of data-driven ERM combined with a focus on the rail sector.

A third shortcoming of the ERM body of knowledge is the dominant focus on risks. Risk management is not limited to safeguarding assets from damages. The ERM philosophy also promotes seizing opportunities by addressing risks in a comprehensive manner (Mishra et al., 2019). Taking responsible risks when there is room for some risk-taking is also part of risk management. Risk assessments can provide insights into areas where more risks can be taken, thereby creating business opportunities.

Within organisations, mindsets need to change to use risk management to increase performances by seizing opportunities instead of use risk management for solely risk avoidance (Boustras and Waring, 2020). This new mindset is important for the implementation of data-driven work processes. The data-driven approach to ERM can support the risk assessments but also introduces additional risks. An example of new risks due to data-driven work is the growing dependency on input data and data integrity (Kavoya, 2020; Kiron, 2016). The current body of knowledge lacks the in-depth analysis of seizing opportunities, such as the use of data-driven work. This research aims to provide the first steps in understanding the negative consequences and the benefits of data-driven work on ERM.

1.3. Relevancy

This master thesis research is both of societal and scientific relevance. The insights emanating from this research contribute to the knowledge gaps of data-driven ERM. Further, the exploration of the uncultivated research field of data-driven ERM in the rail sector leads to future research recommendations to broaden the academic body of knowledge. The policy recommendations at the end of this thesis focus on the societal contribution of this research. The policy recommendations aim to improve the risk management function of Dutch rail organisations. The following two subsections elaborate more on the two kinds of relevancy of this research.

1.3.1. Societal relevancy

Managing the risks of the rail sector is important from a societal point of view. Nowadays, societies have become hugely dependent on critical infrastructures (Svegrup et al., 2019), such as public transport, utility services, emergency services, and many more. The failure of these infrastructures results in "... a serious impact on health, safety, security or well-being of the society or effective functioning of governments and/or economies ... " (Bialas, 2016, p.240). In the case of the public transport and the rail sector, "... disruptions decrease the public transport accessibility of areas" (Yap et al., 2018, p.1161). People are restricted to go to work or school and dependent on cars if they have access to one. Public transportation fulfils a vital role in the day to day lives of people (Liu et al., 2020). Besides, the use of cars for daily commuting is worse than the use of public transportation. Public transport is more sustainable than automotive transportation (Busch-Geertsema et al., 2021; Liu et al., 2020) because it emits less air pollution and emissions (Borck, 2019; Frederick et al., 2018). Therefore, it is key to prevent disruptions of the Dutch rail sector. The rail sector is the largest transportation mode of Dutch public transportation. Managing the risks of the rail sector is vital to reduce disturbances. This research looks into policy recommendations for data-driven ERM to manage rail risks in the Netherlands. A proper risk management methodology will reduce disruptions and is, therefore, more sustainable and is better for the Dutch commuter population.

1.3.2. Scientific relevancy

There are three arguments for the scientific relevance of this research. First, this research is scientific relevant because it will contribute to an underdeveloped research field. As mentioned above, the current body of knowledge is lacking and is not sufficient. The exploration of this research discovers potential new starting points for future research. Furthermore, this research explores the use of data-driven ERM in the rail sector. Second, developments, such as data-driven work processes, change the risk management of organisations. The risk management dynamics change because the protection and integrity of data will be more important when strategic decision-making becomes data-driven. Enterprise risk management is a technique that explores these new developments by constantly reducing risks and searching for opportunities. However, there is a fine line between seizing opportunities and taking too much risk in ERM (Marshall et al., 2019). The current academic literature needs to address ERM and developments in the risk management function of organisations (Choi et al., 2016). Third, the current ERM body of knowledge focuses on a limited number of critical infrastructures, namely banking, insurance, and energy supply (Anton and Nucu, 2020). Research into other critical infrastructures is non-existing or underdeveloped. This is the reason why this research looks into the rail sector because the current body of knowledge of ERM does not yet cover it. The three limitations of the academic literature show the relevancy of this research by contributing to fill knowledge gaps.

1.4. Research question

The objective of this research is to contribute to the body of knowledge by gaining academic insights into the use of data-driven ERM in the Dutch rail sector. As mentioned before, the current body of knowledge is not extensive. The research field is novel and needs exploration to clarify knowledge gaps while providing insights in the Dutch rail sector regarding data-driven ERM. Combining both the research objective and the knowledge gaps result in the following research question:

What is the added value of data-driven work on the enterprise risk management of passenger transporting rail organisations in the Netherlands?

Multiple sub-questions are formulated to answer the main research question. The first two sub-questions focus on state-of-the-art knowledge and a brief review of the Dutch rail sector. The following three sub-questions focus on the use of data-driven work in the ERM of Dutch rail organisations. The last sub-question aims to answer why and how Dutch rail organisations should implement data-driven ERM.

1. What is the state-of-the-art knowledge in ERM and data-driven work?
2. How is the Dutch rail sector organised, and what are the risks rail organisations face in the Netherlands?
3. To what extent are Dutch railroad companies using data-driven work for their enterprise risks management?
4. What are the risks and opportunities of using data-driven work for the risk management of Dutch rail organisations?
5. To what extent do organisations differ in their adoption of data-driven enterprise risk management?
6. Why should Dutch rail organisations implement data-driven enterprise risk management?

1.5. Thesis structure

The remainder of the thesis is structured as follows. Chapter 2 presents a state-of-the-art review of ERM and data-driven. This review addresses both concepts but also their interaction. Chapter 3 explores the Dutch rail sector by addressing the history, regulations, stakeholders and risks that the sector faces. Chapter 4 discusses the research approach and the research methods. First, it is explained why the exploratory research design was chosen. Second, the use of desk research and semi-structured interviews are elaborated. Chapter 5 shows the research result from the desk research and the interviews in a systematic manner. The findings of the results are discussed and interpreted in chapter 6. This chapter also addresses the research limitations and the possibilities for future research. This thesis is wrapped up with the conclusion to the research questions and recommendations for the Dutch rail sector in Chapter 7.

2

State-of-the-art ERM and data-driven work

This chapter discusses the current knowledge of the two main concepts of this research, enterprise risk management (ERM) and data-driven work, to answer the first sub research question: 'What is the state-of-the-art knowledge in ERM and data-driven work?' Section 2.1 presents a framework to assess the start-of-the-art knowledge of both concepts. The framework consists of five questions that explore the latest body of knowledge regarding the two concepts. Section 2.2 looks into the state-of-the-art literature about ERM The section determines a working definition for this research. Additionally, section 2.2 discusses the three common ERM frameworks. Finally, the section explores the added value of ERM. Section 2.3 follows a similar structure as section 2.2 does. Firstly, section 2.3 establishes a working definition of data-driven work. After this, the section assesses the added value of data-driven work. Section 2.4 summarizes the chapter and aims to answer the first sub-question.

2.1. Framework for state-of-the-art concept analysis

The framework presented in this section safeguards the systematic structure of the literature analysis. The framework aims to analyse the literature of ERM and data-driven work in a structured way to conclude current state of the literature at the end of this chapter. Figure 2.1 shows the different steps of the state-of-the-art literature analysis. The first step of the analysis explains the two concepts. During this step, it is important to establish definitions of both concepts to use in this research. In addition, the first step discusses the purpose of both concepts. The second step of the framework reviews the added value of adopting these concepts. The review focuses on the advantages of concepts and use cases that adopted the concepts already. The last step of the framework is the conclusion of the current status of the academic literature. This review focuses on both the positive and negative implications of using data-driven ERM. To fully describe the current knowledge about the concepts, the framework uses a few questions to structure the answers to the three steps. These questions will give guidance to a systematic approach of reviewing the current status of ERM and data-driven work. The framework for the state-of-the-art concept analysis of this research addresses the following questions:

Step 1

1. What does the concept mean?
2. What is the definition of the concept?
3. Are there frameworks of the concept?

Step 2

4. What are the advantages of the concepts?

Step 3

5. Conclusion of the state-of-the-art review

These five questions are the backbone of the state-of-the-art literature review. The aim is to include as much recent published literature and insights as possible. The main criterion of the literature is that it needs to be of an academic origin because this review aims to assess the current academic body of knowledge. Figure 2.1 shows the structure of the framework, including the three steps and the nine questions. The framework displays two so-called 'swimming lines': ERM and data-driven work. The concept analysis discusses the two concepts separately for the first two steps.

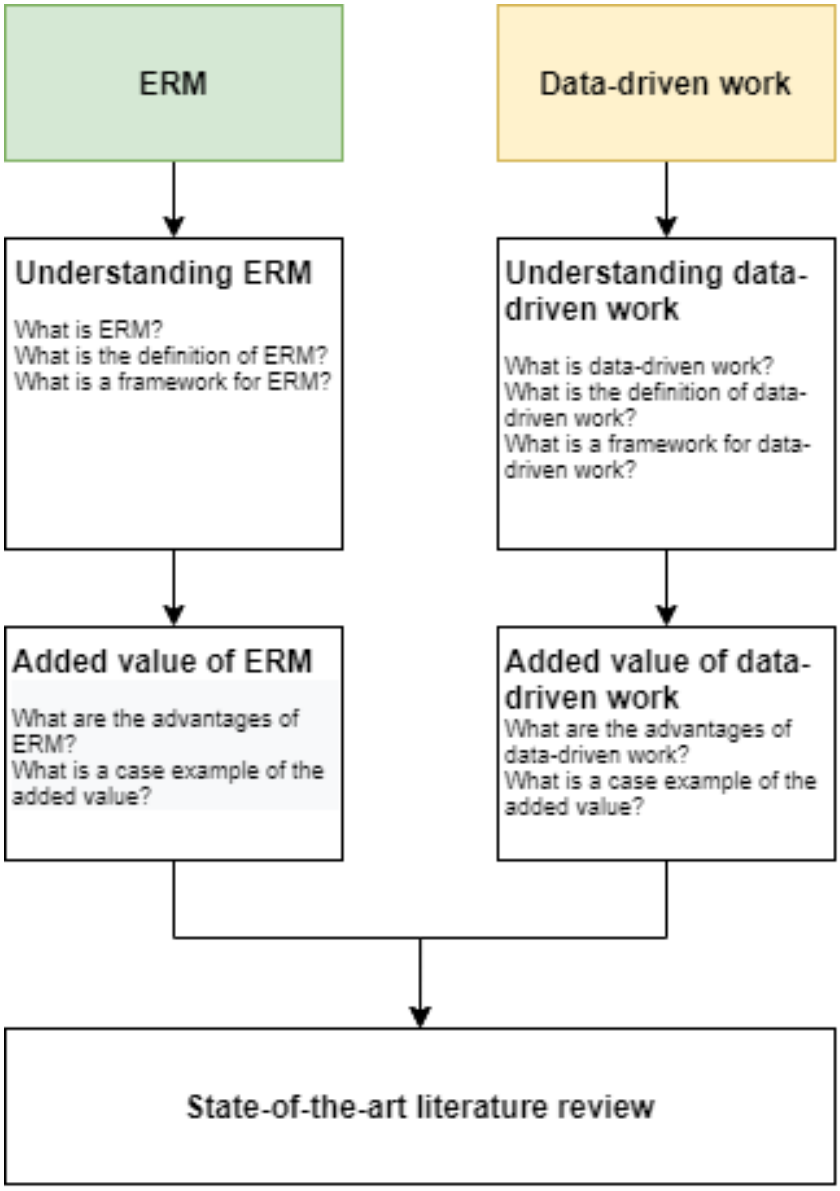


Figure 2.1: State-of-the-art concept assessment framework.

2.2. Enterprise risk management

This state-of-the-art analysis focuses partly on the ERM risk management method. The ERM method is a fairly new and unknown risk methodology. Consequently, the academic body of knowledge is not very extensive. The state-of-the-art review of ERM provides insights in the current status of the ERM literature. The state-of-the-art analysis of this research requires a clear understanding of ERM. Creating this understanding based on the latest academic knowledge is done in subsection 2.2.1. The state-of-the-art analysis continues by discussing the added value of ERM according to the newest insights gained from the literature

2.2.1. Understanding the ERM methodology

This subsection aims to make ERM more understandable. Three questions explore and explain the ERM concept. The three questions are; 1) What does ERM mean?, 2) What is the definition of ERM?, and 3) Are there ERM frameworks?

What is ERM?

ERM gained interest from the financial sector after multiple scandals in the U.S. at the start of the twenty-first century (Choi et al., 2016). ERM is a methodology to manage risks of an organisation. Some may call ERM a methodology, and others call it a philosophy, but the common denominator is that it facilitates a special way of looking at risk. ERM focuses primarily on the most important risks that an organisation faces, the so-called top risks (Hunziker, 2021). Managing all of the top risks of an organisation requires a holistic, integrated approach to addressing all the risks an organisation faces (Muhammed Altuntas and Hoyt, 2020). ERM identifies risks across the enterprise and compares the risks to prioritize them into top risks. The executive management levels (the C-suite) receive these top risks, after which they determine how it influences the organisation's strategy (Burta, 2017). ERM enables the active integration of the corporate governance structure into risk management (Burta, 2017). The C-suite is accountable for managing the risks that an organisation faces at the end of the day. Corporate accountability for risk management lies with (upper-) management and not the risk department of its specialist (Green, 2015).

For instance, Boeings ignoring the design flaws of the 737-max and the subsequent airplane crashes is a clear example of corporate accountability due to improper risk management. The 737-max was announced in 2010 and entered service in 2017. Boeing hired a new CEO Commercial Airplanes one year before the commissioning of the Boeing 737-max in 2017. This new CEO was not involved in most of the process to get the airplane into service. However, after the grounding of the 737-max in 2019, the CEO was held accountable, which led to his removal. It is challenging for managers to oversee all risks within the organisation (Green, 2015). A manager cannot know all the risks that his or her organisation faces. He or she depends on the specialized knowledge from each risk area to report the important risks. For example, it requires a different set of capabilities to understand cybersecurity risks and financial risks. Add to this the differences in assessing risks and risk terminology each risk area may use. It takes a lot from managers to let them prioritize uncomparable risks without specialized knowledge. ERM approaches all risks within an organisation in a systematic manner, resulting in comparable risks. The ERM function compares these risks and combines them in a unified top risk portfolio. These portfolios support the C-suits in their decision-making process (Kline and Hutchins, 2017). This process requires input and a focus on risk management from every part of the organisation. The so-called 'tone at the top' plays an important role in shifting the tone for the entire organisation and culture to risk-focused (Fraser and Simkins, 2010). It shows the commitment of management to a comprehensive risk approach (Hunziker, 2021).

What is the definition of ERM?

There is no clear, unambiguous and generally accepted definition of ERM in the academic literature (Lam, 2014). Although all definitions reflect the above mentioned holistic approach to risks, they differ in addressing the key elements of ERM (Marchetti, 2012). Hence, this research needs to establish a working definition of ERM that will be used from this point onwards in this research. Below are six slightly different definitions of ERM, each emphasizing different elements. The six definitions are the basis for the work definition of this research.

> **Definition 1**
> *"Under ERM, all risk areas would function as parts of an integrated, strategic, and enterprise-wide system. And while risk management is coordinated with senior-level oversight, employees at all levels of the organization using ERM are encouraged to view risk management as an integral and ongoing part of their jobs" (Fraser and Simkins, 2010, What is enterprise risk management section, para. 2).*

The core elements of the first definition are; 1) an integrated system for a strategy on enterprise-level, and 2) risk management culture throughout the organisation.

Definition 2
"ERM is an approach to aligning strategy, process, and knowledge in order to curtail surprises and losses as well as to capitalize on business opportunities" (Marchetti, 2012, ERM Introduction section, para.2).

The core elements of the second definition are; 1) a combined view of strategy, process, and knowledge, and 2) using risk management for both reducing risk and identifying opportunities.

Definition 3
"Enterprise risk management (ERM) provides integrated analyses, integrated strategies, and integrated reporting with respect to an organization's key risks, which address their interdependencies and aggregate exposures. In addition, an integrated ERM framework supports the alignment of oversight functions such as risk, audit, and compliance" (Lam, 2014, Integration adds value section, para. 4).

The core elements of the third definition are;1) an integrated process to identify top risks of an organization, and 2) ERM frameworks oversee risk-related functions.

Definition 4
"Enterprise risk management is a system in which managers are concerned with managing the risks of the entire enterprise" (Green, 2015, p.3).

The core element of the fourth definition is managing all the risks of the entire organization.

Definition 5
"ERM adds a holistic perspective to a firm's risk-management processes, whereby risk management becomes an integral part of a firm's governance and strategy" (Bogodistov and Wohlgemuth, 2016, p.234).

The core elements of the fifth definition are; 1) holistic approach of the risk management function, and 2) embedded part of the governance and strategy of an organization.

Definition 6
"Enterprise Risk Management (ERM) is an enterprise-wide process to identify, assess, and manage all key risks. The goal is to generate value for all stakeholders" (Hunziker, 2021, p.1).

The core elements of the sixth definition are; 1) managing the top risks of the entire organization, and 2) creating added value.

The six definitions show different perspectives on the use and functionality of ERM. The common denominator of the definitions is their enterprise-wide focus and the supporting role ERM has in the organizations' strategy. Two of the definitions also included the creation of value or finding opportunities due to ERM. This way, risk management does not only protect an organization but is also of added value for the growth of an organization. The work definition of this research combines these characteristics.

Work definition:

Enterprise risk management approaches risk management from a holistic perspective to support the strategy from an enterprise-wide basis, to manage risks and identify opportunities.

Are there ERM frameworks?
ERM describes a methodology for the risk management of an organization. Applying ERM as a methodology is difficult because it does not provide guidelines on implementing ERM within the risk management function of an organization. Therefore, several ERM frameworks ensure the applicability of the ERM in practice. The framework guidse how to organize the risk management function of an organization according to the ERM methodology. This thesis research focuses on the three most commonly used ERM models/frameworks: CAS 2003, and ISO 31000, COSO ERM (Perera, 2019; Zhao et al., 2015). The ISO 31000 and COSO ERM frameworks are the most well-known and applied ERM frameworks at the moment (Hunziker, 2021).

CAS 2003

The Casualty Actuarial Society (CAS) developed the CAS 2003 framework in 2003 (Sun et al., 2017). The CAS is a globally recognised organisation "… devoted exclusively to property/casualty actuarial science" (Boa and Gorvett, 2014, p.787). The CAS (2003) attributes the increasing popularity of ERM to its competitive advantages and corporate governance pressure. Seeing ERM as a part of the business that creates competitive advantages is significantly different from the cynical view that risk management only costs money and does not add value to the organisation. The renewed perspective of risk changes how organisations deal with risks. Previously, risk was seen as something to avoid or minimize; a so-called defensive stands towards risks. The CAS 2003 approach recognises the defensive stands of ERM but also sees the opportunistic side of ERM (CAS, 2003). The key of this approach is to operate between risk boundaries, when the defensive and opportunistic sides are combined. The objective of the framework is to maximize the value of an organisation (Perera, 2019).

The CAS 2003 framework defines ERM as: "... the discipline by which an organization in any industry assesses, controls, exploits, finances, and monitors risks from all sources for the purpose of increasing the organization's short- and long-term value to its stakeholders" (CAS, 2003, p.8). Special about the ERM definition of the CAS is that it points to the fact that ERM is applicable in every sector. This general applicability is in contrast to the reality where the financial sector applies ERM the most. Furthermore, the definition of the CAS 2003 framework partially matches the working definition of this research. Using risks from all sources suggests that ERM takes all the risks within an organisation into account, which corresponds with the holistic nature of ERM. Additionally, CAS 2003 focuses on creating value by reducing negative impacts and seizing opportunities. The only part that the CAS 2003 definition misses is the supporting role ERM has in the decision-making process of the C-suite.

The CAS 2003 ERM framework consists of two dimensions: a risk management process and a risk categorisation. The risk management process of CAS 2003 follows seven steps iteratively (Zhao et al., 2015): 1) establish context, 2) identify, 3) analyse/quantify risks, 4) integrate risks, 5) assess/prioritize risks, 6) treat/exploit risks, and 7) monitor & review. Figure 2.2 is a graphical representation of the CAS 2003 process. At first glance, this process looks like an ordinary risk management process. However, the CAS 2003 process is especially applicable to ERM. The ERM elements are: quantify, prioritise, and exploit risks. The quantification and the prioritisation of risks support the decision-making process because the quantification makes all the risks comparable to prioritise them into top risks for the C-suite.

Figure 2.2: Four ERM risk types (CAS, 2003, p.10).

The second dimension of the CAS 2003 ERM framework is the risk categorisation. The CAS 2003 framework distinguishes four types of risks an organization faces: hazard, financial, operational, and strategic risks (Razali and Tahir, 2011; Verbano and Venturini, 2011). The hazard category focuses on risks that are out of the control of the organisation, e.g. extreme weather events. The other three risks categories represent the risks that are controlled by organisations. All the risk factors that an organisation faces fall into one of four categories. The exact placement of risk is less important to a certain extent. The key is that the CAS 2003 ERM framework "… covers all categories and all material risk factors that influence the organization's value" Zhao et al., 2015, p.45). The category does not determine the priority of the risk or the managing process. Table 2.1 shows these four types with some example risks.

Table 2.1: Four ERM risk types (CAS, 2003, p.10)

Hazard	**Financial**	**Operational**	**Operational**
• Fire and other property damage • Windstorm and other natural perils • Theft and other crime, personal injury • Business interruption • Disease and disability • Liability claims	• Price • Liquidity • Credit • Inflation/purchasing power • Hedging/basis risk	• Business operations • Empowerment • Information technology • Information/ business reporting	• Reputational damage • Competition • Customers wants • Demographic and social/cultural trends • Technological innovation • Capital availability • Regulatory and political trends

The CAS 2003 framework combines the risk classifications and the ERM process into a matrix. The two-dimensional framework shows the iterative process of managing the four risk classes Zhao et al., 2015). Table 2.2 shows the representation of the CAS 2003 framework.

Table 2.2: CAS 2003 framework (CAS, 2003, p.9)

Risk management process steps	Types of risks			
	Hazard	Financial	Operational	Strategic
Establish context				
Identify risks				
Analyse/quantify risk				
Integrate risks				
Assess/Prioritize risks				
Treat/Exploit risks				
Monitor and review				

ISO 31000

The International Organization for Standardization (ISO) developed the ISO 31000 ERM framework in 2009 to guide organisations in implementing ERM. ISO is an organisation that seeks to standardise the risk management process worldwide and create a benchmark for all risk management practices (Almeida et al., 2019). ISO used the input of hundred risk professionals for 28 countries to construct the ISO 31000 ERM framework (Purdy, 2010). The text of the framework is quite abstract and is not a clear step by step guide to an ERM organisation (Leitch, 2010). The philosophy of the ISO 31000 ERM framework is to adopt the useful elements of the framework because each organisation has its context, which requires a different approach to risk management (Gjerdrum and Peter, 2011). The versatility of the framework allows it to be applied to appearing entities, e.g. "...public, private or community enterprise, association, group or individual" (Gjerdrum and Peter, 2011, p.9). The tailoring nature of ISO 31000 makes it applicable in almost all situations. However, there are differences in the degree of ERM maturity between organisations using ISO 31000.

The ISO 31000 ERM framework addresses risk as the "effect of uncertainty on objectives" (Purdy, 2010, p.822). The risk definition of ISO 31000 implies that risks have effects, the direction of the effect is not clarified. The effects of a risk on an organisations objective may be either positive or negative. The 2018 revision clarifies the ambiguity of the definition of risks. The new ISO 31000 ERM framework defines that "the purpose of risk management is the creation and protection of value" (ISO, 2018, Principles, para. 2). The clarification in the 2018 revision makes it clear that there are positive and negative effects of risk management. Obviously, ISO 31000 focuses on reducing negative effects and exploiting the positive effects. An additional requirement for risk management according to the

ISO 31000 framework is it needs to "... be an integral part of all business" (Farrell and Gallagher, 2015, p.652). This describes the holistic approach of the ERM methodology. The ISO 31000 ERM framework highlights two elements of the working definition of the ERM: the holistic perspective and the focus on risks and opportunities. The supporting role of ERM to the strategy is present in the framework but less emphasised than the other two core ERM elements.

The objective of the ISO 31000:2018 ERM framework is to guide organisations in their implementation of risk management across the organisation (ISO, 2018). Figure 2.3 shows the graphical representation of the framework. As mentioned before, the ISO frameworks do not present a checklist or roadmap to an ERM using organisations but tailormade implement only the relevant elements of the framework. The ISO 31000 ERM framework advocates for tailored made risk management based on the characteristics of the organisation (Purdy, 2010). The ISO framework distinguishes three elements: principles, framework, and process. The three elements have different degrees of abstraction. The framework part of ISO 31000 provides the design cycle for the implementation of ERM (Parviainen et al., 2021). The design process centres around leadership and commitment. Management needs to commit to ERM and create an ERM tone at the top. The abstraction level of the framework is high because this is a normal design cycle not specially developed for ERM. The process part of ISO 31000 provides a process to manage risks. The process is less abstract than the framework because it describes the step that needs to be taken to by a risk management function. However, the iterative process of ISO 31000 does not solely apply to ERM (Parviainen et al., 2021). The process is a standard risk management process. The process consists of the six steps: "1) defining the scope, context, criteria, 2) risk assessment (including risk identification, risk analysis, and risk evaluation), 3) risk treatment, 4) recording and reporting, 5) monitoring and review, and 6) communication and consultation" (Parviainen et al., 2021, pp.2-3). The abstraction level of the process element is less than the framework level because it focuses on risk management but not ERM. The third element of the ISO 31000 framework is principles. There are eight principles for a risk management process to become an enterprise risk management process (ISO, 2018; Parviainen et al., 2021). This is the only part of the framework that exclusively applies to ERM and not to an overarching concept.

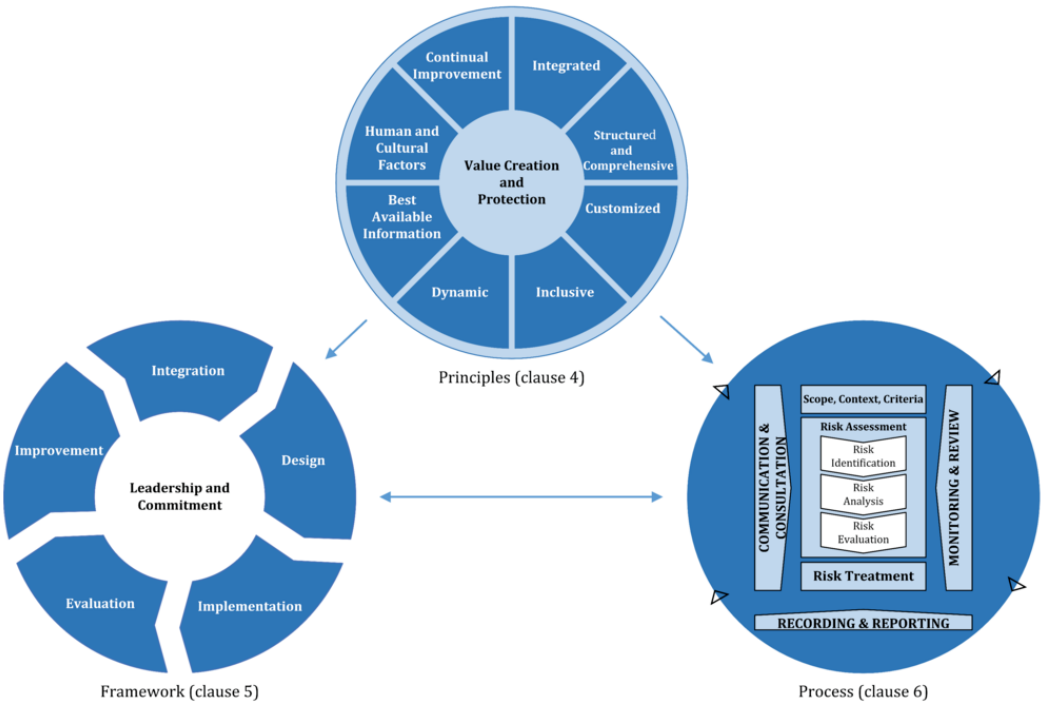


Figure 2.3: ISO 31000 ERM framework (ISO, 2018).

COSO ERM

The Committee of Sponsoring Organizations (COSO) developed the COSO ERM framework in 2004 and updated it in 2017 (Prewett and Terry, 2018). COSO originally focused on internal control

issues but also addresses risk problems nowadays. The key concept of the COSO ERM framework is risk appetite. COSO defines risk appetite as: “the types and amount of risk, on a broad level, an organization is willing to accept in pursuit of value” (Lanz, 2018, p.6). This notion of risk appetite relates directly to ERM because the C-suite makes decisions about how much risk can be taken to add value. The COSO framework sees ERM not as a checklist or a department of an organisation. ERM is “the culture, capabilities, and practices that organizations integrate with strategy-setting and apply when they carry out that strategy, with a purpose of managing risk in creating, preserving, and realizing value” (COSO, 2017, p.3). The COSO ERM framework focuses strongly on the integration of the holistic scope of ERM and the role of ERM to the strategy decision-making process of the C-suite. Meanwhile, COSO does also emphasise the creating value element of ERM by seizing opportunities. So, the definition of ERM of the COSO ERM framework corresponds with the working definition of this research. The COSO ERM framework uses three dimensions: process, components, and principles. The graphical representation of the COSO 2017 ERM framework is abstract and difficult to understand quickly (Prewett and Terry, 2018). Figure 2.4 shows the COSO 2017 ERM framework. The ribbon in the figure represents the five components at the bottom: 1) governance & culture, 2) strategy & objective-setting, 3) performance, 4) review & revision, and 5) information, communication & reporting (COSO, 2017). The intertwined ribbons aim to communicate that the components are embedded in every aspect of the ERM process: mission, vision & core values, strategy development, business objective formulation, implementation & performance, and enhanced value (Prewett and Terry, 2018). The process and components of COSO are generic; there is no direct link to the ERM definition of COSO or the working definition of this research. The applicability to ERM is in the underlying principles of the components. All five comments consist of multiple principles which focus on ERM, e.g. risk oversight by the C-suite risk appetite and risk prioritisation (COSO, 2017). Figure 2.5 shows the principle and their corresponding component. The principles are practices that are associated with ERM.

Figure 2.4: COSO ERM process and components (COSO, 2017,p.6).

Figure 2.5: COSO ERM principles (COSO, 2017, p.7).

Comparing the risk approaches of the frameworks The three ERM frameworks discussed above have a lot in common. However, there are essential differences between them. The three key differences between the frameworks are: the ERM emphasis of the frameworks, the implementation of the frameworks, and the risk approach. Fundamentally, the definitions of ERM emphasise different

elements across the frameworks. The working definition of ERM applied in this research combines components from all three frameworks. The level of use of the three frameworks also differs a lot. The most often used framework is the ERM COSO framework followed by ISO 31000. The CAS 2003 ERM framework is the least used of the three frameworks (Perera, 2019). The three differences between the frameworks are: the ERM emphasis of the frameworks, the implementation of the frameworks, and the risk approach

All three frameworks strive for the same goal: use ERM to determine the top risks from all the risks of the organisation to support the strategic decision-making process to add value. However, each framework emphasises other elements of that goal. The CAS ERM framework emphasises: adding value to the organisation and monitoring risks from all sources as key elements of ERM. The monitoring of risks from all sources relates to the holistic approach or ERM, considering all the risks of an organisation to formulate top risks. The notion of adding value relates to how risks are perceived with ERM. Reducing the impact or probability of risks does not directly create value; it reduces the negative effect of risks. Seizing the opportunities identified with ERM adds value to an organisation. The CAS ERM framework does not clearly emphasise the input ERM gives to the strategic decision-making process of organisations. The ISO 31000 ERM framework emphasises that organisations need to integrate ERM into the entire organisation, and it needs to protect and create value for an organisation. Like the CAS ERM, ISO 31000 emphasises the holistic nature and adding value function of ERM. ISO 31000 does not explicitly mention the use of ERM for the strategic decision-making process. However, the notion of integrating ERM in all the business areas also includes the decision-making process. The COSO ERM framework emphasises that organisations need to imbed ERM in their business processes and culture to support their strategies to create and preserve value. Hence, the COSO ERM framework emphasises the three key elements of ERM, according to the working definition of this research. Namely, a holistic embedded approach that supports the strategy to create value. The difference between the frameworks is that COSO includes all the aspects of ERM, while CAS and ISO lack the focus of the strategy supporting role of ERM.

The applicability of the three frameworks differs from each other. For example, all three frameworks generically discuss risk management processes. They describe which elements a risk management process needs to contain, but they are not step-by-step descriptions of how to design it. The differences lie in the additional elements of the frameworks. The CAS ERM framework discusses risk types to structure the risk collection of ERM and to identify top risks. In addition, it gives insights into risk opportunities. The ISO 31000 ERM framework presents a design cycle to implement an ERM process in an organisation. Moreover, ISO discusses eight principles that help to create and protect value. The latter comes close to a step-by-step checklist because the eight principles are the best practices for ERM (Parviainen et al., 2021). The idea of ISO is that no ERM is the same and that an organisation needs to adopt the elements that apply its context, a tailor made ERM. The idea of only applying what is necessary reoccurs in the COSO ERM framework. COSO describes the process ERM should follow and the components ERM should contain. The principles corresponding to the components are less strict. They represent ERM practises that differ per organisation (COSO, 2017). Overall, there are a lot of similarities between the frameworks. They provide process designs and practices to implement ERM. However, the above-mentioned framework-specific determine which frameworks suit which context.

Lastly, the three cases differ in how they perceive risk. Both the COSO and ISO frameworks define risks. In contrast, the CAS ERM framework does not define risk. This makes that framework less clear than the other two. The definitions of the COSO and ISO framework differ from each other. COSO defines risk as "... a consideration in many strategy-setting processes" (COSO, 2017, p.4). This definition implies that risks are a result of a decision-making process answering the question of whether or not something is a risk to the organisation. ISO defines risk as the "effect of uncertainty on objectives" (ISO, 2018, n.d., Risk, para. 1). This definition implies that reducing uncertainties will solve the risks, which is an abstract perspective on risk management. The two risk definitions show that ISO and COSO address risk differently. COSO deems something a risk when it is considered a risk. This definition is vulnerable to black swan and gray rhino events. ISO sees risks as the result of uncertainty which closes the door for risk concepts such as risk resilience. The uncertainty remains, but the effect of the uncertainty is reduced.

2.2.2. What is the added value of ERM?

This subsection reviews the added value of ERM. In order to do that, this subsection first compares ERM to the alternative: traditional RM. After that, the advantages and disadvantages of ERM are discussed.

ERM vs traditional risk management

To identify the benefits of ERM a situation without ERM needs to be established. Traditional risk management (TRM) is such a situation. TRM models approach risk management in a siloed manner. It focuses on managing risks from a specialistic point of view within a business process or business unit (Green, 2015). This creates a decentralised risk management structure. The business silo manages and assesses their own risks separately from each other (Green, 2015). The business silos report the risk assessment to the C-suite of the organisation. TRM does not safeguard a uniform presentation of the risk assessment to the C-suite. The diversity of the different risk assessments makes it difficult for the C-suite to prioritise the risk to indicate top risks to the organisation. The deviation between risk assessment can occur on the level of detail and risk assessment methodologies. ERM ensures that the different risks of each silo come together in one compressive risk management approach. This coordinated approach makes it easier to communicate the entire risk management of all the business silos to the executive level of an organisation (Green, 2015). Figure 2.6 represents both TRM and ERM.

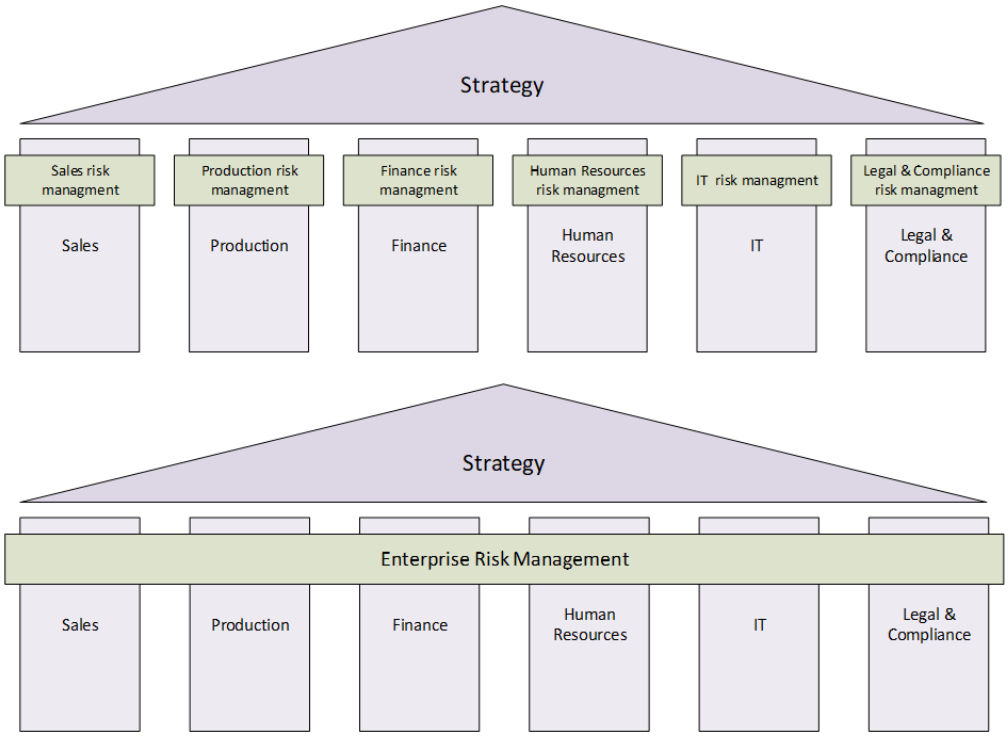


Figure 2.6: Traditional risk management structure and the enterprise risk management structure.

ERM has several advantages over TRM. The overarching advantage of ERM is that it enhances the profitability of an organisation (Lai and Shad, 2017). The profitability of an organisation increases because ERM embeds risk assessments in the management structure, giving management better insights into the risks and opportunities the organisation faces (Hanggraeni et al., 2019). ERM influences the profitability of an organisation due to several advantages. First, the integration of risk management into the decision-making process of the C-suite reduces costs due to better insights (Hanggraeni et al., 2019). These insights improve the competitiveness of the organisation, less value reducing endeavours and more value-creating business opportunities (Hanggraeni et al., 2019; Kulathunga et al., 2020; Saeidi et al., 2019). Consequently, implementing ERM reduces cost and increases revenues which leads to an increased cash flow (Callahan and Soileau, 2017). Second, ERM increases profitability

due to the improvement of risk awareness within the organisation (Kulathunga et al., 2020; Lai and Shad, 2017; Lam, 2014). The holistic risk approach requires everybody's involvement from the operation to the C-suite. Third, ERM standardises risk reporting to compare the different risks (Arena et al., 2017; Paape and Speklé, 2012). Prioritising these risks lead to a list of top risks for the organisation. The C-suite can adapt its strategy based on these top risks provided by ERM. The three advantages contribute to increasing the profitability of an organisation that implements the ERM methodology.

ERM also has several disadvantages compared to TRM. First of all, a disadvantage of ERM is its dependency on the willingness to change because "ERM is a change management initiative" (Fraser and Simkins, 2010, p.691). ERM stands or falls with its acceptance within the organisation. The tone at the top is crucial to gain support within the organisation. However, some corporate cultures are not open to ERM, and therefore ERM will not work in these organisations. Second, the most commonly used frameworks are difficult to implement. They provide little to no support for the implementation of ERM within an organisation (Hanggraeni et al., 2019). The processes and key points of the framework are very generic. Hence, implementing ERM straight from the frameworks is difficult due to the abstract descriptions. The ERM methodology is easy to understand but living up to it is difficult. Third, it is challenging to maintain the ERM focus of everyone associated with the ERM process (Ketcham and Louisot, 2014). The entire organisation must remain focused on ERM because ERM is embedded in all facets of the organisation. If the attention is lost, then the effectiveness of ERM shall decline. Fourth, the comprehensive risk inventory is a challenge for ERM. It is important to include all the risks without overloading risk management systems. It is a fine line between being comprehensive and being excessive. "Identifying too many risks" is a challenge for the implementation of ERM (Fraser and Simkins, 2010, p.691). The four disadvantages of ERM are challenges regarding the design and implementation of ERM. It is necessary to think in advance about how the implementation of ERM in an organisation.

2.3. Data-driven work

2.3.1. Understanding data-driven work

This subsection aims to make data-driven work more understandable. Three questions explore and explain the data-driven work concept. The three questions are; 1) What does data-driven work mean?, 2) What is the definition of data-driven work?, and 3) Are there data-driven work frameworks?

What is data-driven work?

The concept of data-driven work is difficult to grasp. Academic literature uses quite often the term data-driven work without providing an explanation or definition of the concept. It often also happens that this term is only used in the title of an academic article as a buzzword without using it in the article. The explanation for the lack of an unambiguous and generally accepted definition or description of data-driven work is probably that the concept speaks for itself. However, this review needs an explanation and definition to assess the state-of-the-art insights into the data-driven work. Without a working definition, it is difficult to review and compare the latest knowledge. Therefore, this review also includes the related concept of data-driven, data-driven approach, and data-driven organisation to broaden the scope of the literature review.

The term data-driven is embedded in the academic literature, and it seems that it no longer needs to be defined. However, when an article presents a definition of data-driven work, it shows how straightforward the concept is. For example, a definition of data-driven is: "the process of using the input-output data to denote the actual output" (Jianwang et al., 2021, p.395). This definition shows a process that transforms data (input or output) into other usable data. In addition, implementing data-driven processes in organisations is not a novel idea. Data has played a key part in decision-making processes for multiple organisations in the last century. The movie, Moneyball, is a great example of the use of data in the decision-making process of an organisation. The movie portrays the Oakland Athletics baseball franchise, which based the scouting process 2002 purely on player statistics. At the end of the season, the Athletics made the postseason playoff, which was unimaginable with their lack of all-star players. However, the data analysis of the player statistics created an outstanding team. This true story shows how data can help an organisation in its decision-making process. The example is slightly exaggerated because success does not only rely on data, especially in sports. Another example of the historical use of data-driven work is the former Defense secretary of the United States of America,

Robert Strange McNamara. During his military career in World War II and later in his political career, he used six strategy drivers. One of them is facts, “McNamara insisted that all available facts, particularly numerical data, were assembled before a decision was taken” (Grattan, 2006, p.430). Data and facts are the foundation of decision-making, according to McNamara. These two examples show that using data in the decision-making process is not something new or revolutionary and is not specific to only one sector, as sports and the military are different industries (entertainment vs war).

The question arises, why is data-driven work such a hot topic in recent years? The use of data during the decision-making process is not new. The renewed interest in data-driven work lies in the availability of data. In recent years the availability of data is increased vast (SONEHARA et al., 2019). In the past, decisions were supported by incomplete information and the intuition of the decision-maker (SONEHARA et al., 2019). The technological developments of recent years make it possible to collect more data that can support the decision-making process. The renewed interest in data-driven working gains momentum due to the enormous amounts of data that have become available. More available data means that more decisions can be supported by facts and data, according to the strategy drivers of McNamara

What is the definition of data-driven work?
As mentioned in 2.3.1, the academic literature barely discusses a definition or a description of data-driven work or data-driven in a more general sense. However, this research needs to establish a working definition of data-driven work that will be used from this point onwards in this research. The four definitions presented below relate all to data-driven work. A data-driven organisation uses data-driven work, and data-driven work finds its origin in the data-driven methodology.

Definition 1
“The data-driven methodology extracts useful and relevant information by interpreting data structures and its statistical features” (Lakhal et al., 2019, p.239). In addition, “the data-driven methodology is useless when it is applied based on highly uncertain data” (Lakhal et al., 2019, p.239).

The core elements of the first definition are: 1) the interpretation of data creates useful and relevant information, and 2) the input data needs to be reliable.

Definition 2
“... data-driven organization acquires, processes, and leverages data in a timely fashion to create efficiencies, iterate on and develop new products, and navigate the competitive landscape” (Patil and Mason, 2015, What Is a Data-Driven Organization?, para. 4).

The core elements of the second definition are: 1) transforming data into useful new products, and 2) the output of data-driven work helps to understand the competitive landscape.

Definition 3
“... being a data-driven organization is a continual and iterative process as opposed to a defined project” (Vallejo et al., 2012b, p.15).

The core element of the third definition is the iterative nature of data-driven work.

Definition 4
A data-driven organization has a “… data-driven culture in which data collection, data quality, and analytics are used to make decisions to gain competitive advantages (Svensson and Taghavianfar, 2020, p.4).

The core elements of the fourth definition are: 1) data-driven culture uses data to support decision-making, and 2) data-driven work creates competitive advantages.

The four definitions show different perspectives on the use and functionality of data-driven work. The common denominator of the definitions is processing data into useful information. In addition, data-driven work creates competitive advantages. Hence, it supports management in their decision-making process. The work definition of this research combines these characteristics.

Work definition:

Data-driven work is an iterative process where reliable data is processed into useful and relevant information to support decision-making.

Are there data-driven work frameworks?

Contrary to ERM, data-driven work does not have a framework. There are no frameworks on how to implement data-driven work in an organisation. However, there is a framework to assess the implementation of data-driven work within an organisation: the data-driven maturity model. There are several variations of the maturity model. This review discusses two completely different variances. The first maturity model consists of five stages: 1) ad hoc, 2) defined, 3) integrated, 4) optimised, and 5) advanced. The organisations within the ad hoc stage use the bare minimum amount of data (Cech et al., 2018). The organisations within the defined stage structure their data. In addition, management is aware of the strengths and vulnerabilities of the data (Cech et al., 2018). The third stage, integrated, is for organisations that embed data with tools into their processes for analysis. This is the starting point of a " culture of evidence-based decision making ..." (Cech et al., 2018, p.144). Organisations within the fourth stage, optimised, optimise their data with data analytic skills within the organisation. These organisations use data to predict and diagnose business developments (Cech et al., 2018). The last stage, advanced, mainly consists of university-related organisations' data used to do experiments (Cech et al., 2018). Other experimental setups are replaced by data in this stage. The fives stage maturity model looks at how organisations use their data to classify them.

The second data-driven maturity model consists of four stages: 1) data-agnostic, 2) data-sensitive, 3) data-oriented, and 4) data-driven (Drapp and Prabhala, 2021). Data-agnostic organisations have a limited basic understanding of their data and the possibilities (Drapp and Prabhala, 2021). Data-sensitive organisations use some data. However, their knowledge about the use of data is limited, causing mistakes in the data analysis (Drapp and Prabhala, 2021). Data-oriented organisations rely on data to improve their business processes and performances. However, data does not support the strategic decision-making process (Drapp and Prabhala, 2021). Data-driven organisations use data in all their business processes (Drapp and Prabhala, 2021). Data is the most important asset for a data-driven organisation. Both models address the data-driven maturity of organisations differently. The five-stage model looks at the embeddedness of data-driven work into an organisation. Meanwhile, the four-stage model looks at the capabilities that the organisation poses to work with data.

2.3.2. What is the added value of data-driven work?

The previous section 2.3.1 compares ERM with TRM. Such a comparison is not possible with data-driven work because every organisation uses data in some way or another. Therefore, this subsection discusses the added value of data-driven work by addressing the advantages and disadvantages.

Advantages of data-driven work

The challenges of data-driven work are about the effect it has on decision-making. Firstly, the decision-making process needs a culture change to be able to implement data-driven work (Svensson and Taghavianfar, 2020). Data is going to support the decision-making process, changing the input from subjective to objective. The intuition of the decision-makers becomes less important. This immediately creates the second challenge, trust in the data. Decision-makers need to trust the data before they leave the intuition behind. The integrity of the data is key for this challenge because the data can be altered (Svensson and Taghavianfar, 2020). Thirdly, the lack of skilled employees poses a challenge to data-driven work. Using and interpreting data requires knowledge about data analytics: a specialised skill (Svensson and Taghavianfar, 2020). The fourth challenge is the presentation of the output of data-driven work (Svensson and Taghavianfar, 2020). How can data be understandably visualised to support decision-makers? This question is important when the decision-making process uses data-driven work. All four challenges are not disadvantages of data-driven work but things that need to be considered when implementing data-driven work.

The advantage of data-driven work is that it adds value to the organisation. Data-driven work provides competitive advantages because business decisions are made with real-time information (Phillips-Wren and Hoskisson, 2015). Data-driven work improves the quality of decision-making (Svensson and Taghavianfar, 2020). The use of objective data improves decisions by supporting the decision-making process with more informed, accurate, specific, reliable and faster information (Svensson and

Taghavianfar, 2020). Hence, data-driven work improves decisions in several ways. Better decisions lead to increasing opportunities and possibilities. The third advantage of data-driven work is the predictive abilities that it creates (Buschmann et al., 2021). Data-driven work uses historical data to predict future developments, e.g. developing innovative products and services or changing competitive environments (Svensson and Taghavianfar, 2020). The advantages are less obvious than the challenges because all the advantages lead to improving business performance. Since, business performance is already the main goal for most organisations, the contribution of data-driven work is obscured.

2.4. Chapter summary

The state-of-the-art literature review shows some difficulties with ERM and data-driven work. ERM is a novel research area. The main focus lies on the financial sector for its case study research. However, the literature in this area is quite extensive. The review defines ERM as a risk management methodology that looks at risk management from a holistic point of view. In addition, ERM supports the strategic decision-making process to create added value by reducing the impacts of risks and seizing opportunities. ERM has some advantages over traditional risk management. Profitability is the main advantage of ERM. The standardisation and increasing risk awareness of ERM creates a risk culture that is focused on reducing risks and seizing opportunities. Moreover, ERM support decision-makers in their decision-making process by providing them with the top risks of the organisation. However, ERM has its disadvantages. For example, it requires the commitment of the entire organisation to function properly. ERM depends on the involvement of all the aspects of the organisation. In addition, the common ERM frameworks are difficult to implement because they are quite abstract. The commonly used ERM framework are CAS 2003, ISO 31000, and COSO ERM.

A similar assessment of data-driven work is done in this chapter. The current body of knowledge does not contain sufficient literature covering data-driven work. However, the literature about data-driven organisations comes close and has some overlap with data-driven work. This research defines data-driven work as an iterative process that transforms data into useful and relevant information. It is impossible to compare data-driven work with a situation that does not use data. For decades, data plays a role in the decision-making process of an organisation. Therefore, the added value of data-driven work shows its importance. The main advantage of data-driven work is that it creates value for the organisation by improving the performance of the organisation. Real-time monitoring of risks enables a quick response to incidents. Moreover, the predictive capabilities of data-driven work improve the competitive position and make it easier to find business opportunities. There is not a commonly accepted framework that helps to implement data-driven work. The data-driven maturity model gives insights into what an organisation has implemented and what it can do more to increase the use of data-driven work. There is a significant mismatch between the state-of-the-art literature and the concepts of this research. The literature does not cover the concept completely. Therefore, an abstract literature search is performed to review the broader context of ERM and data-driven work.

3

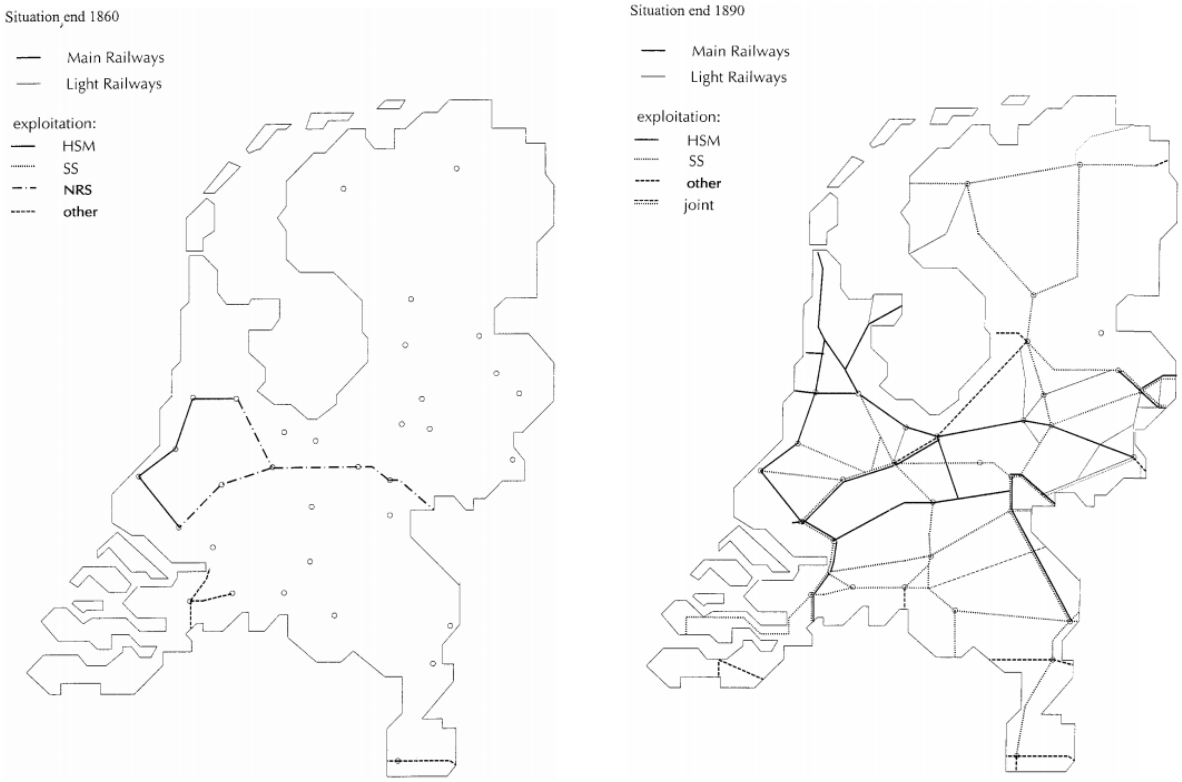
The Dutch rail sector

This chapter provides a detailed overview of the Dutch rail sector to answer the second sub research question: 'How is the Dutch rail sector organised, and what are the risks rail organisations face in the Netherlands?' Section 3.1 gives an overview of the development of the Dutch rail sector over the past centuries. This overview discusses the historical evolution of the Dutch rail sector and the run-up to the current structure of the Dutch rail sector. Section 3.2 explains how rail companies can get access to the Dutch rail network. Tendering and granting concession rights is used for the transport of passengers. Section 3.3 provides an overview of the stakeholders of the Dutch rail sector. The stakeholders range from rail transport organisations to Dutch ministries, who own shares in multiple Dutch rail organisations. Section 3.4 analyses the risks that passenger-carrying rail operators face. This analysis uses the different risks mentioned in financial statements and annual reports of multiple passenger-carrying rail operators. Section 3.5 summarises the chapter and aims to answer the third sub-question.

3.1. Historical background of the Dutch rail sector

The first rail activity in the Netherlands was the train ride between Amsterdam and Haarlem (Fremdling, 2000). The two steam locomotives (the Arend and de the Snelheid) made their maiden voyage on September 2, 1839. Hollandsche IJzeren Spoorweg Maatschappij (HSM) operated the rail transport on the first route of the Netherlands, thereby becoming the first Dutch rail company (De Pater, 2019). The HSM was a privately owned business until a merger a hundred years later. The second rail company in the Netherlands was the Nederlandsche Rijnspoorweg Maatschappij (NRS), founded with the support of the then Dutch king (Veenendaal, 1995). The reason for the creation of NRS was to realise the construction of a railway connection to Prussia (nowadays Germany). In 1860 the first outlines of the Dutch rail network became visible with the routes of the NRS and the HSM. Figure 3.1 shows the railway track in the Netherlands in 1860. The first step of the construction of the Dutch rail infrastructure was to connect several cities in the western part of the country. The rail infrastructure connected the larger cities, them being Amsterdam, Haarlem, Leiden, Den Haag, Rotterdam and Utrecht (De Pater, 2019).

The western focus of the rail infrastructure changed when the Dutch government decided to connect the Dutch rail infrastructure with neighbouring countries (Fremdling, 2000). In addition, the rail network had to connect the entire country, not just the major cities in the west of the Netherlands (De Pater, 2019). Hence, the Dutch rail infrastructure became a national interest. From this point onwards, the Dutch government became responsible for constructing rail infrastructure in the Netherlands (Fremdling, 2000). The Dutch State assigned the Maatschappij tot Exploratie van Staatspoorwegen (SS), a privately owned company, to exploit these new routes (Fremdling, 2000). The changes in the rail infrastructure were visible at the end of 1890. Figure 3.1 illustrates the different railways in the Netherlands at the end of 1890. Figure 3.1 shows two changes in the rail sector. First of all, the dominant player has become the SS. In 1890 most of the railway connections in the Netherlands were exploited by the SS and HSM. Secondly, the focus does not lie anymore on the major cities in the western part of the Netherlands but the entire county. Secluded towns in sparsely populated areas also became accessible by train. Besides, more routes were cross-border compared to 1860.



(a) rail infrastructure in 1860 (Fremdling, 2000, p.532) (b) rail infrastructure in 1890 (Fremdling, 2000, p.532

Figure 3.1: Expansion of the Dutch rail infrastructure between 1860 and 1890.

In 1917 HMS and the SS, the dominant players in the Dutch rail sector, founded the Nederlandse Spoorwegen (NS). The NS started as an interest group for the rail sector. On January 1, 1938, the HSM and the SS merged into the N.V. Nederlandsche Spoorwegen, which still exists nowadays (Veenendaal, 1995). The Dutch government bought all private owned shares during this merger. Besides the exploration rights of both companies, the NS also gained the rail infrastructure managing function. Hence, the NS became a state-owned monopolist in the Dutch rail sector (Veenendaal, 1995). The NS was for many years the sole operator and maintainer of the Dutch rail network. In the 1990s, the Dutch government decided to privatise the relation with the NS and the rail sector. The privatisation enabled the separation of the passenger operator part and the infrastructure operator part of the NS (Veenendaal, 1995). The maintenance part later became ProRail in 2005, which is still owned by and under the supervision of the Dutch state. ProRail maintains and build the rail infrastructure in the Netherlands but is also responsible for the traffic control on the rail network (Steenhuisen and van Eeten, 2008). The sole shareholder of the remaining operating part of the NS is currently still the Dutch ministry of Finance (Steenhuisen and van Eeten, 2008). After the privatisation of the NS, other companies could also access the Dutch rail market. Concession tenders regulate who is allowed access to the passenger rail infrastructure and where. Section 3.3 elaborates more on the concession system. Once in a predetermined period operator can bid on the rights to operate on the Dutch rail network. This created space for smaller and local/regional operators, which resulted in more active operators.

3.2. The rail sector as a critical infrastructure

In chapter 1, the rail sector has already been labelled as a critical infrastructure while discussing the societal relevancy of this research. This section takes a closer look at the critical status of the Dutch rail sector. Societies can no longer function properly without the services that critical infrastructures provide (Sonesson et al., 2021). They depend on these services, for example, electricity, water supply and public transport. The railway sector fulfils the vital task of transporting goods and people over long distances. Managing risk is, therefore, an important task within this critical sector. However, critical infrastructures are not stand-alone ecosystems; they interact with and depend on other infrastructures.

Critical infrastructures connect to a high degree among each other (Rinaldi et al., 2001). Disruptions or failure of one infrastructure can cause a cascading effect on other critical infrastructures. For example, the electricity grid: an electric blackout influences the rail sector because electricity powers trains, signals, and crossings. The interconnectedness makes the complexity of protecting critical infrastructures difficult. Rail organisations cannot control all the risks they face, e.g. the electricity example.

The rail sector fulfils an essential function within societies (Cedergren et al., 2019), and therefore it is a critical infrastructure. Traffic jams would increase without the daily passenger commute by rail (Wilson and Norris, 2006). In 2016, the train was the second largest mode of transport for commuters, with a share of 10,6% for distances beyond fifteen kilometres in the Netherlands (CBS, 2018). In addition, the rail sector makes it possible to transport passengers and cargo over a long distance in large quantities (Wilson and Norris, 2006). The Dutch rail sector transported 38 million tonnes of goods in 2019 (CBS, n.d.-a). Seaports, like the port of Rotterdam, are vital for supply chains to the hinterland of Europe (Loh et al., 2017). Rotterdam is one of the few seaports that connects the European hinterland with the rest of the world regarding freight transport. There are three alternatives to transport further into Europe: road, rail, and inland waterway (Behdani et al., 2020; Hu et al., 2019; van Ierland et al., 2000). Most of the freight transport currently takes place by road (Hu et al., 2019). In light of the European climate goals and the Green Deal, the preferred modes of transport are inland waterways as they are environmental friendlier (de Miranda Pinto et al., 2019; Wolf et al., 2021). Therefore, the demand for these freight transport modes increases. Disruptions in these supply lines can have serious consequences for production in the hinterland (Loh et al., 2017; Woodburn, 2019). Although not a rail-related example but the blocking of the Suez Canal in 2020 by the containership the Ever Given showed the global impact of disrupted supply chains. Disruptions of the Dutch rail sector will also impact economies in the hinterlands of Europe, although on a smaller scale than the Ever Given incident. Although freight transportation is outside of the scope of this research, this paragraph shows how important the Dutch freight transporting rail sector is for the Netherlands and Europe. Passenger transport in the rail sector is mainly important for the Dutch context. In 2019, before the COVID-19 pandemic hit the rail sector, the number of passenger-kilometres was 210.9 billion in the Netherlands (CBS, 2020). The same year the NS transported an average of more than 1.3 million passengers a day (NS, 2019b). Both numbers show the importance of the passenger transporting part of the Dutch rail sector. Altogether, the Dutch rail sector is a critical infrastructure for the Netherlands, but also for Europe.

The Netherlands uses a ranking of critical infrastructures to indicate their importance. The Dutch government has divided the critical infrastructures into two categories: A and B. The impact of disruptions or outages on Dutch society determines the classification. Four impact criteria decide the category of the infrastructure: economic, physical, social, and cascading impact (NCTV, n.d.). Table 3.1 shows the thresholds for each criterion per category. Infrastructure is critical when it meets one of the criteria. The Dutch government has categorised the rail sector, both passenger and goods, as a B type critical infrastructure (NCTV, n.d.). In addition, the Dutch intelligence agency, Algemene Inlichtingen- en Veilighiedsdienst (AIVD), has designated public transport as a vital sector. The widespread use, with millions of passengers, and the easy accessibility makes the public transport sector vulnerable to attacks (AIVD, n.d.). The nature of transport infrastructures, "… being geographically extended, interconnected, mainly in the open…" (Khoudour et al., 2011, p.384), makes it tough to protect it against risks. Therefore, proper risk management is needed to reduce the vulnerability of the sector. Besides, the insights gained from risk management can help prepare for disturbances and increase resilience to risks (Salem et al., 2020). Resilience to disruptions is important for the rail sector to prevent a complete standstill of rail transport (Setola et al., 2015). This way, the rail sector adapts to incidents without a major impact on society

Table 3.1: criteria for critical infrastructure categorization (NCTV, n.d.).

Impact	Category A	Category B
Economic	Damages bigger than 50 billion euros or a 5.0% decline in real income	Damages bigger than 5 billion euros or a 1.0% decline in real income
Physical	More than 10.000 deaths, injured or chronically ill	More than 1.000 deaths, injured or chronically ill
Social	More than 1.000.000 people experience emotional or severe social survival problems	More than 100.000 people experience emotional or severe social survival
Cascading	Failure leads to failures of at least two other sectors	Not applicable

3.3. Access regulation to the Dutch rail infrastructure

In the Netherlands, getting access to the rail infrastructure differs between passenger-carried rail companies and freight transporters. Different rules apply for access to the rail infrastructure for both categories. A concession system arranges the access rights for passenger transport in the Netherlands. Accessing the Dutch railroads as freight transporters requires; access agreements, safety certificates, and business licenses. Freight transporters can use the rail infrastructure in consultation with the planner at ProRail's traffic control if they comply with the regulations (ProRail, n.d.-b). There are no additional rules or regulations for the transportation of hazardous substances besides stricter safety requirements. The transport of dangerous goods need to comply with the set regulations, and rail traffic control must monitor the entire transport (location, speed, etc.) (ProRail, 2019). The use of concessions in the Dutch rail sector is already briefly mentioned in the previous sections. The following paragraph discusses the Dutch concession system in-depth. An in-depth review is needed because this research focuses on the passenger transport part of the Dutch rail sector and the concession system determines which stakeholders are active within the sector for a long period of time.

A concession is defined as "… an agreement between a government and a private company (the "concessionaire"), in which the government transfers to the company the right to maintain, produce, or provide a good or service within the country for a limited period, but the government retains ultimate ownership of the right" (Miranda, 2007, p.512). The fourth railway package of the European Commission (EC), issued in December 2016, defines the rules of tendering concessions within the European Union. The legislation aims to liberalise the European rail market further (ACM, 2019b). New concession rights need to be tendered and not be given to rail companies privately. The private awarding of concession rights to a rail company is only possible in special cases and under certain circumstances (EC, 2016). The NS is such an edge case regarding their concession rights. However, detailed analysis of these edge case situations falls outside the scope of this research. From 2021 onwards, the legislation also makes it possible to use the rail infrastructure without the access rights of concessions (EC, 2016). There are two types of rail concessions in the Netherlands:

- The HRN (in Dutch: hoofdrailnet) concession includes the mail rail network of the Dutch railways. The HRN routes facilitate intercity trains. However, slow trains (in Dutch; the sprinter) also use the HRN rail tracks but are not limited to them. The HRN also includes the high-speed rail track, the HSL-Zuid. The NS currently holds this concession, which runs from 2015 to 2025. The Dutch government did not allocate the HRN concession by an open and public tender. They decided to give it privately to the NS without a concession tender because they deem the HRN an edge case (ACM, 2019a). Due to the concession, NS has the largest market share within the Dutch rail sector regarding passenger transport. In 2017 the market share of the NS was 85% (ACM, 2019b). The other 15% of the passenger rail market is allocated based on the second type of concessions. The Ministry of Infrastructure and Water Management grants the concession rights of the HRN for periods of ten years (ACM, 2019b).

- The second type of concessions focuses on regional routes. Dutch provinces issue tenders to award these concessions rights. The regional tenders are open and public, according to the European regulations (EC, 2016). There are multiple of these regional concessions in the Netherlands. Most of these routes are in the east of the country. The duration of regional concession contracts

differs between eight and twenty-five years (ProRail, 2020). Some concession rights are owned by a partnership between Dutch and German local governments because it concerns routes that cross the border.

There are in total 19 rail concessions in the Netherlands, without considering the HSL-Zuid track. One of these concessions is the HRN concession. The other 18 concessions are regional rail routes. Arriva B.V. has the most concession rights, with eight concessions in five provinces (ProRail, 2020). In total, eight different rail companies own concessions right in the Dutch rail sector. Seven of them are regional operators, and NS provides nationwide passenger transport. The next section discusses the stakeholder with the rail sector in more detail.

3.4. Stakeholders

The Dutch rail sector consists of a lot of companies and organisations. This research distinguishes infrastructure-related companies and rail carriers. The rail carriers are briefly discussed in the previous section, the passenger and freight transporting companies. The infrastructure-related companies are not actively transporting goods or people but are responsible for maintenance, asset management, and traffic control of the rail infrastructure. The assets, in this case, are the rail tracks, switches, crossings, stations, etc., everything related to the rail infrastructure except the trains. In the Netherlands, ProRail is responsible for all these activities, except for the HSL-Zuid track (ProRail, n.d.-a). Infraspeed provides the asset management function for the HSL-Zuid (Infraspeed, n.d.). The last category of rail companies combines rail contractors. ProRail contracts them to maintain or build rail infrastructure in the Netherlands. Contractors do not use the capacity of the Dutch rail infrastructure when they work on the railroads. Most of the time, they close rail routes temporarily to do maintenance or construction. Therefore, this research does not take this category into account. Although rail contractors play an important role within the rail sector, disruptions in their operations do not immediately bring Dutch society to a standstill. In the meantime, failures in the asset management and traffic controller of ProRail can make the rail infrastructure unusable. Disruptions at an operator level mean that there is no passenger transport possible. A recent example is the traffic controllers shortage this summer. This situation led to a disruption of rail traffic around Utrecht, the epicentre of the Dutch rail sector (Obbink, 2021). The two categories that are interesting for this research are passenger carriers and the infrastructure asset managing organisation. Both categories relate directly to transport people from point A to point B.

An extra category regards governmental bodies. They are involved in the rail infrastructure and sector, but not the daily operations. The regulating governmental institution of the Dutch rail sector is the Human Environment and Transport Inspectorate (in Dutch Inspectie Leefomgeving en Transport (ILT)). ILT is part of the Ministry of Infrastructure and Water Management (I&W) and supervises rail organisations operating in the Dutch rail sector (ILT, n.d.). The second ministry related to the rail sector is the Ministry of Finance, which holds 100% of the shares of the NS, the largest rail company in the Netherlands. The interests of the Dutch government in the key players of the rail sector, largest passenger operator and asset manager, shows how closely connected they are with each other. The involvement in the Dutch rail sector originates from the historical development of the rail sector, as shown in the first section of this chapter. For years, the rail sector was a state-owned infrastructure. It was no exception that critical infrastructures were state-owned, e.g. electricity was traditionally state-owned (Antonsen et al., 2010). In the 1980s and 1990s, the liberalisation and privatisation of critical infrastructure sectors led to state-owned monopolies splitting up (Antonsen et al., 2010; de Bruijne and van Eeten, 2007). Splitting up a state monopoly happened during the ‘privatisation’ of the Dutch Rail sector and splitting the tasks of NS into ProRail and NS passenger transport.

The thought behind the privatisation of state-owned enterprises is that adopting a free-market increases productivity and improves cost-efficiencies of these infrastructures (Anton and Nucu, 2020; Blank et al., 2019; Cedergren et al., 2018; Sonesson et al., 2021). The Dutch rail sector is privatised in name only. The largest Dutch passenger operator, with a concession monopoly on the HRN, and the sole infrastructure operator have the Dutch State as a shareholder. A broad definition of privatisation is: “… the myriad ways in which the private for-profit sector displaces the public sector in the provision of goods and services …” (Mercille and Murphy, 2017, p.1045). The Dutch rail sector is not a privatised sector because a company with the Dutch State as its sole shareholder owns 85% of the rail passenger concession rights. At most, the Dutch rail sector is a semi-private sector with a dominant state-sponsored operator. The shares of the Dutch government in the rail sector shows the still existing

public control of the government within the rail sector. The Netherlands is not different from other European countries. For example, the largest Belgian rail company, Nationale Maatschappij der Belgische Spoorwegen (NMBS), is also state-owned. This trend also applies to Germany (Deutsch Bahn), France (Société nationale des chemins de fer français), and Italy (Ferrovie dello Stato Italiane S.p.A.). These foreign state-owned rail companies mentioned above are shareholders of rail companies operating in the Netherlands.

Appendix A.1 shows an overview of rail contractors, infrastructure managing, passenger-carrying, freight carrying companies in the Netherlands. As mentioned earlier, this research focuses only on the rail infrastructure maintenance organisation ProRail and passenger carriers. Appendix A.2 and A.1 gives a complete overview of the passenger and infrastructure operators active in the Dutch rail sector. This overview of these organisations is more elaborate, containing the country of the headquarter of the company, parent companies, and shareholder information.

3.4.1. Infrastructure operators

Two companies are managing and maintaining the Dutch rail infrastructure. ProRail is responsible for the entire 'normal' rail infrastructure as an asset manager. Furthermore, ProRail is responsible for rail traffic control in the Netherlands. The Ministry of I&W is the sole shareholder of ProRail, since its establishment in 2005. Infraspeed Maintenance B.V. (IMBV) is the second infrastructure operator in the Netherlands. IMBV is responsible for the asset management and maintenance of the HSL-Zuid track. HSL-Zuid is a high-speed rail track from Schiphol, near Amsterdam, to Antwerp in Belgium. NS International B.V. and its partners (Thalys and Eurostar) use HSL-Zuid for routes between the Netherlands and Belgium, with the final destination Paris or London. IMBV is, in contrast to ProRail, fully private owned. The shareholders of the company are Siemens and Koninklijke BAM Group. IMBV does not provide rail traffic control for the HSL-Zuid this is done by ProRail.

3.4.2. Passenger operators

The Dutch rail sector has several passenger operators operating within it. These operators are divided based on two characteristics: ownership structure and area of presence. The ownership structure knows three classifications: public, semi-public, or private. Passenger operators with a state-owned parent company or shareholder are public rail operators. Private owned operators are operators whose shareholders do not have a connection with any governmental body. Semi-private operators have both state-related shareholders but also private ones. The operators have a regional, national, or internal presence. During this research, an interesting fact came to light. All of the active passenger operators in the Netherlands have shareholders who relate to European governmental bodies. These shareholders are the state-owned rail companies of Germany, France, and Italy.

Table 3.2 shows all the passenger operators in the Netherlands. Except some international rail operators are missing. Thalys, Eurostar and ÖBB Nightjet are international partners of NS International B.V. Therefore, ProRail does not see them as separate entities. The majority of the companies operate on regional concessions. The NS is the only operator with the concession rights of the main track and, therefore, it has a presence throughout the entire Netherlands. The DB Regio AG and NS International B.V. provide international rail connections. The rest are regional passenger operators. The ownership structures of the passenger operators show interesting findings. Mainly, foreign states have ties with several passenger operators. Appendix A.1 shows which operator has connections with foreign state-owned organisations. In addition, private investment firms own shares of Connexxion and Keolis. The other shareholders are related to domestic or foreign governmental bodies. Appendix A.1 shows the distribution of the shares amongst the shareholders.

Table 3.2: Passenger carrying operators in the Netherlands.

Company	Ownership structure	Operating level
NS	Public	National
Arriva B.V.	Public	Regional
Abellio Rail GmbH	Public	Regional
DB Regio AG	Public	International
Connexxion Openbaar Vervoer N.V.	Semi private	Regional
Keolis Deutschland GmbH & Co. KG	Semi private	Regional
Keolis Nederland B.V.	Semi private	Regional
NS International B.V.	Public	International
NS Reizigers B.V.	Public	Regional
Qbuzz B.V.	Public	Regional
Thalys	Public	International

3.5. Risks in the rail sector

Chapter 2, State-of-the-art ERM and data-driven work, identifies several risks that relate to ERM. Specifically, the CAS 2003 provided an extensive risk classification, shown in table 2.1. However, these risks are generally applicable to all kinds of organisations. This section focuses on rail sector-specific risks. The risk inventory of the rail sector analyses annual reports and financial statements of railroad companies. Both kinds of company documents are a source to identify risks that an organisation faces. These documents inform shareholders about the performances and the direction in which the organisation wants to go. A reoccurring element in both documents is risk assessments (Cho et al., 2019; Pavaloaia, 2015). Obviously, the financial reports focus more on financial risk. However, non-financial risks can still have financial impacts in the end (Veltri, 2020). Unfortunately, the annual reports and financial statements of some Dutch rail organisations are not all publicly available. If this is the case, the inventory includes documents of the parent company, if possible. The annual reports or financial statements of Arriva and Qbuzz are not publicly available. Therefore, the analysis uses the reports and statements of the Deutsch Bahn and FS Italiane as their parent companies. Both parent companies are national state-owned enterprises in another European country. The analysis includes two extra rail organisations. As mentioned in the previous section, France and Belgium also have dominant state-owned rail enterprises. The analysis includes them to research whether state-owned rail organisations perceive or experience risks differently. Both state-owned enterprises have a connection with the Dutch rail sector. The France state-owned rail enterprise is the majority shareholder of the parent company of Connexxion. The connection with the Belgium state-owned rail enterprise is a partnership with the NS regarding the HSL-Zuid. Another addition is the financial statement of Transdev, the parent company of Connexxion. The annual report of Connexxion is a quality report; this report does not contain enough information regarding risk assessment. Transdevs' financial statement provides additional information. Table 3.3 shows a list of documents that are the basis of the risks inventory.

Table 3.3: Overview of document to analyze risk within the rail sector.

Dutch rail companies	**Document**
NS	Annual report 2020
Connexxion	Annual report quality 2019 Transdev financial report 2019
Keolis	Financial report 2019
ProRail	Annual report 2020
Foreign rail companies	
Deutsche Bahn (DB)	Integrated report 2019 (combination of annual report and sustainability report)
Nationale Maatschappij der Belgische Spoorwegen (NMBS)	Annual report 2020
Société nationale des chemins de fer français (SNCF)	Annual financial report 2018
Ferrovie dello Stato Italiane S.p.A. (FS Italiane)	Annual report 2020

Like the CAS 2003 framework, most annual reports identify risk clusters, such as strategic, financial, and compliance risks. These clusters contain more detailed risks. For the risk inventory of this research, the classification of CAS 2003 is used, except hazard because they are an operational risk for the rail sector and therefore part of the operational risk category. Table 3.4 below shows an inventory of risks that the Dutch rail sector faces. The orange checkmarks indicate top risks according to the organisation. The blue checks marks are risks mentioned in the documents, which are not top risks.

Table 3.4: Risk inventory of the rail companies related to the Dutch rail sector from annual reports and financial statements.

	NS	**Connexxion**	**Keolis**	**ProRail**	**DB**	**NMBS**	**SNCF**	**FS Italiane**
Financial								
Financing from the financial market		✓		✓			✓	✓
Exchange rates foreign currencies	✓	✓	✓		✓	✓	✓	✓
Credit	✓	✓	✓	✓	✓	✓	✓	✓
Liquidity	✓		✓		✓	✓	✓	✓
Interest rate	✓	✓	✓	✓	✓	✓	✓	✓
Commodities	✓	✓	✓				✓	
Incorrect management information/reports	✓			✓				
Energy price	✓		✓	✓	✓	✓	✓	✓
Revenue losses	✓	✓		✓		✓		
Investments	✓				✓			
Tax		✓	✓		✓		✓	✓
Hedging			✓				✓	✓
Third party			✓	✓	✓		✓	✓

Continued on next page

Table 3.4 – continued from previous page

	NS	Connexxion	Keolis	ProRail	DB	NMBS	SNCF	FS Italiane
Raw materials			✓					✓
Pricing						✓	✓	✓
Operational								
Safety and security failures (incl. health employers)	✓	✓	✓	✓	✓	*	✓	✓
Continuity and availability of information systems	✓			✓	✓		✓	✓
Disruptions due to weather events (e.g. climate change, extreme weather)	✓	✓	✓	✓	✓		✓	✓
Lack of infrastructure capacity	✓							
Lack of skilled employees				✓	✓			
Disruption train service			✓	✓				
Agility	✓							
Accidents		✓	✓	✓				
Sector's technical complexity							✓	
Contagious diseases (e.g. COVID-19)	✓			✓				✓
Strategic								
Risk to non-compliance	✓	✓		✓	✓	✓	✓	✓
Changing economic landscape and market		✓			✓		✓	✓
Reputation	✓							✓
Dependency of stakeholders				✓				
Lack of infrastructure capacity				✓				
Ethics and fundamental rights risks		✓	✓		✓			✓
Social risks		✓					✓	✓
Environmental	✓	✓	✓		✓		✓	✓
Corruption/fraud	✓	✓	✓	✓	✓		✓	✓
Project					✓			✓
Legal/contractual risks					✓	✓	✓	✓
Penalties for performance losses	✓		✓		✓			✓
Transformational risk			✓					
Personal data			✓				✓	
Human resources			✓				✓	✓
Business and strategic							✓	✓

* The financial statement of NMBS does not report operational risks
✓ = top risk
✓ = normal risk

The risk inventory highlights several interesting points. First, most top risks are within the strategic risk cluster (28 top risks). Meanwhile, the financial risk cluster has the least amount of top risks (11 top risks). A reason for this can be that mainly annual reports are used for this inventory. Annual reports

discuss the performance of the entire organsation. While financial statements mainly focus on financial results and risks. However, even the financial statements of Keolis and SNFC reported more strategic top risks than finance top risks. An explanation can be that financial risks are perceived to be part of the game, and their importance rarely changes, where strategic risks relate to the everchanging strategic goals of an organisation. The annual report of NC State University's ERM Initiative and Protiviti (2020a), which looks into the risk perspectives of executives, partially confirms the top risk distribution seen in table 3.4. This report places only two financial risks in the top 10 top risks. Like in table 3.4, finance risks are seen to a lesser extent as top risks. However, the report also only puts two strategic risks in the top 10. From an executive's perspective, the majority of the top risks relate to the operations of an enterprise. This research could not find a clear explanation for the differences between the risk inventory of this research and the report. Even the service industry-specific report results show the same division of top risks (NC State University's ERM Initiative and Protiviti, 2020b). Table 3.5 gives insight into a possible explanation; it shows the ownership structure and the number of operational and strategic top risks per company. The semi-public rail companies have a higher strategic/operational ratio, meaning they perceive strategic risks more often as top risks. Another explanation for the difference is that FS Italiane has a dominant focus on strategic risks. The strategic/operational ratio of FS Italiane is 5.0, meaning that for each top operational risk FS Italiane identifies five top strategic risks. This research cannot find a reason for the dominant strategic risk perspective of FS Italiane. However, the risk inventory analysis of this research provides a tentative conclusion. Public-owned rail enterprises tend to be more operational risk-focused than semi-public rail enterprises, which focus more on strategic risks.

Table 3.5: Strategic/operational ratio of the top risks

Rail enterprise	**Ownership structure**	**Top risks in operational cluster**	**Top risks in strategic cluster**	**Ratio strategic /operational**
NS	State-owned	5	3	0.6
Connexxion	Semi-public	1	3	3.0
Keolis	Semi-public	2	5	2.5
ProRail	State-owned	5	3	0.6
DB	State-owned	2	1	0.5
NMBS	State-owned	0	0	N.A.
SNCF	State-owned	3	3	1.0
FS Italiane	State-owned	2	10	5.0

The second observation is that one risk stands out: safety and security. All the documents mention safety and security as a risk, five of which even classified it as a top risk. Rail safety includes passenger safety, environmental safety, employee safety (Jamshidi et al., 2017). It goes without saying that the rail sector has a specific focus on rail safety and security. Regulators and regulations generally focus on rail safety (Peterson and Church, 2008). Safety issues are high on the agenda of decision-makers within the rail sector for years (Plant, 2008). It is for good reasons because rail safety incidents can have considerable consequences. For example, in 2020, the derailment of the Abellio ScotRail train, a subsidiary of the NS, near Stonehaven killed three people and injured six (Johnston et al., 2021). These kinds of incidents have a considerable impact on the rail sector, and therefore, safety risks are important for the rail sector. In addition, rail organisations are bound to comply with strict safety regulations to maintain their operating licenses. Addressing rail security issues is important because these issues can disrupt rail services and jeopardise rail safety (Yucel and Ozturk, 2017). Rail cyber security is a great example of a security issue that can disrupt rail services (Z. Zhang et al., 2018). May 31st 2021, ProRail had a major malfunction in their telephone system which resulted in an almost nationwide standstill of the Dutch rail sector. It is clear why rail organisations experience safety and security as an important risk; failure can have significant consequences for the rail sector.

The third observation is the ranking of the risks within the risk clusters visible in table 3.4. The three most often mentioned financial risks are interest rates, credit, and energy prices. Two of them are not specific to the rail sector; credit and interest rate risks are standard financial risks of organisations. The energy price risk belongs to the rail sector because rail operators depend on energy (electricity or diesel)

to run their trains. The NS uses 90% of its energy to run its train operation (NS, 2020). In addition, during the COVID-19 pandemic, the NS purchased energy for 257 million euros in 2020 (NS, 2020). A price fluctuation of +1% means that the cost will increase by 2,6 million euros. The investments risk is also an interesting financial risk. Only two rail operators see investments risks as a risk while they spend enormous amounts of money on their investments. The NS had 1184 million euro outstanding investments in 2020 and had a cash flow of 602 million euro from investment activities (NS, 2020). The three most often mentioned operational risks are the availability of IT systems, safety and security, and disruptions due to weather events. The previous paragraph already discusses the availability of IT systems and safety and security risks. Both risks can disrupt rail operations. Rail disruptions due to weather events are becoming more common and more severe (Ludvigsen and Klæboe, 2014). The risk of climate change-driven extreme weather events is something rail organisations need to consider more often in the future. All the rail organisations should mention (extreme) weather events as a risk in their annual reports or financial statements. The sixth AR (assessment report) of the IPCC (2021) predicts a near future with more extreme weather events. The three most often mentioned strategic risks are non-compliance, corruption/fraud, and environmental risk. Both the non-compliance and corruption risks do not specially apply to the rail sector. They also apply to other industries and all kinds of business. The environmental risk is also widely applicable. The rail sector is not the only sector that wants to lower its emissions and reduce air pollution. However, the rail sector has environmental risks that other industries, such as transporting hazardous goods. The most notable risk is the fourth most mentioned risk; changing markets and competition. All rail organisations face this risk during tenders for concession rights. However, only half of the organisations mentioned competition as a risk. ProRail and the NS do not perceive competition as a risk, according to the documents. It makes sense because both organisations are state-owned monopolies with no competition in the Netherlands. The NS has sole access rights to the HRN for many years, and ProRail is the sole infrastructure operator. Altogether, the risk inventory of Dutch operating rail organisations has led to several interesting insights.

3.6. Chapter summary

This chapter provided a detailed overview of the Dutch rail sector to answer the second sub research question: ‘How is the Dutch rail sector organised, and what are the risks rail organisations face in the Netherlands?’ The Dutch rail sector is a sector that exists almost two centuries. It started off with several private enterprises, each owning and exploiting a rail connection. At the beginning of the twentieth century, the two largest rail organisations merged and formed the state-owned NS. The NS was the sole transport and infrastructure operator. It changed at the end of the twentieth century when the Dutch government decided to privatise the NS. The Dutch government transferred the infrastructure operating tasks of the NS to a new organisation, ProRail. In addition, other rail organisations could access the Dutch rial sector through concession tenders. However, the concession rights to the main track (85% of the rail infrastructure) remained in the hands of the NS. After the ’privatisation’ of the Dutch rail sector, both the NS and ProRail remained state-owned organisations. Currently, the Dutch rail sector is a free market with one monopolist state-owned operator that possess 85% of the access rights. In addition, the infrastructure operator is also a monopolistic state-owned organisation.

The risk inventory of the Dutch rail sector showed an extensive list of risks. The most important risk to the rail sector is safety and security because they have a considerable impact on the continuity of the rail services. In addition, the competition risk that some rail operators face does not apply to ProRail and the NS. The reason for this is their state-owned monopolistic structure. The last risk that especially concerns the rail sector is disruption due to weather events. Due to climate change, more disruptive weather events will occur and impact the Dutch rail sector.

4

Method and data

This chapter discusses the research and data collection methods of this research. Section 4.1 gives an overview of different research approaches. From these approaches, the exploratory case study approach fits the research objective of this research the best. The remainder of the section discusses the case study approach and elaborates on the design choices and the case study setup. Section 4.2 provides an overview of different data collection methods. From this overview, two methods are selected: desk research and interviews. Section 4.2 also discusses the suitability and limitations of desk research and interviews. In addition, it substantiates the interview setup and the selection of the interviewees. Section 4.3 summarises the chapter.

4.1. Research approach

There are several approaches to conduct research, each with different research objectives. Lambert (2012) discusses eleven research approaches which are shown in table 4.1. In addition, table 4.1 displays the research objectives of the different research approaches and whether they suit the research objective of this research: to contribute to the body of knowledge by gaining academic insights into the use of data-driven ERM in the Dutch rail sector.

Table 4.1 shows that out of the eleven research approaches, three are suitable to achieve the research objective of this research: the case study research approach, exploratory research approach, and the comparative approach. The research objective of this research asks to combine all three research approaches. Firstly, case study research is a useful approach for this research because this approach focuses on gaining insights into a broader setting or population by researching and understanding cases‘(Gerring, 2007). In the context of this research, the case study setting is the Dutch passenger rail transport sector. Secondly, the exploratory research approach also fits the research objective by adding knowledge to the novel research field of data-driven ERM. Exploratory research aims to research areas where previous research is limited or non-existing (Brown, 2011; Patton, 2002). The research areas of data-driven ERM and ERM applied in the rail sector are these kinds of novelties. Exploratory research will contribute to adding much-needed knowledge in these research areas. In addition, the exploratory research approach aims to create a clear understanding of complex situations (Sreejesh et al., 2014). The Dutch rail sector on its own is already a very complex system. Chapter 3 illustrates the complexity of regulated monopolies and the vital position the rail sector fulfils. Understanding the added value of ERM in such a system is even more complex. Finally, the comparative research approach compares different cases to gain insights into differences and similarities between research entities (Etse et al., 2021). This research benefits from the comparative research approach identifying differences and similarities regarding the adoption of data-driven ERM in the Dutch rail sector. In addition, the added value of ERM to different rail organizations can shine some light on adoption differences.

Table 4.1: Research approaches (Lambert, 2012).

Research approach	Research objective	This research
Theoretical research	Aims to research the theory of ideas or concepts without looking at the practical use	Not suitable for this research
Action/practitioner research	Aims to improve current practices, and the researchers are mainly practitioners themselves	Not suitable for this research
Evaluative	Aims to research the performance of an organization, person or action	Not suitable for this research
Experimental	Aims to research different scenarios by conducting a structured experiment setup	Not suitable for this research
Cause and effect research	Aims to research causal relations between multiple entities or actions	Not suitable for this research
Case study research	Aims to research an phenomenon/phenomena in-depth in a real-life context	Suitable for this research
Systematic review	Critically assess research data and/or literature	Not suitable for this research
Exploratory research	Understanding the research topic more in-depth or from new perspective, than previously is done	Suitable for this research
Comparative research	Making a comparison between to different situations	Suitable for this research
Grounded theory research	Creating an overarching theory based on extensive research	Not suitable for this research
Ethnography research	Researching cultures or groups in their natural context	Not suitable for this research

All three approaches are helpful to answer some parts of this research. Therefore, this research combines all three research approaches. This research uses an exploratory comparative case study to answer the research questions. The main focus of this research lies on the exploratory case study part of the research approach because the research objective is to contribute to the novel body of knowledge. Hence, this research needs to explore the research area in-depth. This exploration lies at the core of the exploratory research approach. The case study approach is a structured methodology to research specific elements of the Dutch rail sector (Harrison et al., 2017), such as data-driven ERM. Due to time constraints, it is not feasible to perform in-depth research of the entire Dutch rail sector by analyzing all the Dutch rail organizations. Consequently, the comparative research approach selects some rail organizations to compare them in a case study to gain insights into the use of data-driven ERM in the Dutch rail sector.

4.1.1. Exploratory case study

The overarching research approach of this research is the exploratory research approach. It fits best with the research objective of exploring the novel research area of data-driven ERM. The case studies are a useful extension of the exploratory approach. Most of the case study research explores unknown phenomena (Gammelgaard, 2017). Furthermore, the case study approach provides structured guidance to explore novel research areas. Yin (2003) introduced four design types for the case study methodology. Two criteria form the basis of the division of the four design types. These criteria are the number of research phenomena and the number of cases to research. Figure 4.1 shows these four types.

The research objective and research units determine which design type suits best the purpose of the research. First, the use of a single- or multiple-case design is determined by two case characteristics. A single-case design addresses edge-case situations. Yin (2014) distinguishes two of these edge-cases. The edge cases are a critical case of a well-framed theory and a unique case within a research area. Any other situation justifies using a multiple-case design. Both of the edge cases do not apply to

this research. There is no well-framed theory for this research in this novel research area. Moreover, there is no unique case within this research that can be generalised to the entire Dutch rail sector. The research area needs exploration before a unique or critical case can be identified. Additionally, the passenger transport part of the Dutch rail sector has many companies, each having unique properties, as shown in chapter 3. The multiple-case design fits this research best. Subsection 4.1.2 discusses the case selection of the multiple-case study design of this research.

The second step in choosing a case study design is looking into the number of analysing units. Yin (2014) distinguishes between a single-unit (embedded case study design) and multiple-units of analysis (holistic case study design) case study. According to Yin (2014), research that analyses multiple processes or parts of a case or cases uses an embedded case study design. The holistic case study design analyses the general nature of the case (Yin, 2014). The most suited design for this research is the holistic case study design. The unit of analysis of this research is the added value of the adoption of data-driven ERM. Other business processes of the Dutch rail sector are out of the scope of this research. However, the analysis of data-driven ERM also uses sub-units of analysis to broaden the scope. For example, to understand data-driven ERM, data-driven work and ERM must be analysed separately to identify challenges with the adoption of both concepts together. Research in the use of ERM within the Dutch rail sector also leads to an inventory of risks and opportunities the Dutch rail sector faces. However, all the sub-units of analysis are united in the overarching unit of analysis to find the added value of data-driven ERM. Section 4.1.1. discusses the unit of analysis and the sub-units in more detail. Combining the two dimensions of the case study results in a holistic multiple-case design for this research.

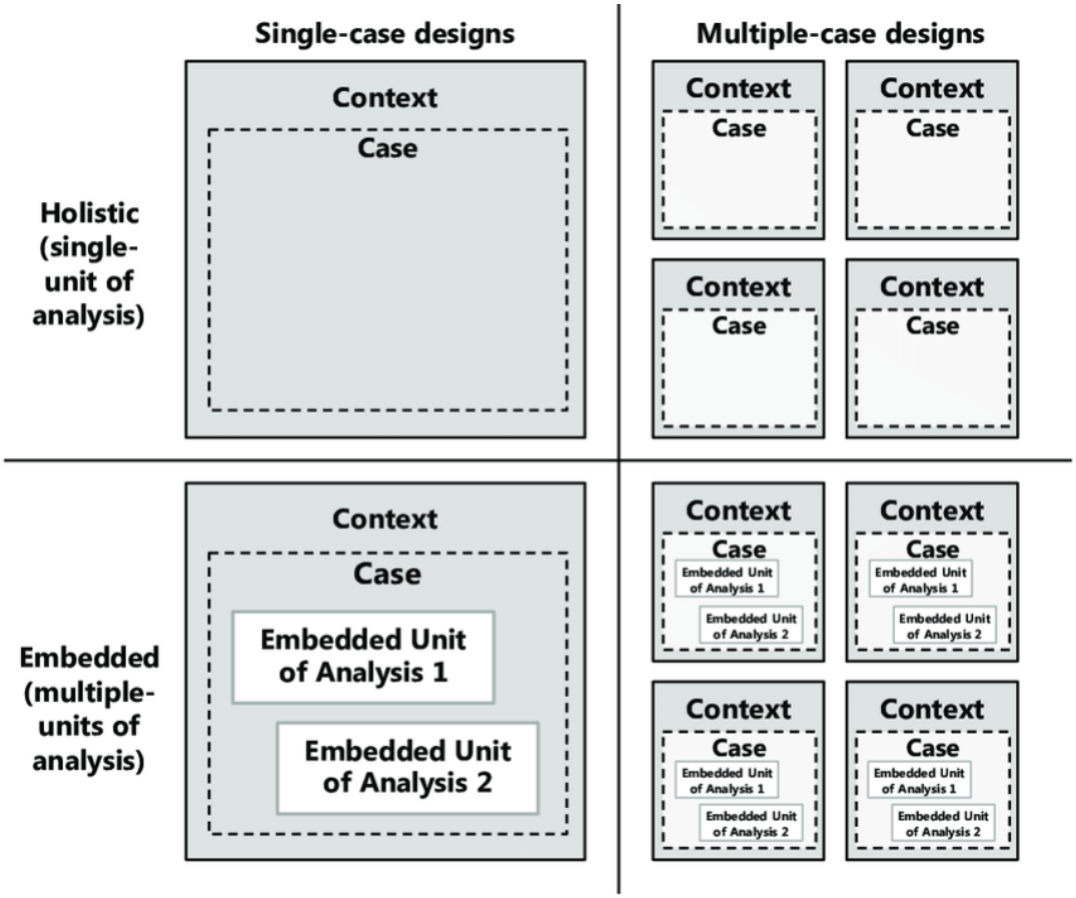


Figure 4.1: Case study designs (Yin, 2014,p.50).

4.1.2. Case study setup

Subsection 4.1.1 determined that this research shall use a holistic multiple-case design for its case study. Therefore, both the cases and the unit of analysis need to be selected. The case study setup discusses the decision to be made regarding the selection choices.

Case selection

The cases of the holistic multiple-case design are chosen based on the stakeholder analysis shown in table 3.2 in chapter 3. This research aims to add as much knowledge as possible. Therefore, the cases must contain different rail organisations to include as many different perspectives as possible. The cases used in this research are rail organisations that are involved with the transport of passengers. Chapter 3 distinguishes between passenger operators and infrastructure operators. The case selection uses the same categories. Selecting an infrastructure operator case is straightforward. ProRail is the sole infrastructure operator of the 'normal' Dutch rail infrastructure, disregarding the HSL-Zuid high-speed track. Consequently, the first case of the case study is ProRail. The passenger operators provide the other cases for the case selection. The selection of the other cases uses two criteria to ensure that the passenger operators' cases are also as diverse as possible: ownership structure and operating level. Table 3.2 in chapter 3 showed only two types of ownership structures within the Dutch rail sector: public and semi-public. Hence, minimally two cases need to be added to the case study to accommodate these differences. However, the cases also need to differ regarding their operating level. This extra dimension causes problems for the case selection. There are no semi-public passenger operators that operate nationwide. The state-owned monopolistic structure of the NS is responsible for the lack of this category of passenger operators. In addition, during this research, it was not possible to contact public-owned regional passenger operators and let them participate in this research. For this reason, the case selection does not select a public-owned regional passenger operator for the case study. The same problem occurred with the international operators. The limitations for the case selection for passenger operators result in two criteria combinations that can provide suitable cases for the case study: public-owned national operating passenger operators and semi-public regional passenger operators. Once again, selecting a case of a public-owned passenger operator that operates nationwide is straightforward. The NS is the only rail organisation in this category. There are two options for the semi-public regional passenger operator case, Connexxion and Keolis. Contact was made with both organisations and asked whether they would cooperate with this thesis research. Keolis did not see the time to participate. Fortunately, Connexxion was willing to help. So, Connexxion becomes the third and last case of the case study. The case study of this research uses ProRail, the NS, and Connexxion as cases.

Unit of analysis selection

The holistic case study design has one unit of analysis. In the context of this research, the unit of analysis is the added value of data-driven ERM. This research focuses on the phenomenon of the data-driven ERM in the Dutch rail sector and zooms in on its added value. Other aspects of data-driven ERM, e.g. the implementation, fall outside of the scope of this research. Consequently, the case study is sharply focused and has a demarcated unit of analysis.

The case study uses two sub-units of analysis to understand and research the added value of data-driven ERM. The sub-units themselves are not a unit of analysis because they support the added value of the data-driven ERM unit of analysis. The sub-units of analysis both address a part of the unit of analysis: 1) the use of ERM and 2) the use of data-driven work. The case study examines whether the cases use ERM within their organisation or the organisations plan to do so in the future. Additionally, the case study analysis addresses the status of the adoption of ERM as their risk management methodology. A similar approach to the case study analysis applies to the second sub-unit. First, the case study analysis identifies the current status of data-driven work within the case organisations. Second, the case study analysis explores whether the case organisations have future developments planned regarding data-driven work. The two sub-units cover most of the unit of analysis. However, the added value of data-driven ERM is not immediately apparent. For this reason, the unit of analysis itself uses two example risks to provide specific insights into the added value of data-driven ERM.

The choice to only include two example risks in the case study analysis has to do with the feasibility of this research within the set period of a master thesis research. As the risk inventory of chapter 3 already illustrates, the Dutch rail sector faces a significant number of risks. For this reason, the case study analysis only uses one risk of each risk cluster. Hence, the analysis includes three example risks. However, section 3.5 states that the risks within the financial risk cluster do not apply specifically to the rail sector. Additionally, the financial risk cluster also does not contain many top risks to rail organisations. Hence, the case study analysis does not consider risks from the financial risk cluster. Meanwhile, the other two risk clusters can provide example risks gaining insights into the added value

of data-driven ERM. The operational example risk is the disruption of rail services due to (extreme) weather events. This risk occurred a lot in the risk inventory of table 3.4 in chapter 3, but organisations do not perceive it as a top risk. Extreme weather events will occur more often in the future due to the effects of climate change (Osaka and Bellamy, 2021; Weilnhammer et al., 2021). In addition, the impact of weather events also increases due to their increasing severity (Weilnhammer et al., 2021). The vulnerability of the rail sector to extreme weather events lead to disruptions of rail services (Green, 2015). Hence, it is interesting whether data-driven ERM has some added value to address this risk. The strategic example of risk is a changing competitive environment. Some of the passenger operators in the Netherlands perceive competition as one of their top risks, while others do not. It is interesting to analyse the underlying motivation of the different rail organisations. The case study analysis also looks into the added value of data-driven ERM on the risk of a changing competitive environment. This example risk is a situation where risks become opportunities. A risk assessment of the competitive landscape gives insights into both competitive shortcomings but also competitive opportunities. The two example risks help to analyse the added value of data-driven ERM.

Case study analysis structure

Incorporating the comparative research approach into the case study approach requires a structured analysis of the cases. A systematic approach safeguards the possibility to compare the three cases of the case study. The selection of both the unit and sub-units of analysis are starting points for this structure. First, the case study analysis needs to address the sub-units. The first step of the case study is to analyse the use of ERM and the use of data-driven work by the three case organisations. If a case does not use data-driven work or ERM, then data-driven ERM is not possible. However, the sub-units of analysis should look into future implementation uses when this is the case. The second step of the case study is to analyse the use of data-driven ERM by the case organisations. An additional task in the second step is to use the two risk types, one operational risk and one strategic risk, to find the added value of data-driven ERM. Note that the strategic risk does not apply to the ProRail case because there is no competition. The third and last step of the case study structure is the comparison of the three cases. The case study analysis compares the results of the passenger operators with the results of ProRail and compares the results of the NS and Connexxion with each other. Figure 4.2 is a graphical representation of the case study structure. The case study analysis assesses the three cases based on the following six points:

- The use of enterprise risk management
- The use of data-driven work
- The implementation of data-driven enterprise risk management
- The added value of data-driven enterprise risk management to the operational risk of extreme weather
- The added value of data-driven enterprise risk management to the strategic risk of competition
- The reasons for the differences between the adoption of data-driven enterprise risk

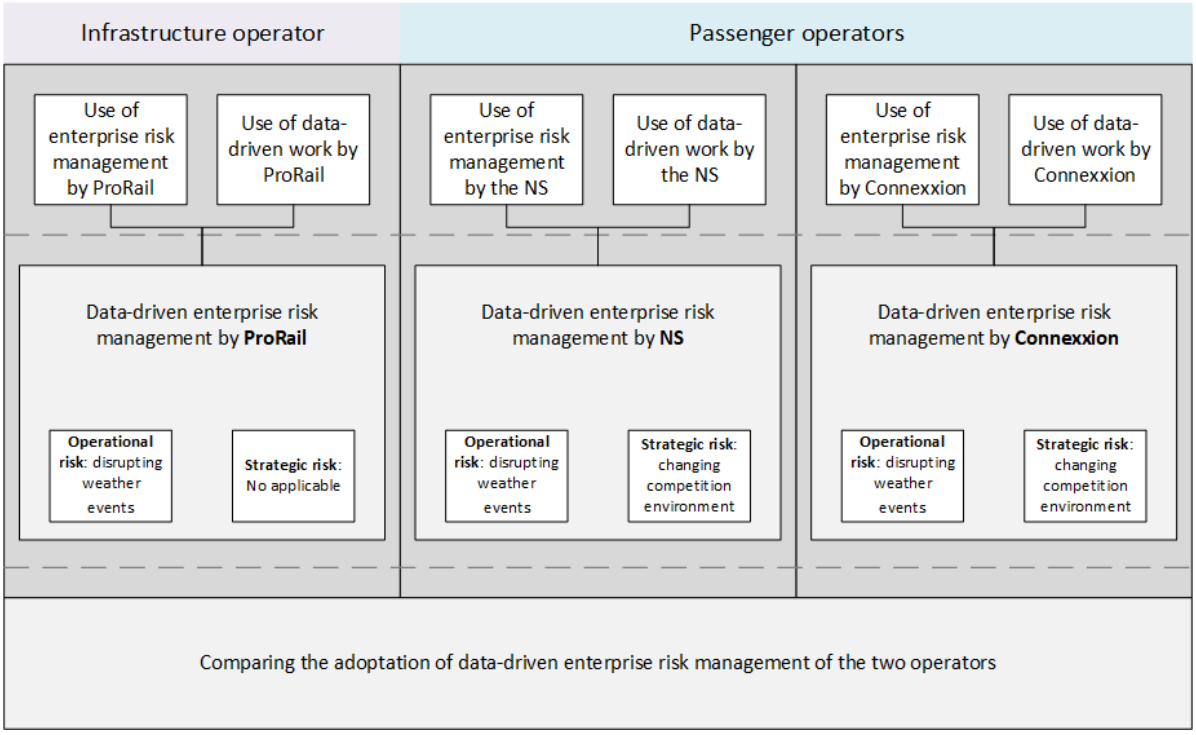


Figure 4.2: Case study analysis framework

4.2. Data collection methods

The case study requires input data for its analysis. As with the different research approaches, there are several ways to collect research data. Lambert (2012) identified four data collections methods for exploratory research. Table 4.2 gives a short overview of these four methods, stating their advantages and disadvantages. The data collection methods that provide the case study analysis with sufficient input data are discussed further in this section.

Table 4.2: Overview of research methods for data collection and their advantages and disadvantages (Lambert, 2012).

Method	Disadvantage	Advantage
Questionnaires/Survey	• Time consuming • Not flexible after designing the structure	• Large number of respondents • Structured way to get answers on the same questions
Interviews	• Recording or taking notes can be difficult • Deviate from the research topic	• Explore unwritten knowledge • Discussing topic in-depth
Observation	• Not everyone wants to be observed • Hard to stay objective	• Variety of data • Can be used flexible
Desk research	• The intent of the document is not always clear • Restricted access	• Gives factual information • Easy to compare

The case study analysis uses two data collection methods, shown in table 4.2, for its data collection: interviews and desk research. One advantage of interviews is that they added unwritten knowledge. This advantage is important in the context of this research because there is little to none written knowledge about data-driven ERM. The interview method ensures that the knowledge of the interviewees is converted into academic knowledge. Furthermore, interviews also offer the opportunity to discuss

research topics in-depth. In the context of this research, this in-depth discussion is needed to explore the novel research area of data-driven ERM. The lack of previous research makes it difficult to understand all the ins and outs of the research topics. The in-depth discussions clear some of the fogginess around the research topic. The subjective nature of interviews is a weakness of the method. Interviewees speak from their own experiences and perspectives and are not always factual. The desk research method provides a solution to the biased interview results. The advantage of desk research is that it generates verifiable data. The verified data from the desk research reduces the subjectivity of the interviews. Additionally, including interviews with interviewees who have different perspectives on the research matter or with outsiders helps to reduces biased interview results.

The other two data collection methods do not suit the case study setup. A large-scale questionnaire or survey is redundant when there are only three cases to analyse, and the unit of analysis of the case study is very specific. The advantages of questionnaires and surveys do not apply to this research. Furthermore, the use of the observation data collection method does not fit the nature of this research. This research aims to understand the added value of data-driven ERM by exploring current affairs and future development. Developments in the future are not yet observable. Consequently, this research does not use both the questionnaires/surveys and observation data collection methods for the data collection for the case study analysis.

4.2.1. Desk research

The desk research method is comparable with a literature review and analyses published data (Zhou and Nunes., 2016). The desk research method can use both academic and grey literature for data collection (Bush and Glover, 2016; Camarasa et al., 2020). A definition of grey literature is: "...that which is produced on all levels of government, academics, business and industry in print and electronic formats, but which is not controlled by commercial publishers" (Paez, 2017, p.233). This research uses the academic literature to make sense of the research results and put the conclusions of this research in a broader perspective and the current body of knowledge of both data-driven work and ERM. The TU Delft library search engine and the search engine of ScienceDirect are the tools to access the academic literature for this research. All the academic literature from these search engines need to be peer-reviewed or else it is considered to be grey literature.

The grey literature used in this research focuses on the case study analysis of the adoption of data-driven ERM. The case study analysis uses the grey literature from the desk research to analyse and compare the cases. The case comparison requires comparable grey literature data sources for each case in the case study. Annual reports are suited for this purpose because each of the cases publicly publishes them each year. The annual quality report of Connexxion of the last two years is publicly available. The annual reports of NS and ProRail go back several years, respectively 2015 and 2012. Annual reports provide insights into how organisations view times about their risk management function and the use of data. Besides the case study analysis, chapter 3 also used this type of grey literature to make a risk inventory of the risks that the Dutch rail sector faces. Table 4.3 shows the grey literature source used in the case study analysis. Please note jaarverslag is the Dutch translation of annual report.

Table 4.3: Overview of grey literature of the desk research

Organisation	ProRail	Connexxion	The NS
Grey literature source	• Jaarverslag 2020 (ProRail, 2020) • Jaarverslag 2019 (ProRail, 2019) • Jaarverslag 2018 (ProRail, 2018) • Jaarverslag 2017 (ProRail, 2017) • Jaarverslag 2016 (ProRail, 2016) • Jaarverslag 2015 (ProRail, 2015)	• Jaarverslag kwaliteit 2019 (Connexxion, 2019) • Jaarverslag kwaliteit 2018 (Connexxion, 2018)	• Annual Report 2020 (NS, 2020) • Annual Report 2019 (NS, 2019) • Annual Report 2018 (NS, 2018) • Annual Report 2017 (NS, 2017) • Annual Report 2016 (NS, 2016) • Annual Report 2015 (NS, 2015)

Limitations of desk research

Desk research has two main limitations which apply to this research: data availability and data quality (Stewart and Kamins, 1993). Table 4.3 shows a difference in how long annual reports are available online, e.g. the annual reports of ProRail go back to 2015 and the annual reports of Connexxion to 2018. Consecutive reports provide a picture of how an organisation develops over time and shows how events impact organisations. For example, before 2019, none of the annual reports spoke about a pandemic; it changed after 2019 because of COVID-19. Discovering these kinds of trends is more difficult with a limited number of consecutive documents. In addition, the quality of the data is the second point of concern. The advantage of desk research, to easily compare data, requires data of similar quality. The annual reports of the three cases need to have a similar level of detail. Comparable levels of detail of the data avoid a situation that compares apples with oranges. Unfortunately, Connexxions' annual quality reports are short and not in-depth. Meanwhile, the annual reports of the NS and ProRail are elaborate and contain a high level of detail. Comparing them with Connexxion requires some effort to generalise the level of detail of the NS and ProRail. Working around the two limitations of desk research takes some effort.

4.2.2. Interviews

The interview method focuses on discussing a research topic between the interviewer and the interviewee (Hennink et al., 2011). There are three types of interviews: structured, unstructured, and semi-structured interviews (Lambert, 2012). Unstructured interviews often start with a single question, after which the conversation between interviewer and interviewee decides the direction of the interview (Twycross, 2018).. Additionally, unstructured interviews focus on the interviewee's perspective on a research area (Kottmann and Reiher, 2020).. In contrast, structured interviews use predetermined interviews question from which no deviation is possible. The interviewer is in control of the direction of the interview (Twycross, 2018). Testing a hypothesis is the main driver of the use of structured interviews (Kottmann and Reiher, 2020). The semi-structured interviews sit between the structured and unstructured interviews. Semi-structured interviews try to find answers to predetermined key research areas, but there is some room to deviate a little during the interview (Twycross, 2018).

Semi-structured interviews fit best to the purpose of this research, to find the added value of data-driven ERM and explore the novel research area of data-driven ERM. Semi-structured interviews help reveal knowledge that the current academic body of knowledge lacks (Leech, 2002). For this reason, this research uses semi-structured interviews for its data collection. This research uses recordings of the interviews to transcribe the interviews afterwards. The case study analysis uses the transcripts to process them into research results to answer the research question. Transcribing the interviews is done manually. This way, the interviewee's privacy is guaranteed because no third party has access to the recordings. Additionally, the transcripts do not show sensitive and private information related to the interviewee. As a result, interviewees can speak completely freely.

Limitations of interviews

The main limitation of the interview method is the limited number of respondents. The interview method is a time-consuming endeavour. Consequently, only a limited number of interviews are possible within the master thesis time frame. Fortunately, the use of semi-structured interviews reduces the preparation time of the interviews by reusing the same pre-defined set of questions multiple times (Qu and Dumay, 2011). The reduced preparation time makes the interviews less time-consuming. However, the limited number of respondents is still a valid concern to generalise the research conclusions.

Interview setup

The interviews of this research have two purposes: 1) providing insights for the case study analysis and 2) exploring the novel research area of data-driven ERM and putting the case studies in perspective. The aim of the case study related interviews is to assess the three cases. The assessment follows the case study setup presented in subsection 4.1.2. The interviewees for the case study related interviews are employees of the three case organisations, the NS, ProRail, and Connexxion. However, not everyone within the organisation is a suitable interviewee candidate. Hence, two criteria determine whether an employee has sufficient knowledge about data-driven work or ERM.

The first criterion is whether their jobs have a connection to risk management. Consequently, three groups within an organisation are eligible to provide suitable interview candidates: the risk department, the internal audit function and managers. Obviously, the risk department provides eligible interview candidates for research into risk management. However, the eligibility of the internal audit functions requires some explanation. The internal audit function ensures compliance with ERM and risk management by executing internal audits within the organisation (Viscelli et al., 2016). Managers are eligible interview candidates because they are amongst those who are responsible for the assessment of internal risk controls (Moeller, 2007). Therefore, they have in-depth knowledge about the risks they face. Despite that, this specialist knowledge about a specific risk does not match the holistic risk approach of ERM. Employees with a general overview of all the risks an organisation faces suits the ERM methodology and this research better.

The second criterion is whether the interviewee has some kind of knowledge about data-driven work. A specific department does not contain all the data-driven knowledge of an organisation. Knowledge about data-driven work spreads throughout the entire organisation when it is adopted. Hence, the interview candidate needs to have a relation to data-driven work. Table 4.4 shows how the interviewees score on these criteria. Table 4.4 does not show the personal information of the interviewees, such as their names and their precise job title, for privacy reasons.

Table 4.4: Case related interviewees

Organisation	**Criterion 1: job related to ERM**	**Criterion 2: knowledge of data-driven work**
ProRail	The interviewee is part of the internal audit function	The interviewee focuses on IT audits
Connexxion	The interviewee is Quality and Safety coordinator	The interviewee uses data for the integrated risk an safety function data
Connexxion	The interviewee is manager at the rail division of Connexxion	Not applicable
NS	The interviewee is senior Internal IT auditor	The interviewee focuses on IT audits

Table 4.4 shows that one of the interviewees does not meet the second criterion. Additionally, the same interviewee fulfils a managing role within Connexxion. This subsection earlier states that managers are not suitable as interviewees because they lack a holistic risk overview. It does apply to an organisation such as Connexxion. Connexxion is a small regional passenger operator with an integrated business structure. The interviewee oversees the risk management process of Connexxion because the different departments report to the interviewee. Hence, the interviewee has a holistic risk overview of the organisation. Additionally, a duo interview with a colleague who has sufficient

knowledge of data-driven work compensates for the limited data-driven work knowledge of the manager. Furthermore, the table shows no interviewees from a risk department. Unfortunately, the risk departments of the case organisations were too busy to partake in an interview.

The aim of the second group of interviews is to look at the data-driven ERM in the Dutch rail sector for a distance. The second group of interviewees consists of people who have knowledge about the Dutch rail sector and data-driven work. They provide a general impression of the state of the Dutch rail sector regarding data-driven ERM. Table 4.5 shows how the expert interviewees score on the interview criteria.

Table 4.5: Expert interviewees

Organisation	**Criterion 1: job related to ERM**	**Criterion 2: knowledge of data-driven work**
Ministry of the Interior and Kingdom Relations	The interviewee is a former employee of the Infrastructure and Water management	The Interviewee has worked in the information provision department
EY	The interviewee is manager cybersecurity	The Interviewee focuses on cybersecurity and uses data-driven work for risk assessments.
EY	The interviewee is manger technology risks	The interviewee focuses on technology risks and uses data-driven work for risk assessments.

The two interview groups do not receive the same interview questions during the interviews. The questions differ based on the different purposes of the two interview groups: the first group receives case-specific questions, and the second group gets more general questions. Appendix B shows the two interview protocols of both groups. Although both interview protocols differ in their focus, they have a similar structure. Hennink et al. (2011) divide the interview structure into three parts: opening questions, key questions, and closing questions. The interview protocols of this research follow this same division. The interview starts with some introductory questions about their experiences and their relation to the research topic. Additionally, the last opening questions align the definition the interviewee had of data-driven work and ERM and the working definitions of this research. The interview protocols continue after the opening questions with the key questions. The key questions focus on three research questions:

1. What are the current practises of ERM?
2. What is the current use of data-driven work?
3. What are the risks and opportunities of using data-driven ERM?

The interview protocols have prompt questions for each key question to get the maximum amount of knowledge from the interviews. The interview protocols conclude the interviews with some closing questions about the differences the interviewee experiences within the rail sector regarding the adoption of data-driven ERM. The interview structure shown in the interview protocols is fluid due to the semi-structured style of the interviews. In the end, the interviewee needs to answer all the key questions satisfactorily.

4.3. Chapter summary

This chapter discussed the research approach and data collection methods. The research approach that best suits this research is an exploratory comparative case study. This approach combines the exploratory research approach, the comparative research approach, and the case study research approach. The exploratory nature of the approach fits the research objective to explore the novel research area of data-driven ERM. This research uses the case study approach to explore the added value of data-driven ERM for the Dutch rail sector without researching all the passenger operating rail organisations in the Netherlands. The diversity of the cases ensures that this research covers as many

elements of the Dutch passenger rail transportation sector as possible. The case study analysis uses the NS, ProRail and Connexxion as cases. Additionally, the unit of analysis of the case study is the added value of data-driven ERM. The case study approach also applies the comparative approach in its analysis. The case study analysis of this research compares the three cases while analysing and interpreting the results.

This research uses two data collection methods to collect the data for the case study analysis: desk research and interviews. The desk research method uses both academic and grey literature. The grey literature for the case study analysis consists of the annual reports of the case organisations. Additionally, the case study analysis uses interviews with experts to gain more knowledge in the novel research area of data-driven ERM. The semi-structured interviews of this research have two purposes: 1) providing insights for the case study analysis and 2) exploring the novel research area of data-driven ERM and putting the case studies in perspective. The interview purposes divide the interviews into two groups, each focused on a purpose. In total, seven interviewees have contributed to this research.

5

Results

This chapter presents the case study analysis results to answer the last four sub research questions: 'To what extent are Dutch railroad companies using data-driven work for their enterprise risk management?'; 'What are the risks and opportunities of using data-driven work for the risk management of Dutch rail organisations?'; 'To what extent do organisations differ in their adoption of data-driven enterprise risk management?' and 'Why should Dutch rail organisations implement data-driven enterprise risk management?'. Section 5.1 presents an analysing framework to discuss the results. The framework structures the presentation of the results from the case study related interviews, expert interviews, and desk research. Section 5.2 presents the results and extracts findings from the case study results. The results separately discuss the six elements of the case study structure shown in chapter 4: the unit of analysis, the subunits of analysis, two example risks, and the case comparison. Section 5.3 concludes the results chapter by giving a chapter summary that answers the above-mentioned sub research questions.

5.1. Analysing framework

The structure of the case study, presented in chapter 4, provides already some guidance to the case study analysis. It distinguishes the six case study elements: the unit of analysis, the subunits of analysis, two example risks, and the case comparison. Each element requires a separate analysis of the case study results. Hence, the following subsections discuss each one element. The assessment of the six elements needs a systematic approach to be able to compare the three cases.

A systematic approach to the analysis ensures that the assessment of each element contains the same level of detail for the comparability of the case study analysis. The systematic analysis provides insights from different case perspectives in how the passenger side of the Dutch rail sector develops regarding data-driven ERM. The analysing framework aims to guide the assessment process and presentation of the case study results. Furthermore, a systematic analysis framework increases the validity of the research to be more precise; it increases external validity. External validity is a research validity that looks into the extent to which findings are applicable for entire groups (Brink, 1993; Yin, 2003). A systematic approach safeguards the comparability of the results, so that conclusion can be drawn from the case study research. Guidelines for a systematic data review is beneficial for the external validity and the resulting generalisation (Avellar et al., 2016). Moreover, a systematic analysis framework increases the validity of the research. In the context of this research, the group is the passenger transporting part of the Dutch rail sector. Analysing the case study results that have a similar level of abstraction makes it possible to compare the cases to find generalising insights. The analysing framework combines the different input data flows of the two data collection methods to answer the sub-questions.

The case interviews are the starting point of the input to the framework. The results from the case interview occupy the first row of the table that presents the results. The second step is analysing the findings from the desk research of case business documents. The results of this analysis occupy the second row of the table. The third step of the framework is an assessment of the case study element based on the results from the first two steps. The fourth step is to interpret the assessment with the

help of the expert interviewees (Hereinafter reffered to a the experts . This interpretation leads to a key insight. The key insights of a case study element look into similarities and differences between the cases. The discussion chapter aims to put the findings in a broader perspective and explain the findings. The key insights are also the concluding remarks regarding a case study element. The answers to the sub research questions that this chapter addresses use the insights to draw conclusions. Figure 5.1 shows a graphical representation of the analysing framework.

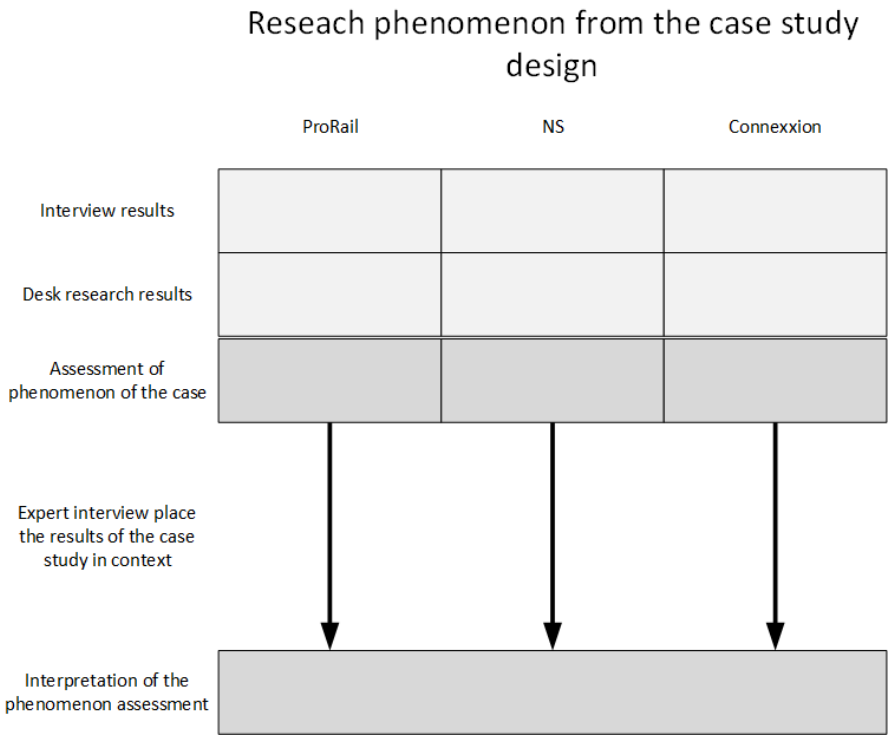


Figure 5.1: Analysing framework for the results.

5.2. Results of the case study analysis

The following subsections present the findings of the case study analysis according to the framework from section 5.1.

5.2.1. The use of enterprise risk management

Table 5.1 presents the results of the case study analysis on the use of ERM. The table represents two analyses: 1) the use of ERM according to the case interviewees, and 2) the use of ERM according to the annual reports. The rest of the subsection focuses on the interpretation of the case study results and compares the three cases. A key finding concludes the subsection.

Table 5.1: Case study results of the use of ERM.

	ProRail	**Connexxion**	**NS**
Interviews	At the moment, ProRail is in a transition to a new risk management system. ERM was the basis of the previous risk management system. However, the adherence to the approach disappeared over time. Hence, the full potential of ERM decreased for ProRail. The new system will not completely disown the ERM philosophy. (Appendix C.1)	Connexxion does not fully apply the ERM approach. Their risk assessments focus on multiple risks besides just financial risks nowadays. Hence, creating a more holistic way of addressing risks to some degree. Furthermore, management expresses the importance of risk management. But still, the adoption of ERM by Connexxion is limited compared to a larger rail company like the NS. The number of resources and their cultures are the causes of the difference. The NS has more resources at its disposal and has a silo driven risk culture. On the other hand, Connexxion has fewer resources and is, therefore, more integratedly focused. (Appendix C.4)	The NS works according to an ERM like approach. Departments such as risk management and internal audit address risks in an enterprise-wide manner. These departments report directly to the C-suite of the organisation. The risk management function is more hands-on in its involvement with risks, where the internal audit function operates more independently to assess the risk controls. The C-suite adjust its strategy based on the input of both departments. The input of the internal audit function is an objective perspective on the risk profile of the NS. (Appendix C.6)

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Table 5.1 – continued from previous page

	ProRail	Connexxion	NS
Desk research	The risk management system of ProRail finds its origin in the ISO31000 and COSO ERM frameworks, according to the annual report of 2020. The board of directors prioritises the top risks. The new risk management system of ProRail will apply more elements of the ERM approach (ProRail, 2020). Every annual report of ProRail mentions ERM explicitly in the risk management chapter since 2013.	The annual reports, 2018 and 2019, of Connexxion do not mention the use of an enterprise or holistic risk management approach.	The 2015 annual report mentions ERM for the first time. The NS would adopt the COSO ERM approach (NS, 2015). The following year, the annual reports state that there was still no system or tool for the integrated risk approach or ERM in place (NS, 2016). The 2017 annual report announces a newly selected system for the ERM (NS, 2017). In 2018, the annual report stated that the NS uses an ERM methodology (NS, 2018). The annual report after 2018 does not mention enterprise risk management anymore. In 2019 it was replaced by integral risk management (NS, 2019a). The 2020 annual report does not mention integral nor enterprise risk management (NS, 2020).

The interview results and the analysis of the annual reports show that both ProRail and NS use the ERM approach. Both organisations have adopted the COSO framework as guidance for their enterprise risk management function. However, in recent year's NS stopped using the ERM terminology to address their risk management and started to call it an integrated risk approach. The core principles of ERM are still present according to the working definition of ERM of this research: 'Enterprise risk management approaches risk management from a holistic perspective to support the strategy from an enterprise-wide basis, to manage risks and identify opportunities'. Firstly, the ERM function needs to be holistic. A holistic risk approach is comparable with an integrated risk approach. Secondly, it needs to support the decision-making process of the C-suite. According to the NS case interview, both the risk management and internal audit department report directly to the C-suite of the NS. Thirdly, the risk management function needs to focus on risks and opportunities. It was not clear from the desk research and the interview whether the NS focuses on the opportunity part of de ERM methodology. Hence, the NS is an organisation that applies a lot of the ERM principles but possibly lacks the focus on seeking opportunities. ProRail, on the other hand, is a bit strayed from the ERM philosophy in recent years. The holistic enterprise-wide principle of addressing risks is disappearing slowly. Therefore, ProRail wants to implement a new risk management system that will incorporate more elements of the ERM methodology, which ones are not clear though. Hence, this research deems ProRail as an organisation that applies ERM but does not enforce the methodology strictly. The new system may change this.

A clear result from the case study is that Connexxion does not actively use the ERM methodology for its risk management. However, Connexxion possesses some characteristics of the ERM methodology naturally. The size of the organisation demands an integrated risk management approach. Hence, Connexxion complies with the first principle. Siloed risk management is not possible for Connexxion due to its limited size. Consequently, Connexxion addresses risk in an integrated manner because management can oversee the risks of the entire organisation as it is such a small organisation. The compliance to the holistic ways of ERM is more out of necessity than the commitment to an ERM framework. The limited number of employees requires employees who are multi-disciplinary skilled. Additionally, the size of the organisation determines the business culture and the adoptability of ERM. Larger organisations are more likely to have a silo business structure because the C-suite cannot oversee everything in an organisation with thousands of employees. Therefore, large enterprises need to actively push for the implementation of ERM to keep the C-suite up-to-date on the top risks. Smaller organisations are more integrated and automatically work according to a holistic approach. Smaller rail organisations lack the resources to implement specialised methodologies and hire the associated qualified employees, like ERM. It is for them difficult to change risk approaches because it will not generate added value for them in the short term. The larger passenger operating organisations have adopted ERM in some way or another. They have the resources to create completely new risk management systems, like the NS and ProRail are doing at the moment.

The aforementioned expert interviewees, from subsection 4.2.2, have limited insight into whether Dutch rail organisations use the ERM methodology. Therefore, two of the interviewees could not say for sure if this is the case. They could only make an educated guess. The technology risk professional works with Dutch rail companies and confirms the use of ERM by his clients (see Appendix C.5). A larger rail organisation applies the methodology of ERM within its organisation. In the meantime, smaller rail companies use the philosophy of ERM but are not committed to ERM. The resources and willingness are lacking by smaller organisations, leading to smaller risk and compliance departments. Larger risk departments can increase the ERM maturity of an organisation by implementing and enforcing the three principles of the working definition. The experiences of the professional interviewee correspond with the insights from the case study results. Additionally, an interviewee notes that the country of origin from the parent company of Dutch rail companies influences the maturity of the ERM implementation. If the parent company uses ERM because it is mandatory, it will influence the subsidiary

The key insights this sections provides are:

The largest passenger operator and the only rail infrastructure operator in the Netherlands use ERM frameworks, ISO 31000 and COSO ERM. However, in recent years the maturity and the strict enforcement of ERM has declined within these organisations. Smaller passenger operators lack the resources and commitment to adopt ERM, but their integrated nature allows them to have an integrated risk management function.

5.2.2. The use of data-driven work

Table 5.2 presents the results of the case study analysis on the use of data-driven work. The table represents two analyses: 1) the use of data-driven work according to the case interviewees, and 2) the use of data-driven work according to the annual reports. The rest of the subsection focuses on the interpretation of the case study results and compares the three cases. A key finding concludes the subsection.

Table 5.2: Case study results of the use of data-driven work

	ProRail	**Connexxion**	**NS**
Interviews	Within the organisation, maintenance and asset management are the business units that are already data-driven. Asset management develops models to predict infrastructure failures with input from sensors. ProRail generates input data from the infrastructure and receives additional data from operators. A focal point is defining data ownership. The awareness of data risk differs per business unit. In addition, the amount of data used for work processes determines the data awareness of the business units. Not creating a proper setup for the use of data-driven work in advance is a risk. ProRail has a data lab that prevents this risk. (Appendix C.1)	Using data-driven work is a point of attention for Connexion. The area of risk quantification can gain a lot from data-driven work. Currently, Connexxion uses data to assess the key performance indicators. Although Connexxion has a lot of data, the question lies in whether the data is usable and whether the company possesses the capabilities to interpret the data. An opportunity for data-driven work is identifying areas where data is missing. Both quantitative and qualitative data is needed. Interpreting quantitative data requires context. (Appendix C.3)	Data is important for the NS. The NS has a strategy to become a data-driven organisation and support the decision-making process with data. In addition, the daily operation of the NS depends on data for maintenance, planning etc. The NS uses both qualitative and quantitative data. The operational data is mostly quantitative. The qualitative data originates from cameras and drones to identify dangerous situations or safety risks. The NS is not very far with its implementation of the strategy for a data-driven organisation. The first step of the strategy is creating a framework to assess the data-driven maturity of departments. The NS finished this framework recently. (Appendix C.6)

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Table 5.2 – continued from previous page

	ProRail	Connexxion	NS
Desk research	The 2020 annual report of ProRail devotes a small section to data-driven work. From 2020 the ICT department is responsible for the development and implementation of data-driven work (ProRail, 2020). In 2019 ProRail describes the multi-year plan for the development of a more data-driven ProRail (ProRail, 2019). 2019 is also the first year that the annual report mentions data-driven work. In the previous years, they only talked about data analysis and data collection.	The use of data-driven work is not mentioned explicitly in the annual reports. However, the annual reports present the performance of Connexxion regarding their KPIs. This assessment requires the use of data, both data from Connexxion itself but data about the national average scores on the KPIs. Furthermore, one of the goals of Connexxion is to monitor the realisation of policies by generating management information (Connexxion, 2019)	All the annual reports of the NS describe the use of data for the monitoring of the KPIs. Trend analysis uses data, and the data quality is also analysed (NS, 2017). In the last two years, the annual reports explicitly contained the words data-driven. The 2019 annual report labels the data-driven concept as a strategic pillar. The NS needs to invest in the transition to become data-driven (NS, 2019a). The reason for the transition is the quickly changing context in which the NS operates. An agile, digital, and data-driven organisation can increase efficiency and effectiveness to improve financial results (NS, 2020).

The interviews results and the analysis of the annual reports show that all three cases use data-driven work. The extent to which they use data-driven work differs between them. The baseline is the use of data for the monitoring of key performance indicators (KPIs). Connexxion is the less developed rail company between the three cases regarding data-driven work. The use of data does not exceed the KPIs. Connexsion's KPI assessment uses both internal and external data. The internal data reflects the performance of Connexxion. The external data is to benchmark Connexxion's performance against that of other rail organisations. Data-driven work is a point of attention for Connexxion. Although Connexxion gathers some data, the question is whether the data is usable to improve business processes and if Connexxion possesses the processing capabilities. The aim is to increase the monitoring capabilities with data-driven work to assess the business goals.

The NS is the opposite of Connexxion regarding the use of data-driven work. In the last two annual reports, NS explicitly mentions their desire to use data-driven work. It even became a strategic pillar for the future of NS. The interviewee even confirmed the existence of a long-term strategy to become a data-driven organisation. Currently, NS uses data for its trend analysis and analysis to assess the quality of the data. NS uses data-driven work but aims to increase it to become a data-driven company. It will help them in the future with a rapidly changing business environment. However, at the moment, the NS just started its transformation.

ProRail is more like the NS. Multiple departments use data-driven work but not all. The main issue that ProRail faces is the ownership and the corresponding responsibilities. However, as of this year, the ITC department is responsible for adopting data-driven work within ProRail. With this, ProRail commits to a data-driven future for its business processes. The case study shows a division between the three rail companies. Large organisations possess the capabilities and resources to make progress

in business innovation, such as data-driven work. Smaller organisations lack the capability to fully utilise the benefits of data-driven work.

From the perspective of the aforementioned expert interviewees (subsection 4.2.2), the rail sector makes extensive use of data. The professional from the ministry states that data-driven work is not something of the last decade, but organisations rely on information for centuries. However, technology enables data-driven work to use a new way to process, analyse and collect data. The sheer volume of data is rapidly growing (see Appendix |C.3). The two professional interviewees from EY both acknowledge the extensive use of data-driven work within the Dutch rail sector. Travel behaviours of passengers are monitored and predicted with data. In addition, the input for the assessment of the KPIs is data. Missing data sources indicate that failures can also emerge from data. For example, no check-in or check-out data means a problem with the passenger registration system (see Appendix C.2 and C.5). Although data-driven work is used, there is still some ground to win. The data-driven processes need to be extensively thought through (see Appendix C.2). Otherwise, there is a risk that incorrect input is used for decision-making (see Appendix C.3). The reflection of the professionals on the sector shows that the Dutch rail sector uses data-driven work. However, sometimes the use of data is seen as normal and not especially data-driven.

The key insights this sections provides are:

All rail organisations in the case study use data-driven work to some degree. However, to what extent depends on the size of the organisation. Larger rail companies possess more resources and capabilities to implement data-driven work in more places within their organisation. As a result, larger companies are committing to increase data-driven work in the future. The smaller rail organisations are not fully aware of the possibilities and lack the resources to evolve as fast as the larger ones.

5.2.3. The use of data-driven ERM

Table 5.3 presents the results of the case study analysis on the use of data-driven ERM. The table represents two analyses: 1) the use of data-driven ERM according to the case interviewees, and 2) the use of data-driven ERM according to the annual reports. The rest of the subsection focuses on the interpretation of the case study results and compares the three cases. A key finding concludes the subsection.

Table 5.3: Case study results of the use of data-driven ERM

	ProRail	**Connexxion**	**NS**
Interviews	ProRail uses data-driven risk management to a certain extent. The advantage of data-driven risk management is the possibility to real-time monitor risk controls. The quality of the data is the biggest risk for data-driven ERM. The output of the risk assessment is the input for the risk monitoring systems. This results in a self-enforcing feedback loop. Incorrect data can shift the focus of the feedback loop away from the real pressing risks. Furthermore, well-thought-out designs of risk management systems reduce the impact of a data overload. The use of data-driven stands and falls on a good understanding of the business processes behind the data. (Appendix C.1)	Using data-driven work in the risk management of Connexxion is something of the future. However, it is a goal for Connexxion to increase the use of data. Data-driven risk management has three advantages for the Connexxion organisation. Firstly, using data will reduce risks and prevent them. Data increases the predictive abilities of events and incidents. Secondly, data gives personnel insights into their behaviour. The insights improve the training and education opportunities of staff members. Thirdly, data can confirm the intuition of the professional. (Appendix C.3)	Using data-driven risk management ensures a better risk identification. Data-driven work also improves the prioritisation of the identified risks because it improves the impact assessments. In addition, real-time data improves the quality of decisions because real-time data supports the decision-making process with the most accurate information. The challenges of data-driven risk management is the need for employees with the right skills set and training programs for the employees. In addition, data-driven work creates a lot of data, filtering the right data is key. (Appendix C.6)
Desk research	The 2020 annual report of ProRail mentions the data-driven work to control one of the top risks: management information and reporting ProRail, 2020. The annual report of 2020 mentions a data-driven solution in the risk management chapter of ProRail for the first time.	The annual reports do not specifically describe the use of data for any risk management system.	Currently, the NS already uses data for monitoring risk and controls NS, 2020.

The interview results and the analysis of the annual reports show that data-driven (enterprise) risk management is still in its infancy. The two larger rail organisations, ProRail and NS, use data to monitor their risks and the effectiveness of the risk controls in real-time. For Connexxion, real-time data-driven risk management is something for the future. Connexxion uses data for their assessment, but they do not use the full potential of data-driven work in their risk management function. However, Connexxion sees added value in data-driven work for its risk management. It will reduce and prevent risks. In addition, data-driven work provides insight into the behavioural risk of employees. The behavioural insights are input for training and education of staff. Lastly, data-driven work can support the intuition of risk professionals. Currently, Connexxion is not using data to achieve these three points. Both ProRail and the NS are a bit further in implementing data-driven work in their ERM, but not very much. The NS sees data-driven work as an added value to ERM because it prioritises the impacts of the risks better. At the moment, all three cases use data for one part of ERM, namely preventing risks. Finding opportunities is still lacking. In addition, there are also some challenges to using data-driven work. ProRail emphasises the feedback loop mechanisms of risk management. Risk assessments provide risk areas. Risk controls manage these risk areas. The monitoring of risk controls creates data regarding the risks, which is input for future risk assessments. Incorrect input data may cause underestimation of risks. A well-structured design of the use of data-driven work in ERM prevents it. The NS warns of an overload of data. Finding the right data from this mountain of information is a challenge. The difference between larger and smaller organisations is their capabilities and willingness to adopt both data-driven work and ERM.

The aforementioned professionals, from subsection 4.2.2, from were asked about the benefits and disadvantages of data-driven ERM. The cybersecurity expert from EY sees the functionality of data-driven risk management as an advantage and disadvantage. Data-driven risk management creates a baseline to identify risks. However, more data points mean less visible deviation. Deviations are only recognisable on a case basis. The edge cases disappear in the baseline when the design of data-driven ERM processes is poor. The upside of data-driven ERM is the predictive abilities. Historical data provides insights into how to prepare for risks (see Appendix C.2). According to the risk consultant from EY, predicting risk development based on trends and other analyses is the advantage of data-driven ERM. However, the mindset is a challenge. One should not assume that datasets are complete and solely rely on data-driven ERM. Data-driven ERM cannot identify every risk. There are always black swans. Therefore, the unknown risks in missing data is a big challenge of data-driven ERM. In addition, the risk consultant does not see clients being far in the implementation of data-driven ERM (see Appendix C.3). The professional from the ministry sees data quality as the challenge of data-driven ERM. When using data-driven ERM, safeguarding the confidentiality, integrity, and availability of data is important. The advantages are the scalability of data-driven ERM and creating an overview of complex situations (see Appendix C.3).

The key insights this sections provides are:

The (enterprise) risk management of all rail organisations in the case study is slightly data-driven. The organisations use data for the monitoring of risks and risk controls. However, data-driven work is not used to its full potential by all three companies. The advantage of data-driven enterprise risk management is risk predicting abilities. The disadvantages are incorrect risk assessment due to poorly designed processes and the unawareness of unknown edge cases that are in missing data.

5.2.4. The added value of data-driven ERM for the operational risk of extreme weather

Table 5.4 presents the results of the case study analysis on the added value of data-driven ERM for the operational risk of extreme weather events. The table represents two analyses: 1) the added value of data-driven ERM for the operational risk of extreme weather events according to the case interviewees, and 2) the added value of data-driven ERM for the operational risk of extreme weather events according to the annual reports. The rest of the subsection focuses on the interpretation of the case study results and compares the three cases. A key finding concludes the subsection.

Table 5.4: Case study results of the added value of data-drievn ERM for the operational risk of extreme weather

	ProRail	**Connexxion**	**NS**
Interviews	Weather events are a difficult risk for data-driven enterprise risk management from a ProRail perspective. At ProRail, it is more about preventing infrastructure failures due to weather events. Data-driven work plays an important role in analysing the data generated by the infrastructure to locate weaker parts of the rail infrastructure that can fail during an extreme weather event. (Appendix C.1)	Extreme weather events are not a big risk for Connexxion. The operation of Connexxion is quite simplistic and is, therefore, more robust against weather disruptions. The availability of the rail infrastructure during an extreme weather event is a risk for Connexxion. Connexxion depends on ProRail for this specific risk. If the infrastructure fails, it is not possible to operate for Connexxion. (Appendix C.3)	NS can use data-driven ERM to combine different data sources to predict the impact of upcoming weather events. Data-driven ERM makes the response to weather events quicker and more precise. In addition, NS can warn passengers in advance to minimise inconvenience. (Appendix C.6)
Desk research	Extreme weather events, like a heatwave, are disruptive for the train table. However, ProRail has a system that informs chain partners of disruptions (ProRail, 2020).	The annual reports of Connexxion do not mention the risk of disruptions due to extreme weather. However, the annual reports of Connexxion do describe the risk controls of disturbances. For example, agreements with ProRail regarding incident control (Connexxion, 2019)	Although extreme weather or climate is not part of the top risks of the NS, the annual report contains various risk controls to prevent disturbances in the train table. For example, replacing materials to withstand periods of extreme heat better is one of the risk-reducing measures. In addition, NS considers the use of vegetation to reduce heat stress and flooding (NS, 2020).

The interview results and the analysis of the annual reports show that the operational risk of extreme weather is not evenly important amongst the three cases. ProRail does not consider extreme weather events as a risk to their operation. However, extreme weather events trigger weakened elements of

the rail infrastructure to a failing point. Data-driven enterprise risk management can be helpful with the identification and prediction of failing infrastructure. Currently, ProRail is researching methods to collect this kind of input data. In addition, ProRail uses systems to alert chain partners of rail disruptions during extreme weather events. Although NS does not consider extreme weather events a top risk for the organisation, they prepare their equipment to reduce failure due to extreme weather events. In addition, NS researches the effects of vegetation regarding heat stress and flooding risks. NS also thinks that data-driven ERM can help with predicting the impacts of extreme weather events. Hence, their response will be quicker and more precise. In contrast, Connexxion does not perceive extreme weather events as a risk for their operation. The operation of Connexxion is simple and not too complex. Therefore, it is more robust to disturbances. The rail operation of Connexxion focuses on a couple of routes. Restarting the rail operation after disruption is easier for Connexxion than it is for NS, which has a nationwide network. The operational risk of extreme weather is not directly a risk for the cases. The failing of the infrastructure is the underlying risk. The rail operators cannot influence the maintenance of the rail infrastructure. Smaller operators with a less complex operation are more robust against disturbances than larger operators with complex and interconnected rail operations.

Data-driven enterprise risk management is of added value for planning and predicting operational disturbances due to extreme weather events. However, rail organisations do not see extreme weather events as a top risk. The infrastructure operator sees the exposure of weakened infrastructure to extreme weather as a maintenance risk. In addition, operators see failing infrastructure due to extreme weather as an external risk owned by ProRail. Data-driven ERM is of great importance for predicting and planning operational disturbances due to extreme weather events (see Appendix C.2 and C.5). The interviewee for the ministry had less insight into the added value of data-driven ERM on an operational risk as extreme weather events.

The key insights this sections provides are:

Data-driven enterprise risk management is of added value for planning and predicting operational disturbances due to extreme weather events. However, rail organisations do not see extreme weather events as a top risk. The infrastructure operator sees the exposure of weakened infrastructure to extreme weather as a maintenance risk. In addition, operators see failing infrastructure due to extreme weather as an external risk owned by ProRail.

5.2.5. The added value of data-driven ERM for the strategic risk of competition

Table 5.5 presents the results of the case study analysis on the added value of data-driven ERM for the strategic risk of competition. The table represents two analyses: 1) the added value of data-driven ERM for the strategic risk of competition according to the case interviewees, and 2) the added value of data-driven ERM for the strategic risk of competition according to the annual reports. The rest of the subsection focuses on the interpretation of the case study results and compares the three cases. A key finding concludes the subsection.

Table 5.5: Case study results of the use of data-driven work

	ProRail	**Connexxion**	**NS**
Interviews	ProRail does not have competitors as an infrastructure operator and traffic control. Therefore, there is no added value of data-driven enterprise risk management in this case. (Appendix C.1)	Data-driven work has added value regarding the risk management of the competition. Concession tenders require a lot of data from the organisation that register for them. Winning a previously owned concession requires Connexxion to analyse their data, which is plenty. The possession of this data is a competitive advantage. Competitors do not possess the historical data of the previous concession holder. Therefore, an offensive concession tender requires creativity and innovation. Furthermore, the tender owner demands a lot of data to support statements of the tender participants. (Appendix C.3)	NS needs to keep up with possible competitors and innovations to maintain the monopolistic status. It cannot afford to lose the main track concession in the future. However, NS does not experience direct competition. But due to its monopolistic nature it operates in the spotlights, meaning that its performance is under a magnifying glass. (Appendix C.6)

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Table 5.5 – continued from previous page

	ProRail	Connexxion	NS
Desk research	The annual reports do not mention the competitive position of ProRail.	Besides the corona crisis, the developments regarding a tender of one of the concessions held by Connexxion was a focus point for 2020 (Connexxion, 2019). It shows the focus of Connexxion on it competitive position.	The annual reports of NS do not mention the competitive position of the NS. Each year the competitive situation of the subsidiary, Abellio, is discussed in the annual reports. The NS aims to learn from the competition that Abellio faces. The 2014 annual report sees competitiveness as a low and regular business risk. Consequently, there is no necessity for risk controls that reduce the risk (**NS2014**). Competition is not mentioned once in the annual report of 2020. The only thing related to this is that the government has awarded the NS the concession for the main track for the period after 2024 (NS, 2020). As a result, there is no competition for NS regarding their monopolistic market share.

The interviews results and the analysis of the annual reports show that the strategic risk of competition only applies to Connexxion. As an asset, maintenance and traffic managing organisation, ProRail does not have competitors. The Dutch government had designated ProRail as the organisation that needs to perform these tasks. In addition, NS is already given the main track concession for the period after 2024. Currently, they do not compete with other operators over the main track concession. Up until now, there was no tender for the main track concession. It is privately given to NS every time. The only competition that NS encounters is through the Abellio subsidiary, which is active abroad. However, NS perceives pressure to innovate to beat possible competitors in the future. In the meantime, Connexxion competes with other smaller passenger operators over regional concessions. Data is key during the tender procedures of these regional concessions. Previously owned tender concessions benefit from the use of historical data of the previous concession period. Competitors do not possess this data, meaning a competitive advantage. The tender of a new concession asks for creativity due to the lack of data. Using data-driven ERM for the strategic risk of competition position is only applicable to Connexxion.

From the perspective of the aforementioned experts (subsection 4.2.2), the rail sector benefits from using data-driven ERM for strategic risk as a competitive position. The cybersecurity and technology risk experts from EY are united in their response. Data-driven ERM has its added value during tenders.

Communicating KPI results require historical and predictive data, such as punctuality and customer satisfaction rates. The tender process compares the scores of the KPIs of the applicants. Using data to prepare tender applications reduces competitive risks and creates new business opportunities (see Appendix C.2 and C.5). The interviewee for the ministry had less insight into the added value of data-driven ERM on a strategic risk as a competitive position.

The key insights this sections provides are:

Data-driven enterprise risk management is of added value for regional tenders. Smaller operators gain better insights into their key performance indicator scores by using data. Well-informed tender applications reduce competitive risks and create new business opportunities. Data-driven enterprise risk management does not have added value for ProRail and NS because they do not have competitors at the moment.

5.2.6. The differences in adoption of data-driven enterprise risk management based on the organizational structure

Table 5.6 presents the results of the case study analysis on the differences in adoption of data-driven enterprise risk management. The table represents two analyses: 1) the differences in adoption of data-driven enterprise risk management according to the case interviewees, and 2) the differences in adoption of data-driven enterprise risk management according to the annual reports. The rest of the subsection focuses on the interpretation of the case study results and compares the three cases. A key finding concludes the subsection.

Table 5.6: Case study results of the differences in adoption of data-driven enterprise risk management

	ProRail	**Connexxion**	**NS**
Interviews	Data-driven work increases the efficiency of an organisation. State-owned organisations are cost-focused. On the other hand, private organisations are more profit-oriented. The increase in efficiency causes more profits. Better insights in maintenance reduce material failures, which increases income. Data-driven enterprise risk management is profitable for private organisations because it improves predictive risk controls, which increase efficiencies. (Appendix C.1)	It is not a matter between private and public organisations. The resources of the organisation determine the adoption of data-driven work in risk management. Culture is another aspect. The culture of NS is silo driven, whereas the culture of Connexxion focuses on the integrated structure. Connexxion assesses risk from multiple perspectives due to its integrated business culture. Furthermore, state-owned companies are less profit-driven, therefore, are more likely to invest in innovations such as data-driven work. The size of the organisation is the key driver of the differences. However, it is hard to challenge the larger rail companies. An example is the main track concession, which the Dutch State granted to the NS without a tender. As a result, NS retains its large market share. (Appendix C.3)	The interviewee could not answer this question. An explanation for the differences could be the added pressure on the NS by stakeholders. This makes the NS reluctant to lead the wolf pack. (Appendix C.6)

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Table 5.6 – continued from previous page

	ProRail	Connexxion	NS
Desk research	ProRail aims to increase its efficiency by investing in innovations. The Datalab is one department that focuses on innovations. Datalab stimulates the digitalisation of ProRail (ProRail, 2020).	The annual reports do not mention efficiency or the adoption of innovation.	The 2020 report describes the goal of increasing data-driven work within the organisation. Furthermore, the NS has set aside budgets to address risks. The NS has the goals and the resources to adopt data-driven enterprise risk management. The NS implements probabilistic planning and analysis to make risks more explicit and gain better insights into the risk budgets (NS, 2020).

The interviews results and the analysis of the annual reports show that the size and resources of organisations determine the ability to implement data-driven ERM and not the ownership structure of the organisations. The interviewees were only able to assess the rest of the sector from their perspective. The interviewee of ProRail sees more added value of data-driven ERM for privately owned rail companies than for publicly owned companies. Private organisations are profit-driven and aim to optimise efficiency to maximise the revenue of each invested euro. Data-driven ERM increases the risk predicting capabilities of an organisation, resulting in a better allocation of resources. The use of materials, e.g. trains, can be optimised. Hence, replacing equipment on time results in fewer material failures and more income in the end. The interviewees of Connexxion share the same view of maximising the profit of each invested euro. However, the larger rail organisations in the Netherlands have more resources to invest in innovations and data-driven ERM due to their sheer size. The size advantages stem from the history of the Dutch rail sector, with the rail sector monopoly of the NS until the nineties. Both ProRail and the NS have committed to making their operation more efficient through the use of data in the coming years. This commitment to innovation requires budget and investment. The budgets are included in the annual reports of both companies for data-driven innovation and improving risk management. Connexxion lacks the resources to keep up with the implementing pace of the larger Dutch rail organisations.

The aforementioned professionals, from subsection 4.2.2, expect that organisations affiliated with the government will be less likely to implement innovations due to the high degree of bureaucracy. Privately owned organisations are profit-driven and seek innovations to increase effectiveness and efficiency. Publicly owned organisations are social-driven. Providing a public good or a good in the interest of the public is more important than revenues. (see Appendix C.2 and C.3). However, the rail sector is different. The ownership structure is not important. The NS is the most advanced Dutch rail company regarding the implementation of data-driven work. The size organisation and the scale of the operation determine the adoptability of data-driven ERM. The government-affiliated organisations, ProRail and the NS, have large budgets to invest in innovations like data-driven ERM. In addition, government-affiliated organisations are less likely to go bankrupt due to failing policies. The government guarantees the survival of the companies to protect their shares and the critical infrastructure. (see Appendix C.5).

The key insights this sections provides are:

The adoption difference is not caused by a difference in ownership structures, public or private, of the rail companies. The number of resources and the willingness to collect funds causes the difference. The state-owned rail organisations are large organisations with lots of resources, whereas privately-owned rail organisations have fewer resources at their disposal but will profit the most from the adoption of data-driven enterprise risk management. The scale of the organisation determines the adoption of data-driven enterprise risk management.

5.3. Chapter summary

This chapter discussed the results of the case study analysis. The chapter provided a framework to systematically approach the presentation and assessment of the case study results. The framework discusses all six case study elements separately; the unit of analysis, the subunits of analysis, two example risks, and the case comparison. The framework first looks at the results of the case interviews. After that, the framework presents the results of the desk research. The third step is an interpretation of both results, which is placed in perspective by the expert interviews. The end result of this chapter is six key insights. The next chapter will discuss these findings.

The six findings also contribute to answering the four sub research questions on which this chapter focused. The first sub-question is: 'To what extent are Dutch railroad companies using data-driven work for their enterprise risk management?' The (enterprise) risk management function of rail organisations related to passenger transport in the Netherlands does not data-driven work to its full extent. Data-driven work has an added value to rail organisations. However, the larger rail organisations are just starting to set goals for the implementation of data-driven work. A lot of ground can be won regarding data-driven ERM in the near future.

The second sub-question is: 'What are the risks and opportunities of using data-driven work for the risk management of Dutch rail organisations?' The risk of implementing data-driven work into the ERM function is incorrect risk assessment due to poorly designed processes. These processes cannot guarantee the quality of the input of the risk assessment. Additionally, deeming data-driven ERM systems complete and flawless is a big challenge because it creates blind spots for a black swan or even a gray rhino event.

The third sub-question is: 'To what extent do organisations differ in their adoption of data-driven enterprise risk management?' It is hard to pinpoint the root cause of the difference between the rail organisation regarding the adoption of data-driven ERM. It is easy to pull 'the lack of resources' card. Although smaller semi-private owned organisations lack the resource and/or necessity to adopt data-driven ERM, they are the ones that will profit the most from the implementation.

The fourth sub-question is: 'Why should Dutch rail organisations implement data-driven enterprise risk management?' The added value of data-driven ERM is that it prioritises the impacts of risk better and more precisely. A second added value is that it improves the predictive abilities of the ERM function, which results in better and quicker risk responses. The regional operators benefit from data-driven ERM because they can compete better with competitors if they complete and current data.

6

Discussion

This chapter aims to discuss three themes: the findings, the overall explanation of why organisations differ, and the research limitations. Section 6.1 interprets the findings from the case study analysis with academic literature and assesses whether the findings are supported in the literature. Section 6.2 discusses two possible explanations for why the three rail organisations differ in the adaptation of data-driven ERM. Section 6.3 elaborates on the research limitations of this research. This section aims to understand how research choices and circumstances influence the conclusions of this research. Section 6.4 translates the research limitations into future research recommendations.

6.1. Interpretation of the findings

The interpretation of the results follows the same order as the results chapter. All six results are interpreted individually. The interpretation analysis examines whether the findings have any substantiation in the academic literature.

Finding 1
'The largest passenger operator and the only rail infrastructure operator in the Netherlands use ERM frameworks, ISO 3100 and COSO ERM. However, in recent years the maturity and the strict enforcement of ERM has declined within these organisations. Smaller passenger operators lack the resources and commitment to adopt ERM, but their integrated nature allows them to have dent an integrated risk management function.'

The ERM body of knowledge confirms the assumption that not all organisations profit from the implementation of ERM (Hiebl et al., 2019). Implementing ERM requires investments from organisations (Yakob et al., 2020). Therefore, the added value of ERM for the organisation needs to be equal to or larger than the investment costs. Furthermore, smaller organisations "...are less likely to utilize formal risk management frameworks due to the limited availability in required expertise" (Silva et al., 2013, p.289). The resource sizes matter in the implementation of ERM, both financial as human. The first finding of this research has substantiation in the literature. It is, therefore, plausible that smaller organisations are less likely to use ERM due to the associated investment costs and the use of knowledge.

Finding 2
'All rail organisations in the case study use data-driven work to some degree. However, to what extent depends on the size of the organisation. Larger rail companies possess more resources and capabilities to implement data-driven work in more places within their organisation. As a result, larger companies are committing to increase data-driven work in the future. The smaller rail organisations are not fully aware of the possibilities and lack the resources to evolve as fast as the larger ones.'

The academic literature confirms the assumption that data-driven work is an iterative process (Beryl et al., 2012). There are no companies that do not use data anymore. In addition, the commitment to improve the data-driven work processes of an organisation requires large investments (De Luca et

al., 2012). Organisations with large investment resources can adapt earlier to data-driven work. The investment budgets of Connexxion are smaller than those of ProRail and NS, explaining the backlog. However, the resources needed are not only financial. Implementing data-driven work requires human investment, training of employees, and investment in culture, change to data-focused work processes (Kiron, 2016). The second finding of this research has substantiation in the literature. Therefore, smaller organisations are less likely to use data-driven work because they lack knowledge about data-driven work. Additionally, they lack the incentive or willingness to invest in the development of data-driven work.

Finding 3
'The (enterprise) risk management of all rail organisations in the case study is slightly data-driven. The organisations use data for the monitoring of risks and risk controls. However, data-driven work is not used to its full potential by all three companies. The advantage of data-driven enterprise risk management is risk predicting abilities. The disadvantages are incorrect risk assessment due to poorly designed processes and the unawareness of unknown edge cases that are in missing data.'

The interpretation of the third finding focuses on the second part of the finding, the advantages and disadvantages of data-driven (enterprise) risk management. The use of data-driven work and ERM is already discussed with the interpretation of the first two findings. The benefit of data-driven risk management is the ability to assess risks and predict them. Data-driven work can link historical data and risk incidents to create predictive capabilities based on the available data (Nlenanya and Smadi, 2018). However, this is also a challenge. Data-driven work is useful for predicting average risks. It is impossible to predict edge cases based on previous data (Skonieczny et al., 2019). Otherwise, it would not be an edge case. The main advantages and disadvantages found in this research are backed up by academic literature. Although, the body of knowledge regarding data-driven enterprise risk management is very marginal. It is, therefore, difficult to put the third finding in an academic perspective. However, the use of data-driven work in ERM adds value to the risk management function but at the same time creates new challenges.

Finding 4
'Data-driven enterprise risk management is of added value for planning and predicting operational disturbances due to extreme weather events. However, rail organisations do not see extreme weather events as a top risk. The infrastructure operator sees the exposure of weakened infrastructure to extreme weather as a maintenance risk. In addition, operators see failing infrastructure due to extreme weather as an external risk owned by ProRail.'

The academic literature partly confirms the assumption of finding four. The added value of data-driven (enterprise) risk management is not only in the predictions of risk in advance. Data-driven work enables real-time processing abilities, especially for operational risks evolving disasters, which in some cases can be extreme weather (Araz et al., 2016). The real-time processing capabilities are as important as the predictive capabilities. The strategic behaviour of shifting the blame within the Dutch rail sector regarding extreme weather disturbances caused slight differences between the finding and the general academic literature. Infrastructure operators, like ProRail, use real-time data to predict future failures. Real-time tracking of failing infrastructure failures does not reduce the risks of weather-related disturbances. However, combining the real-time knowledge with predictive capabilities reduces risk because failing infrastructures are replaced on time. For this reason, it is difficult to put the third finding in an academic perspective. However, the use of data-driven work in ERM adds value to the risk management function but at the same time creates new challenges. Therefore, data-driven ERM adds value to the maintenance responsibilities of ProRail.

Finding 5
'Data-driven enterprise risk management is of added value for regional tenders. Smaller operators gain better insights into their key performance indicator scores by using data. Well-informed tender applications reduce competitive risks and create new business opportunities. Data-driven enterprise risk management does not have added value for ProRail and NS because they do not have competitors at the moment.'

The academic literature confirms the assumption of finding five. However, a key element of the assumption is skipped. Data-driven ERM not only aims to reduce risks but also to seize opportunities (Mishra et al., 2019). Using Data-driven ERM for a strategic competitive risk is focused on both reducing losses of market position but also increasing market share. Relating to the concessions in the rail sector: defensive concession bids are risk-reducing, and offensive concession bids are seizing opportunities. In addition, data-driven work increases the quality of tender bids (Bilal and Oyedele, 2020). The fifth finding of this research has substantiation in the literature but is incomplete. Accordingly, smaller organisations experience the most added value of data-driven ERM for competitive risks. However, according to earlier findings, smaller rail organisations are less likely to use ERM.

Finding 6
'The adoption difference is not caused by a difference in ownership structures, public or private, of the rail companies. The number of resources and the willingness to collect funds causes the difference. The state-owned rail organisations are large organisations with lots of resources, whereas privately-owned rail organisations have fewer resources at their disposal but will profit the most from the adoption of data-driven enterprise risk management. The scale of the organisation determines the adoption of data-driven enterprise risk management.'

The academic literature is indicative of the difference between public and private organisations investing in innovations. There is literature suggesting that the ownership structure of an organisation does not influence the adoption of innovative developments. Organisational factors such as performance, size, and investments determine the likelihood of adapting to innovations (Demircioglu and Audretsch, 2017). The other train of thought is that public organisations invest way more into research and development, in other words, innovation, than their private counterparts (Acharya and Xu, 2017; Feldman et al., 2021). The academic literature cannot clarify whether the availability of resources and the willingness to use resources are the root cause of the differences. The jury is still out about an explanation of the different adoption maturities of data-driven ERM in the Dutch rail sector. Therefore, section 6.2 presents two alternative explanations of the differences between the cases regarding the adoption of data-driven ERM besides the resource argument.

6.2. Alternative explanations for differences between organisations

The results of the case study analysis show clear differences between large state-owned rail organisations and the much smaller semi-public owned rail organisation, Connexxion. However, the interviewees and the desk research could not find a satisfying explanation for this phenomenon. The resource difference in size itself cannot be the sole explanation, as ERM can add value to small organisations too. Two possible explanations for the difference are: either smaller rail organisations do not believe in the added value of data-driven ERM, or the lack of long-term stability due to concessions reduces the return on investments.

The most obvious explanation for the differences is that smaller rail organisations do not expect data-driven ERM to add value to their organisation. Why should an organisation change its risk management methodology and the associated work processes when its current risk management system already embeds some elements of ERM? In the short term, there is no incentive for them to change. Risk management is still perceived as costing money instead of creating profits for shareholders. Like they say in sports, never change a winning team. However, no innovations or progress equals deterioration. Corporate environments are changing quickly due to rapid technological developments. Organisations operating in rapidly changing business environments focus on innovations and taking risks to adapt to new circumstances (Ebrahimi et al., 2018). Data-driven ERM is an innovative way to address risk management that gives insights into risk areas where taking more risk is possible. Hence, increasing the competitiveness of the organisation. It is in the best interest of smaller rail organisations to commit to a data-driven ERM to safeguard the holistic risk management approach of the organisation. The integrated nature of smaller rail organisations is not set in stone; they will experience increasing bureaucracy and business silos when they grow in the future. It is better to have an ERM system in place that accommodates this possible growth but also shows where there are further growth opportunities. Explaining the adoption difference between the rail organisation by not perceiving added value is short-sided and not future proof.

The second explanation for the differences is that there is no stable foundation to build upon for

Dutch rail organisations. Every rail organisation needs to fight for its place in the market due to the concession right system for passenger transport of the Dutch rail sector, leaving the NS out of consideration. The smaller passenger operator competes with each other on a regional level. This competition is not a stable basis for developing multi-year strategies because they might lose their access rights during the next tender. The return on investment needs to be within the concession period. It is reassuring for the NS and ProRail that they have a stable competitors position (no competitors). Hence, they do not have an operational time limit to return their investment at the moment. The NS already knows it has the 2024 concession for the main track. These certainties make it easier to develop long-term strategies. However, data-driven ERM will also help smaller rail organisations return their investment because proper risk management reduces business instabilities and adds value to the organisation, especially ERM (Crouhy et al., 2014). The results of the case study showed that the data-driven work concept contributes to better tender applications. Smaller rail companies may still be hesitant to implement data-driven ERM because they are in a business environment that is too unstable to adopt major business-changing innovations. This attitude is paradoxical because ERM can help organisations generate more value and stability and improve their competitive position.

6.3. Research limitations

Every research has limitations; this research is no exception to that. Research limitations affect the outcomes of research. Identifying the limitations is part of conducting academic research and offers possibilities for further research (Ross and Zaidi, 2019). The research design of this research has three main limitations.

The first limitation is the scope of the research. The research scope is a limiting factor for the results and the conclusions that follow. Chapter 3 already established that the complexity of the Dutch rail sector due to its history, stakeholder involvement, and its vital function within the Dutch society. , This research misses insights from a transport perspective by solely focussing on the passenger part of the sector. Freight transport is completely different from transporting passengers: other rules for access rights, risks, and stakeholders are involved. Freight transport does not have concession tenders. In addition, there are no safety risks for passengers in freight transport. However, there are safety risks regarding transporting goods. For example, transporting dangerous goods poses enormous safety risks to the entire rail sector because those transports use the same rail infrastructure as passenger trains. The difference within the sector makes it hard to generalise the results of this research to the entire Dutch rail sector. It is feasible to indicate some general insights regarding the passenger transport part of the Dutch rail sector.

The second limitation is the limited sample size of the case study related interviewees. This research included four case related interviewees due to time constraints. Only two of them were with representatives of the same rail organisation. Connexxion provided two interviewees for a double interview. However, it is important to bear in mind that the departments that manage or control risk are often quite small and have little time to conduct interviews. Upper management and the compliance, risk, and audit departments involved in ERM also have a heavy workload. Consequently, it was difficult to arrange multiple interviews with employees working within the relevant departments. Hence, it was not feasible to interview more employees involved with the (enterprise) risk management within the time constraints of this thesis research. Professionals, indirectly linked to the cases and the rail sector, were interviewed to take their overarching perspective into account, to even out the limited number of case interviews. However, they had less sector-specific knowledge as was expected in advance.

The last limitation is the case study selection. The cases of this research are partly chosen based on the availability of contacts within the organisations and the public availability of annual reports. Including more cases would have given more insights into the Dutch passenger rail sector. However, the feasibility of the research limited the number of cases for the case study. In addition, the willingness to participate in this research is also a limiting factor. The same as with the interviewees, not all approached rail organisations were able to give an interview. Fortunately, Connexxion, ProRail and NS were more than willing to participate in the research. However, the characteristics of the cases are very different. ProRail and NS are traditionally large, previously state-owned rail companies. Connexxion, on the other hand, is relatively young and quite small. The resources that the companies have at their disposal differs significantly. This great gap between the organisations also applies to the market shares Connexxion has 1.2 % of the market shares and the NS 85%. However, the research does

show that the history of the rail sector still makes its mark today. But in the end, it is hard to compare the three cases because of their different characteristics. Better comparisons are; 1) critical infrastructure operator, 2) state-owned nationwide active passenger operators, and 3) regional concession owning passenger operators. First of all, benchmarking ProRail with foreign infrastructure operators regarding the data-driven use of ERM. This comparison provides insights into how well ProRail operates as an infrastructure operator. Second, comparing the NS with foreign dominant passenger operator organisations, e.g. Deutsche Bahn, provides a benchmark on the adoption of data-driven ERM by large rail operators. Finally, comparing Connexxion with Keolis or Arriva helps to understand the challenge that smaller organisations have regarding adapting new innovations of methodologies. However, it was not feasible to include all these cases due to the limited duration of the master thesis project. Therefore, the case selection of this research focused on the three cases that span characteristics of the passenger rail operator spectrum. This approach suits the exploratory research design of the research to gain insights into the whole passenger rail sector. As such, this master thesis provides a good starting point for future research.

6.4. Recommendations for future research

Exploratory research ultimately leads to new questions and follow-up studies. This research also yields three follow-up questions and the corresponding future research. The recommendations for further research are based on the interpretations of the research results and the research limitations.

The first suggestion for a follow-up study is to further explore the Dutch rail sector regarding data-driven ERM. This research only focused on passenger transport. The follow-up study can research the use of data-driven ERM in freight transport. It will provide other insights because the market is completely different without a state-sponsored monopoly and concession rights. In addition, also foreign rail operators operate within this part of the Dutch rail sector. The use of data-driven ERM in the Dutch rail sector is best explored when this research and the above-suggested research are combined.

The second suggestion is to benchmark the cases with comparable organizations. The use of data-driven ERM by critical infrastructure asset managing organisations in the Netherlands is an example. ProRail can be compared to TenneT, the network operator of the Dutch electricity grid. Best practices from multiple sectors can provide different insights into possible applications for the rail sector. It could be useful because the use of ERM and data-driven ERM is still in its infancy within the Dutch rail sector.

The third suggestion is to research the root cause of the lack of resources available to dedicate to ERM. The lack of resources is a lack of trust in the investment. Why does management not invest in data-driven ERM? Understanding the reasons for management not to adopt data-driven ERM shows light on the perceived effectiveness and the added value of data-driven work applied in ERM. ‘Which of the two concepts is perceived to not be worthy of the investment?’ investment is a question that future risk may aim to solve.

The last suggestion is to dive into the complexity of the Dutch rail sector and map the risks within the sector in a detailed and quantified way. Instead of interviewing experts involved with ERM, this research should focus on the risk assessment processes of upper management and the risk department of the Dutch rail organisations. The same division that this research uses, freight and passengers, can be applied to fully focus on an in-depth understanding of the Dutch rail sector.

7

Conclusion

This chapter gives the concluding remarks of this master thesis. Section 7.1 answers the six sub research questions and the overarching research question of this research. Following section 7.1.8 gives two policy recommendations regarding the use of data-driven ERM within the Dutch rail sector.

7.1. Answers to the research questions

This research focuses on answering the research question adequately. Answering the research question helps expand the body of knowledge about data-driven enterprise risk management in the rail sector, which was non existing at the time of this research. The research question of this research is:

What is the added value of data-driven work on the enterprise risk management of passenger transporting rail organisations in the Netherlands?

Six sub-questions help to answer the main research question. Each sub-questions either explores the state-of-the-art affair of the research concepts, research context or aims to answer a specific element of the research question. The six sub-question are:

1. What is the state-of-the-art knowledge in ERM and data-driven work?

2. How is the Dutch rail sector organised, and what are the risks rail organisations face in the Netherlands?

3. To what extent are Dutch railroad companies using data-driven work for their enterprise risks management?

4. What are the risks and opportunities of using data-driven work for the risk management of Dutch rail organisations?

5. To what extent do organisations differ in their adoption of data-driven enterprise risk management?

6. Why should Dutch rail organisations implement data-driven enterprise risk management?

All the sub-questions are discussed in the previous chapters. The summaries of the chapters already provided answers to the sub-questions. The first sub-question is answered in chapter 2. The second sub-question is answered in chapter 3. Sub-question three to six are answered in chapter 5 and are discussed in chapter 6. The following subsection presents the conclusions to the sub-questions once again among each other.

7.1.1. What is the state-of-the-art knowledge in ERM and data-driven work?

The state-of-the-art literature review shows some difficulties with ERM and data-driven work. ERM is a novel research area. The main focus lies on the financial sector for its case study research. However, the literature in this area is quite extensive. The review defines ERM as a risk management methodology that looks at risk management from a holistic point of view. In addition, ERM supports the strategic decision-making process to create added value by reducing the impacts of risks and seizing opportunities. ERM has some advantages over traditional risk management. Profitability is the main advantage of ERM. The standardisation and increasing risk awareness of ERM creates a risk culture that is focused on reducing risks and seizing opportunities. Moreover, ERM support decision-makers in their decision-making process by providing them with the top risks of the organisation. However, ERM has its disadvantages. For example, it requires the commitment of the entire organisation to function properly. ERM depends on the involvement of all the aspects of the organisation. In addition, the common ERM frameworks are difficult to implement because they are quite abstract. The commonly used ERM framework are CAS 2003, ISO 31000, and COSO ERM.

A similar assessment of data-driven work is done in this chapter. The current body of knowledge does not contain sufficient literature covering data-driven work. However, the literature about data-driven organisations comes close and has some overlap with data-driven work. This research defines data-driven work as an iterative process that transforms data into useful and relevant information. It is impossible to compare data-driven work with a situation that does not use data. For decades, data plays a role in the decision-making process of an organisation. Therefore, the added value of data-driven work shows its importance. The main advantage of data-driven work is that it creates value for the organisation by improving the performance of the organisation. Real-time monitoring of risks enables a quick response to incidents. Moreover, the predictive capabilities of data-driven work improve the competitive position and make it easier to find business opportunities. There is not a commonly accepted framework that helps to implement data-driven work. The data-driven maturity model gives insights into what an organisation has implemented and what it can do more to increase the use of data-driven work. There is a significant mismatch between the state-of-the-art literature and the concepts of this research. The literature does not cover the concept completely. Therefore, an abstract literature search is performed to review the broader context of ERM and data-driven work.

7.1.2. How is the Dutch rail sector organised, and what are the risks rail organisations face in the Netherlands?

The Dutch rail sector is a sector that exists almost two centuries. It started off with several private enterprises, each owning and exploiting a rail connection. At the beginning of the twentieth century, the two largest rail organisations merged and formed the state-owned NS. The NS was the sole transport and infrastructure operator. It changed at the end of the twentieth century when the Dutch government decided to privatise the NS. The Dutch government transferred the infrastructure operating tasks of the NS to a new organisation, ProRail. In addition, other rail organisations could access the Dutch rial sector through concession tenders. However, the concession rights to the main track (85% of the rail infrastructure) remained in the hands of the NS. After the 'privatisation' of the Dutch rail sector, both the NS and ProRail remained state-owned organisations. Currently, the Dutch rail sector is a free market with one monopolist state-owned operator that possess 85% of the access rights. In addition, the infrastructure operator is also a monopolistic state-owned organisation.

The risk inventory of the Dutch rail sector showed an extensive list of risks. The most important risk to the rail sector is safety and security because they have a considerable impact on the continuity of the rail services. In addition, the competition risk that some rail operators face does not apply to ProRail and the NS. The reason for this is their state-owned monopolistic structure. The last risk that especially concerns the rail sector is disruption due to weather events. Due to climate change, more disruptive weather events will occur and impact the Dutch rail sector.

7.1.3. To what extent are Dutch railroad companies using data-driven work for their enterprise risks management?

The rail infrastructure operator, ProRail, uses enterprise risk management. ProRail uses two commonly used enterprise risk management frameworks, ISO31000 and ERM COSO. Currently, ProRail is redesigning its risk management systems but will not deviate from the enterprise risk management

philosophy. In addition, ProRail also uses data-driven work and has expressed the desire to invest in more data-driven work applications within the organisation. However, it is hard to evaluate how and if both concepts are combined within the risk management function of ProRail.

The largest passenger carrying operator of the Netherlands, NS, also uses enterprise risk management. NS follows the guidance of the ERM COSO framework. However, the focus of NS shifted from enterprise risk management to an integrated risk management approach. Both approaches to risk are similar with slightly different nuances. It is the question of whether NS is changing its risk management approach or changing its terminology. In addition, NS also commits to the use of data-driven work and is set to invest in it in the coming years. Data-driven labelled as a strategic pillar of the future of NS. The extent to which NS uses data-driven work in their enterprise risk management is not clear.

All enterprise risk management applications use data as input for risk assessments and generate data as risk reports and estimates. Therefore, enterprise risk management is by default data-driven because the input for risk assessment is often data, and the risk management produces data to support management in their decision-making process. The use of data-driven work for enterprise risk management is not black or white. It is an iterative process in which organisations can grow.

However, not all rail companies in the Netherlands use enterprise risk management. Connexxion, a smaller regional operator, does not explicitly use enterprise risk management. However, it shows a holistic approach to risk management and other business processes. The reason for this is the nature of the organisation. The organisation is quite small. Hence, it is more integrated because employees need to master multiple aspects of the organisation, and management can keep an overview of the organisation. This approach to risk does not differ from the core principle of enterprise risk management, managing risk in a holistic manner. In addition, smaller rail companies lack the resources to invest in innovations, like enterprise risk management systems or data-driven work applications. It is hard for smaller rail organisations to compete with large companies, like NS and ProRail, regarding the implementations of these kinds of innovations. These two large players in the Dutch rail sector essentially hold monopoly positions within the rail sector. Resulting is a disbalance in the distribution of resources in the Dutch rail sector. Small private organisations lack the resources to invest significantly in innovations. However, the root cause of the investment imbalance is something that needs further research.

7.1.4. What are the risks and opportunities of using data-driven work for the risk management of Dutch rail organisations?

This research has revealed two risks and two opportunities of using data-driven enterprise risk management. The main risk of using data-driven work in enterprise risk management is an incorrectly designed data-driven work process. Incorrect input for risk assessments means that risk controls are used that do not match the actual situation, creating a false sense of security. In addition, poorly designed data-driven work processes can incorrectly process risk signals overloading the system or cancelling out the edge cases. The second risk is not being aware of the shortcomings of the data. The mindset is still too often that the outcomes of data-driven work are irrefutable, and shortcomings of the systems are overlooked. This makes the use of data-driven work for enterprise risk management dangerous. Upper management must always be aware that some risks cannot be captured in data. Knowing hidden risks in missing data is impossible. The mindset needs to change to make data-driven enterprise risk management work. It needs to be seen as a tool and not a conclusive method.

On the other hand, data-driven enterprise risk management provides opportunities. The use of it can increase both the predicting and monitoring capabilities of the risk management function. Analysis of historical data increases the predictive power of risk management. The more precise the predictions, the bigger the risk appetite can be. The margin of error of the predictions is smaller and creates added value to the organisation. The second opportunity is real-time risk monitoring. Data-driven work enables the real-time risk monitoring capabilities of enterprise risk management. This is mainly an advantage for managing operational risks. Adaptive and resilient operations can react to changes in the operating environment. This requires information about the current situation. Data-driven enterprise risk management can help organisations in their real-time risk monitoring and their risk predictions.

7.1.5. To what extent do organisations differ in their adoption of data-driven enterprise risk management?

Rail organisations differ in the adoption of data-driven work and enterprise risk management. The reason for the differences is not the ownership structure of the companies. It does not matter whether the shareholders are public or private actors. Resources availability for these innovations and the willingness to invest in them drives the difference. The differences in available resources are the result of the privatisation in name only strategy of the Dutch State in the 1990s when they privatised the sector but kept complete ownership of the largest passenger operator and the sole infrastructure operator. The results of this policy are still visible in the Dutch rail market, especially the disproportionate distribution of market shares in the Dutch passenger operating sector. The largest concession equals 85% of the market, where the other 18 concessions share the remaining market. The concession of the main track, 85% of the market, is not awarded by a tender procedure. It is privately awarded to NS each time, giving them an artificial monopolistic position. Therefore, it is hard for smaller rail operators to gain market shares and increase their available resources. The size and the market share are the explanatory factors for the differences between the adoption of data-driven enterprise risk management within the Dutch rail sector.

7.1.6. Why should Dutch rail organisations implement data-driven enterprise risk management?

Enterprise risk management adds value to organisations.The use of enterprise risk management improves the performance of an organisation because it prioritises the impacts of risk better and more precisely. A second added value is that it improves the predictive abilities of the enterprise risk management function, which results in better and quicker risk responses. The regional operators benefit from data-driven enterprise risk management because they can compete better with competitors if they complete and current data. The answer to this sub-question is brief because it has a lot of overlap with the main research question.

7.1.7. What is the added value of data-driven work on the enterprise risk management of passenger transporting rail organisations in the Netherlands?

The answer to the research question is two-folded. Firstly, enterprise risk management is of added value for the Dutch passenger rail sector. The history of the Dutch rail sector has left its mark on the sector nowadays. The two largest players are and were state-owned organisations. They have a large organisation that faces a wide range of risks. Organisations need a risk management methodology that oversees all these risks and can spot the most important risks. These top risks need to be the basis of the strategy of an organisation. Enterprise risk management is such a methodology that looks at risk management from a holistic point of view. It ensures uniformity and comparability of the risk assessments within an organisation. Enterprise risk management compares these risks and prioritises them to present top risks to management. These top risks support management in their strategic decision-making process. For smaller rail organisations, the holistic risk approach is less appealing because they are by nature already integrated organisations due to their size. However, implementing enterprise risk management is an investment in the future. It safeguards a risk culture and structure that will help them when their operation scales up. Another added value of enterprise risk management is that it does not solely look into risk reduction. Enterprise risk management also focuses on seizing opportunities. This perspective on risk management creates value instead of solely protecting it because it gives competitive advantages.

Secondly, data-driven work is of added value to enterprise risk management in the Dutch rail sector. Data-driven work enables real-time monitoring of risks. This helps management in their decision-making process because they have the latest information. Management can make decisions better when they are well-informed with precise and current data. In addition, data-driven work adds value to enterprise risk management due to its predictive capabilities. Predicting risks areas preciser leads to better risk reduction controls and provide more insights into the business opportunities in the future. Hence, increasing the performance of the organisation and its competitive position within the sector. The two larger rail organisations, the NS and ProRail, are not triggered by the competitive advantage because they are state-appointed monopolies within the Dutch rail sector. However, their strategies for the future incorporate data-driven work visions. Smaller rail organisations lack the resources to commit

to data-driven work. Implementing it requires financial means and skilled employees. However, this is a short-term issue. In the end, using data-driven work will create value for all organisations because it provides better insights into their performances.

7.1.8. Recommendations for the Dutch rail sector

The above mentioned conclusions result in two concrete recommendations for the Dutch rail sector. Firstly, Dutch rail organisations with enough available resources should invest in the implementation of an enterprise risk management system. It will help them in the long run by identifying the top risks of the organisation and creating a risk aware culture within the organisation. The philosophy to use enterprise risk management for reducing the impacts of risks and identifying business opportunities is of added value to the organisation. On the other hand, smaller rail organisations with a simple and manageable operation should not yet make the switch if resources are limited. Most likely their business culture is already integrate and it has already the advantage of looking at risks from an integrated perspective.

Secondly, data-driven can be used in combination with enterprise risk management. However, before data-driven work processes are integrated into the risk management function, careful thought must first be given to their implementation. How is the quality of the input data guaranteed? How can it be checked whether the risks control, based on data, are still in line with the current risk situation? Is everyone aware of the dangers and shortcomings of data-driven work? If these questions have been carefully considered and sufficient resources are available, it is recommended for rail companies to apply data-driven work to their enterprise risk management. The predicting and real-time monitoring capabilities are of added value to the organisations.

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A

Interview summary

The Dutch rail sector has a lot of stakeholders, ranging from operators to governmental bodies regulating the rail sector. This appendix gives an overview of the organisation that operates within the Dutch rail sector. This overview excludes organisation do not directly relate to transport freight or passengers, e.g. passengers special interest groups. Figure A.1 gives an overview of the stakeholders of the Dutch rail sector. The overview distinguishes five categories: passenger operators, freight operators, infrastructure operators, contractors, and governmental bodies. Note this research excludes international passenger operators, e.g. Thalys and Eurostar. The inventorisation of the different rail organisations is based on the information from ProRail declaring their customers.

Figure A.1: Rail organisations in the Netherlands

Figure A.1 shows that the Freight operator category is the category is with the most active organisation. The reason for this is that the freight operators operate in a free market, with a lot of specialised transport. Not every freight operator can transport every. Think about the transport of hazardous goods. The scope of this research looks into passenger operators only. Figure A.1 highlighted the two rail categories that are studied in this research. The organisation within the two highlighted categories are assessed in further detail in table A.1 and table A.2.

A.1. Passenger operators

Table A.1: Company information of Dutch rail operators (passenger)

Company name	Company information
Abellio Rail GmbH	Land of origin: Germany Subsidiary: Yes Parent company: NS Shareholder of parent company: Dutch government (100%) Classification: State owned Concession type: regional
Arriva B.V.	Land of origin: the Netherlands Subsidiary: Yes Parent company: Arriva plc Shareholder of parent company: Deutsche Bahn Owner of Shareholder: Federal Republic of Germany (100%) Classification: State owned Concession type: regional
Connexxion Openbaar Vervoer N.V.	Land of origin: the Netherlands Subsidiary: Yes Parent company: Transdev Group S.A. Shareholder of parent company: • Caisse des Dépôts et Consignations (66%) • Rethmann (34%) Owner of Shareholder: • Caisse des Dépôts et Consignations (Franch Parliament 100%) • Rethmann (private owned) Classification: semi state owned Concession type: regional
DB Regio AG	Land of origin: Germany Subsidiary: Yes Parent company: Deutsche Bahn Shareholder of parent company: Federal Republic of Germany (100%) Classification: State owned Concession type: regional
Keolis Deutschland GmbH & Co. KG	Land of origin: the Netherlands Subsidiary: Yes Parent company: Keolis SA Shareholder of parent company: • - SNCF (70%) • - Caisse de dépôt et placement du Québec (30%) Owner of Shareholder: • - SNCF (French state 100%) • - Caisse de dépôt et placement du Québec (private owned) Classification: semi state owned Concession type: regional

A.2. Infrastructure operators

Company name	Company information
Keolis Nederland B.V.	Land of origin: the Netherlands Subsidiary: Yes Parent company: Keolis SA Shareholder of parent company: • - SNCF (70%) • - Caisse de dépôt et placement du Québec (30%) Owner of Shareholder: • - SNCF (French state 100%) • - Caisse de dépôt et placement du Québec (private owned) Classification: semi state owned Concession type: regional
NS International B.V.	Land of origin: the Netherlands Subsidiary: Yes Parent company: NS Shareholder of parent company: Dutch government (100%) Classification: State owned Concession type: international
NS Reizigers B.V. B.V.	Land of origin: the Netherlands Subsidiary: Yes Parent company: NS Shareholder of parent company: Dutch government (100%) Classification: State owned Concession type: national
Qbuzz B.V.	Land of origin: the Netherlands Subsidiary: Yes Parent company: Ferrovie dello Stato Italiane S.p.A. Shareholder of parent company: Italian government (100%) Classification: State owned Concession type: regional

Table A.2: Company information of Dutch rail infrastructure operators

Company name	**Company information**
ProRail	Land of origin: the Netherlands Subsidiary: No Parent company: None Shareholder of the company: Dutch government (100%) Classification: State owned
InfraSpeed	Land of origin: the Netherlands Subsidiary: No Parent company: None Shareholder of the company: • Koninklijke BAM Groep (private owned) • Siemens (private owned) Classification: private owned

B

Interview protocols

This research uses two interview protocols: 1) case-related interviews, and 2) expert interviews. Before each interview, the purpose and aim of the interviews needs to be determined. Figure xxx shows the protocol for the case-related interviews. Figure xxx shows the protocol for the expert interviews.

Table B.1: Case-related interview Protocol

		Case-related interview Protocol
Guiding Research Question: **What is the added value of data-driven work on the enterprise risk management of passenger transporting rail organisations in the Netherlands?**		
Research Question 1: **What is the current practices of ERM in the Dutch rail sector?**	Research Question 2: **What is the current use of data-driven work within the sector?**	Research Question 3: **What are the risks and opportunities of using data-driven work for the risk management of Dutch railroad companies?**
Interview Questions	Interview Questions	Interview Questions
To what extent is ERM used in (organisation)? Prompt: • Can you give an example? • How relates the ERM maturity of ..... to other companies in the sector? • Of Transdev, NS, and ProRail, which one is the most evolved in the field of ERM?	To what extent does is data-driven work used in work used at .....? Prompt: • Can you give an example? • What kind of data is used? • Does it generates issues in the daily operations? To what extent does data-driven work get used in the risk management in the sector?	What are the risks when data-driven work is used for risk management? Prompt: • Can you prioritize these risks? • Are these risks different due to data-driven work? • Is the process capability an issue? • Is data integrity an issue? Example risks: What is the added value of data-driven work for the ERM of such a risk? Prompt: • Can you prioritize the benefits/opportunities? • To what extent is real-time monitoring an opportunity? (operational vs strategic) Do you expect differences in the added value of data-driven work in ERM for private and public owned companies? Prompt: • Which of the two is more stimulated to use it? • What is the reason for this difference?

Table B.2: Expert interview Protocol

Expert interview Protocol		
Guiding Research Question: **What is the added value of data-driven work on the enterprise risk management of passenger transporting rail organisations in the Netherlands?**		
Research Question 1: **What is the current practices of ERM in the Dutch rail sector?**	Research Question 2: **What is the current use of data-driven work within the sector?**	Research Question 3: **What are the risks and opportunities of using data-driven work for the risk management of Dutch railroad companies?**
Interview Questions	Interview Questions	Interview Questions
To what extent is ERM used in the Dutch rail sector? Prompt: • Can you give an example? • How does the ERM maturity is in the Dutch railroad sector? • Of Transdev, NS, and ProRail, which one is the most evolved in the field of ERM?	To what extent does is data-driven work used in the Dutch rail sector? Prompt: • Can you give an example? • What kind of data is used? • Does it generates issues in the daily operations? To what extent does data-driven work get used in the risk management in the sector?	What are the risks when data-driven work is used for risk management? Prompt: • Can you prioritize these risks? • Are these risks different due to data-driven work? • Is the process capability an issue? • Is data integrity an issue? Example risks: What is the added value of data-driven work for the ERM of such a risk? Prompt: • Can you prioritize the benefits/opportunities? • To what extent is real-time monitoring an opportunity? (operational vs strategic) Do you expect differences in the added value of data-driven work in ERM for private and public owned companies? Prompt: • Which of the two is more stimulated to use it? • What is the reason for this difference?

C

Interview summaries

Note for all the interviews, they reflex the opinion and the point of view of the interviewee and not the organization they work for. However, their insights are given in the context of their experience and their position within the rail sector or related sector, such as consulting.

C.1. Interview 1

What is your role within the organization, and what is your relation with enterprise risk or risk management?

> ProRail separates the risk and audit departments. But the audits are performed on the areas where we see risks. We use risk management with the identification of the top risks of ProRail. Currently, ProRail changes its risk system from a top-down system to a system with top risks and annual risk assessment by the business units. The risk assessment shows the risks for each business unit and links them to the top risks. The old system was getting a little bit stuck. The operational risks were added to the system but were of no importance to top management. This made it difficult to extract top risks from the system. At the moment, ProRail is between the old system and a new system. The audit function uses the top risks and communicates with the business to understand where problems occur. The audits of ProRail are risk-based due to limited resources. So, the audit function does not assess every business unit, only the ones with the highest risk profiles.

What do you think is the added value of enterprise risk management for the business?

> The old system shows that there was a split between the top risks and the business units. The operational risks contaminated the risk management system. As a result, the output of the system is no top risks, so there is no longer a connection between top risks and the business. The added value of ERM is defining the top risk in advantage which arises from the mission and strategy of the organisation. The business can use the top risks to prioritise the risks of the organisation. Business units translate the top risks into risks in their context.

Do you use data-driven work within your position?

> Data-driven is a broad concept. At the moment, ProRail is in a transition. ProRail has a lot of data at its disposal, such as maintenance and travel data. Currently, ProRail uses data-driven work in its daily operation. For example, predicting malfunctions of the rail infrastructure or calculating the probability of track runners. The track runners application uses school timetables, weather forecasts, previous events and more. Furthermore, the ICT department is also developing data-driven work processes. The use of data-driven work in projects is lacking. Risk management is not really using data-driven work.

To what extent is enterprise risk management embedded in the organization for ProRail?

Regarding this, ProRail has made a wave motion in the adoption of enterprise risk management. There was a point in time that there were periodic risk assessments by the business units. These assessments were the basis of the top risks of ProRail. The risk owner of the top risk communicated back to the business unit to which the top risks belongs. All the risk reports were combined and reported to upper management. Unfortunately, this process slipped away. ProRail was quite far in its implementation of enterprise risk management, but the fading link between the risk management at the top and in the business units decreased the enterprise risk management maturity of ProRail. The new system will not abandon the enterprise risk management approach but bring it back to life.

Do others in the rail sector in the Netherlands also use enterprise risk management?

It is not clear whether more organisations within the Dutch rail sector use enterprise risk management.

What kind of data is used by ProRail for their activities?

Most of the data that ProRail uses is for the maintenance of the rail infrastructure. The asset management department aims to create a predicting model. ProRail adds more sensors into the rail infrastructure. For example, measuring deviations in the currents or vibrations of rail switches, which indicates problems. The development is visible in this area to use algorithms to predict infrastructure failures. Safety on the rail infrastructure uses a lot of data, also keeping track of track runners

Is this data quantitative or qualitative?

A combination of both. Quantitative data are the measurements of the currents and vibrations within the rail tracks. The data about track runners is more qualitative. Another work field is the transport of dangerous goods. Furthermore, cameras identify and keep track of which train contains dangerous goods. Data will replace the paper administration of these dangerous goods transports.

To what extent does ProRail uses external data, such as weather information?

ProRail gets data from rail operators. ProRail measures the vibrations of trains in cooperation with NS. Vibrations increase when the tracks are worn down. ProRail uses sensors on the NS train to collect this kind of data. Also, an App for commuters that measures the vibrations is in the pilot phase. Furthermore, ProRail uses the traveller data of the check-ins and check-outs.

Do you see or expect risks for the daily operation with the usage of data for ProRail?

ProRail performed an audit on data governance. Data ownership is not correctly defined yet. This situation makes it hard to manage the quality of the data. The biggest challenge would be in this area, especially when data-driven work is more implemented. When using data for risk management, it is important to define ownership and record alternations of the data. ProRail is not the only organisation in the Netherlands struggling with this. Data ownership is a requirement of data-driven work. The data governance audits perform the first scan of the data governance maturity, according to the maturity model of the Dutch government. ProRail is at the beginning of the maturity scale. The maturity level and the awareness of data governance depends on the business unit or focus area.

Do you also think that an overload of warning signals could be a challenge of data-driven work?

This is definitely a risk. However, consideration should be given to the purpose of the use of the data is. You cannot expect to get useful information by randomly analysing the enormous amount of data of ProRail. Analysing data requires a specific research purpose. Employees from the business units can come to the asset management data scientists with a targeted question. The analyst and scientist will analyse the data to answer the question. There is a risk when the use of data within the organisation is not properly designed.

How does the real-time element of data-driven work relates to this work process of ProRail?

> The scientists and analysts answer the question by developing applications that enable real-time answering of the questions. For example, the data lab creates dashboards and algorithms. The lab is the link between the data requests and the data.

Are there also risks for the enterprise risk management when data-driven work is applied?

> Quality is the biggest risk. It can create a loop. Risk management identifies risks on which controls are put in place. The controls send data back on which risk management is adjusted. Poor data quality influences the risk controls within this look. The data quality links directly to data ownership. However, it will also create advantages. Risk management can monitor more in real-time. At the moment, risk management and assessment are performed on a periodic basis. Data-driven work enables a real-time determination of residual risks after the implementation of control. Identifying failing controls can be done more adequate. The data quality and a clear understanding of the business processes is important to use data-driven enterprise risk management.

Is the integrity of data an issue for data-driven enterprise risk management?

> The integrity of data is the most important requirement of data-driven risk management. Garbage in is garbage out.

How is the processing capacity an issue for data-driven enterprise risk management?

> It is a risk when the design, in the beginning, is not set up correctly. It could create an overload of signals or false positives. This reduces the ability to control risks.

What are the top three risks for ProRail?

> The annual report of ProRail prioritizes the top risks. The number one risk of ProRail is safety

What is the added value of data-driven enterprise risk management on an operational risk, such as a failing rail infrastructure due to weather events?

> Weather events are difficult. Data-driven work can show whether the heating systems of switches are working properly when it snows. Data-driven work and the resulting predictive maintenance is the future to safeguard safe access to the rail infrastructure. The data regarding the state of the rail infrastructure gives the current status of the infrastructure.

Do you think that there is a difference between the added value of data-driven enterprise risk management of public and private-owned rail operators?

> Data-driven work can increase efficiency. Private organizations that are more efficient generate more profit. Although most operators are related to state-owned companies, they are cost-focused. Data-driven maintenance of the assets of these organizations can lower failure and make them more efficient. The passenger will be more satisfied, and they have a positive effect on the cost or revenue. Data-driven enterprise risk management is of added value for a privately owned organization because it will improve the risk assessment and be able to use predictive risk controls. It will always be more profitable for a private profit-focused organization to use data-driven work for their enterprise risk management.

C.2. Interview 2

What is your role within the organisation, and what is your relation with enterprise risk or risk management?

> Cyber-security specialist is my role. Our team identifies cyber risks in systems, processes and people for the client from a malicious perspective. In the end, it results in recommendations on how to control these risks.

What is the added value of enterprise risk management compared to traditional risk management?

> Traditional risk management is specific for an application, process, or implementation. Enterprise risk management takes a few steps back to look at it from a helicopter view to assess the impact on the business continuity, data integrity, and confidentiality. Enterprise risk management approaches risks more holistically instead of a specific implementation or system.

What is data-driven work according to you?

> Data is useful and hip. However, handling data in such a way that it is useful is a must The pitfall for a lot of organisations is their mindset to use data. They lose track of the purpose of using data when collecting huge amounts of data. A data-driven risk approach is nice if the right data and filters are available. It can be useful if the processes are implemented or designed correctly. An overload of data creates a situation that overlooks risks or where thresholds are set to high and important signals are missed. The threshold for alarms is increased when there is an overload of warning signals.

Do you use data-driven work in your work?

> Hard to say. The clients are quite specific with their implementation. For example, password analysis uses a huge amount of data. Performing open-source intelligence is also data-driven open-source data is used to map clients. However, it uses not a fixed dataset repeatedly.

How far are rail companies with the implementation of enterprise risk management systems, according to you?

> It is unknown whether an organisation such as ProRail uses enterprise risk management. It is suspected that a GRC (Governance Risk & Compliance) like solution is used.

Does ProRail use data-driven work in their daily operation and/or risk management?

> Both the NS and ProRail use a lot of data to perform their operation. They get travellers patterns for their datasets such can indicate bottlenecks that lead to risks. Based on this kind of analysis risks are assessed, and controls are put in place. Furthermore, ProRail uses risk assessments to map the data flows when processing locations are downed. The ambitions to use data are there, the maturity of data-driven work is not there yet. Note that this is not really related to the work of the interviewee, therefore, a complete answer is not possible.

What kind of data is used by rail companies?

> They use mainly snapshots from which datasets are extracted to link the risk with representative examples. They work with data that indicates crowds at stations or failing switches. Giving a specific answer is not possible.

What are the points of improvement regarding the use of data by rail companies?

> The overload of data is a point of concern. It is a risk when the use of data does not originates from a well thought out process, but applications are coupled to already existing datasets that do not fully fit the purpose of the application. Which data is needed to manage or make a risk-based decision is a question that needs to be answered before using data. It creates a risk that the application cannot be used effectively anymore. The amount of data can be too much to make the right decisions.

What is the added value of using data-driven work for the risk management of rail companies?

> In most cases, data-driven has an added value for risk management. However, data will only show the happy use cases, everything which goes well and does not deviate. The special cases are overlooked. Therefore, data-driven work does not fully substantiate risk management. The data creates a standard baseline in a large dataset you will never find deviations. When cyber security is approached data-driven covers the most basic risks. The edge cases and specials cannot be extracted from the data. Data-driven work is useful to create a baseline but is not able to completely manage all the risks.

What are the biggest risks of using data-driven enterprise risk management for rail companies?

> The loss of the ability to detect the edge cases. The trend might seem good when large amounts of data are used but when zooming in on single cases deviations are visible. I am not sure whether the current practices of data-driven work takes this into account and is able to find the edge cases. Management of an organisation needs to act on the deviations to manage risks.

Is there a change in risk profiles of rail companies due to the use of data-driven work?

> Organisations are better prepared because they have more historical data. The insights of previous incidents can help solve current situations due to data-driven work. Furthermore, there is a mindset that the tools that are used will solve most of the problems. There is a misconception that tools with all the data will solve all the risks. In practice, however, this does not apply.

The capacity to analyse risks can be seen as a risk, according to your earlier statements?

> For example, antivirus software gave a single warning in the past. Nowadays, a lot of data is used and analysed giving more signals but also false positives. The tasks of the, mainly small, departments responsible for this have increased enormously in recent years due to the use of more data and systems. The increasing amount of data and number of signals runs into a barrier when the staff is no longer able to adequately check or follow up on everything. Too much cannot be handled which results in ignoring signals. The tools to process that are nice but useless when there is no qualified staff to process it.

Is the risk of data integrity an increasing risk?

> Like the checks on financial statements, such a checking system can be used for the data integrity of enterprise risk. Organizations need to prove that the integrity of the data on which they make risk-based decisions.

Which role can data-driven work play in the case of weather-related operational risks of failing infrastructure and a strategic risk of changing competition?

> Data-driven work can absolutely be used for the weather-related operational risk of failing infrastructure. Measures can be deployed when extreme weather is forecasted. The risks of completions do not really benefit from the use of data. The rail infrastructure in the Netherlands is a stable monopolistic structure and not a free market.

Is the main benefit of the weather-related operational risk the reaction to changing circumstances?

> The amount of data and the historical data can show trends and patterns. Scenarios can be developed from these trends and patterns. It is expected that the organization should use these scenarios to identify risk controls for situations.

What is the importance of the real-time element of data-driven work in this context?

> Real-time is actually already too late. It should be expected that data is used in a predictive manner. However, the is more for the future. At the moment, the rail companies are not there yet.

Coming back to the strategic risk of competition, do you see the added value of data-driven enterprise risk management for smaller regional rail organisations?

> They are more in competition for the smaller tenders of the rail infrastructure. It mainly has added value during tenders to show that you are the best operator, but it is more important for smaller rail companies. The ability to demonstrate better punctuality than competitors through historical and public data benefits the competitive position. The largest players like NS and ProRail have less benefit from this.

To what extent is there a difference between private and public owned companies regarding the adoption speed of data-driven enterprise risk management?

> Government affiliate organisations are slower in their development. It will be easier to implement within a private organisation because public organisations are stricter to comply with regulations and laws. A private organisation has more freedom to move within the set rules.

C.3. Interview 3

Did you come into contact with enterprise risk or risk management or risk management during your employment?

> The management teams I was part of did not explicitly have enterprise risk management on the to-do lists. Some management teams did use guidelines such as ISO INK. Of course, risks are always discussed, but enterprise risk management is not really used as a tool.

What is the added value of enterprise risk management compared to traditional risk management?

> For both risk management and data management, I am in favour of adding the enterprise dimension. First of all, from a business perspective, all business processes are linked to each other and cannot be seen separately. Secondly, there are chain dependencies both on an organisational level but also on a sector level.

Do you experience an increasing use of data-driven work in your field of expertise, and how does this manifest itself?

> Back in the day, the ministry had a primary process, but there was a lack of information. Some people within the organisation tried to make something with data and ICT, which resulted in applications. However, these applications did not meet professional standards and requirements. Information provision has developed into a specialisation. The focus shifted from the primary process to the efficiency of information provision. Nowadays, it is more professional, and the data and IT side seek to return to the primary process. For many policymakers, the use of data is still a step too far. Furthermore, the policymakers are unconscious and incompetent in the use of data. Pushing innovations such as data-driven work is not the way. Starting a conversation about the problem of the primary process is a better way to introduce the possibilities of data-driven work.

Are the incompetents of the end-user risks of data-driven work?

> A lot is possible from a technical perspective. Using data requires agreements about the standardisation of the data. The organisational level faces the biggest challenges. Top management needs to commit to data-driven work. The mindset of top management is important and can be a bottleneck for the implementation of data-driven work.

To what extent is enterprise risk management used in the Dutch rail sector?

> Guessing that an organization such as ProRail is quite similar to Rijkswaterstaat, it is not sure whether enterprise risk management or a similar approach with another name is used. A suspicion from a distance is that their risk management is not called enterprise risk management. It is hard to say something about ProRail. However, at Rijkswaterstaat the name enterprise risk management is not a point on the agenda. Keep in mind that Rijkswaterstaat is more focused on multiple businesses, where ProRail only focuses on the rail sector.

Can you say something about the rail operators?

> Risk management from different approaches, techniques and points of view is more done by technical orientated organisations, from a personal experience within the IT side of the government. However, the different approaches make it sometimes hard to implement a holistic approach, such as enterprise risk management, because everybody sticks to his or her way. The reality is that organisations already have ways of working and that a complete reform of risk management difficult to achieve is. It is more adjustments than changes.

To what extent is the rail sector with the adoption of data-driven work?

> Again from a Rijkswaterstaat perspective analysing ProRail. First of all, a lot of organisations pretend that data-driven work is something new in the last years. Rijkswaterstaat collects and uses data for decades for their way of working. Traditionally, the government is a data-driven organisational body because it is involved in infrastructures that need to be preserved for a long period of time. This does not mean that there are no technological

innovations in the collection and use of data. Data-driven work is not black or white but a development process. Although we are doing good, there is a world to conquer in this field. Within Rijkswaterstaat there is a lot of innovative project regarding data-driven work, the assumption is that this is the same for ProRail and other rail companies.

You say that there is a world to conquer. Can you give an example of this?

A digital twin of the Netherlands to analyse the effect of policies. There I still room for expansion in these kinds of areas. This can be used to plan infrastructural changes in the rail sector.

What kind of data is used by rail companies?

Data can be ordered by location, characteristics, and the state of an object. A development is that Rijkswaterstaat performs its own measurement only and in cooperation with third parties. In addition, there are citizen collectives that collect data. Another development is the shift from binary data to textual data, such as cameras.

These developments of data availability of Rijkswaterstaat is that similar to the rail sector?

The order is similar whether it car driving on the road or a train on a tack. The aviation industry is interesting in this way. They use all the life cycle data of a plane to improve the next generation in a data-driven approach.

These developments of data availability of Rijkswaterstaat is that similar to the rail sector?

The order is similar whether it car driving on the road or a train on a tack. The aviation industry is interesting in this way. They use all the life cycle data of a plane to improve the next generation in a data-driven approach.

What is the risk of becoming dependent on data for data-driven work?

It is a risk when automatic processes are being dependent on input data. The importance of the information provision of vital processes is increasing every day.

To what extent is data-driven work used for risk management?

There are two sides to this coin. On the one hand, the complexity increasing, and we humans can almost no longer oversee everything anymore. In the old days, businesses could be calculated on the back of a cigar box. The processing power and artificial intelligence are needed to perform tasks that increase in complexity. On the other hand, there is a mindset that artificial intelligence, computers and data will say what needs to be done. It is thinking too much about what is possible instead of thinking in terms of problems. The gut feeling is needed to make sense of data assessments. The human factor is important in complex and wicked problems. Data-driven work can be used for easy tasks the sense-making still belongs to humans. Furthermore, the design of these systems creates discussions about privacy.

What are the risks of using data-driven work in the risk management of rail companies?

Whenever data is used it is important to ensure the CIA-triad (confidentiality, integrity, and availability) and the data quality guaranteed. The issue of data governance is becoming increasingly important. This is effectively dealing with data to support the business goals. This is not only an issue for risk management.

What are the benefits of using data-driven work in risk management?

There are multiple benefits to enterprise data management. Firstly, it provides a better overview of the situation. Secondly, it is good that other organisations are aware of what is going on in chain collaborations. Thirdly, the size of the benefits increases when scaling takes place. The rail sector benefits from enterprise data management of its enterprise risk management because of the chain dependencies within the sector.

To what extent can data-driven work enterprise risk management be used in the case of weather-related operational risks of failing infrastructure and a strategic risk of changing competition?

> Every work process benefits from facts and figures. Signals from operating systems that something is about to happen is the goal. This way it is known that something needs to be checked out before it fails. The operational benefits from these kinds of applications of data-driven work. In addition, there is a link between the operation and the strategy. Furthermore, the world is changing around us, data-driven work can provide insights into changing a setting that influences the business. An example of this is the external effects of the climate impact on the business processes. An organisation operates in an unstable context and must be able to respond to a change in context. Models and data provide insights into the changing context.

To what extent is there a difference between private and public owned companies regarding the use of data-driven work in their enterprise risk management?

> The government is not profit-orientated but on public and social values. Private owned organisations are focused on shareholder value. American companies comply with the law and regulation, but ethics is less of an issue. A government-affiliated organisation cannot ignore ethical objections in the Netherlands.

C.4. Interview 4

This interview is conducted with two interviewees. Therefore, two different colours are used in the summary of the interview. *What is the connection between risk management and your role within the organisation?*

> The difference between a bus company and a train company is that a bus company does not really use risk management in the broad sense as it is used within the rail sector. The rail sector is completely risk-driven. The organisation has learned to approach risk and safety management in an integral way, through which it finds its repercussion in everything of the organisation. A system has been set up at the beginning, this system has evolved in an organisation within the rail company where roles are appointed to safeguard safety. Everyone within the team is focused on safety. Safety first! Risk management forms the basis for the implementation of change. Nowadays, the effects of changes are analysed upfront. We are working on safety and risk management daily, e.g. ISO audits and assessments. Annually there is a big audit from ILT. Sometimes bigger rail companies, such as the NS and ProRail, reflect differently to risks than smaller companies. They also have a different way of working. ProRail and the NS are driven by Dutch ministries, constantly explaining their choices due to political accountability. The smaller rail companies are dealing with the regional client, who demands quality for its money. This reduces the political control on smaller rail companies. Connexxion is shareholder driven, and the shareholder wants to see a profit.

> The enterprise risk management approach is focused on strategy, operation, reporting, and compliance. These parts relate to a rail company in the following way: the rail division makes agreements with the overarching organisation about the strategic and operational goals and which tools can be used to report the progress of these goals within complying behaviour regarding the rules and regulations. Connexxion makes risk assessment at a certain level, not only occupational safety but also finance, changing passenger flows due to COVID, or changing requirements of clients. Connexxion quantified and classified the risks for the risk assessments. The management team can discuss these identified risks to accept the risks or create more controls. Risks are monitored in the meantime. The output data can be used to train personnel. Increasing the capabilities of all personnel benefit the safety of the organisation.

What is the added value of enterprise risk management compared to traditional risk management?

> It relates to technology, tools that make it possible to understand current affairs due to the use of data. Performance can be monitored by using data instead of having a gut feeling. The second benefit is culture. More frequently assessing the work culture and how can culture increase the safety of work processes.

> There used to be several separate data sources. The wish is to combine data sources to show performance from different points of view. Back in the days, it was more incident driven. Combing different data sources can provide a completer overview of situations.

To what extent do you apply enterprise risk management, and is it used by other rail companies?

> It cannot be answered with a yes or a no. Some elements of the model are used by Connexxion, but the entire model is not yet full adopted. In recent years, risk assessments are not only focusing on safety risks but also financial risks, organisational risks, and threats. Culture monitoring is an example that shows how to check the actual culture within the organisation, from both managing and operational level. Connexxion improves in the adoption of an enterprise risk or similar approach

To what extent are other rail companies using enterprise risk management, and can you explain the differences in maturity?

> There is a difference which is caused by resources in the form of manpower. The size of rail companies matters. Connexxion can use approximately 1,2 per cent of rail infrastructure, and the NS uses between 80 and 85 per cent. It is not fair to compare the maturity

of Connexxion with the NS. It is a completely different organisation. It would be more interesting to compare regional operators. The revenue models of regional operators are different from that of the NS. The resources of the NS cannot be compared to the resources of Connexxion.

The culture and stricture of both organisations are completely different. Regional operators assess their business more in an integrated manner because the staff and the size of the operation are smaller. The NS has different silos with specialistic groups. There is an employee for everything. Connexxion does not have this; it is not part of the business model due to the limited size of the organisation.

What is meant by the difference in culture, shareholder and ministerial driven?

Yes, but the culture also originates from history. The NS is less adaptive to the new situation because their way of working is entrenched. Their processes and systems are used to the same situation and embedded within the organization. In addition, Connexxion is much less politically driven than the NS and ProRail. Regional politicians are involved with Connexxion, whereas the NS and ProRail are influenced by national politicians.

How is data been used for the risk management of Connexxion, and what kind of data is used?

This is still a point of attention. There is still a lot to gain in quantifying risk through the use of data compared to other sectors. Data is missing to assess some risks, such as red signal passages. The question is whether this data is available within the current work processes or do they need to be adjusted. In addition, is there a model or means for the interpretation of the data? A lot of data is available. However, before using the data it is important to know what should be achieved with the data. Management needs to express the course for the use of data so that they will have more insights into the current risk profile. The use of data-driven work shown missing risks in the current risk profiles of an organization. It can help the risk management of Connexxion. However, at the moment the risk management is not really data-driven.

Connexxion is in this area still in its infancy. There are multiple data collecting tools, but they are not yet used for risk management. Management has et it as a goal for the future.

The goals of Connexxion are already been monitored with data, such as punctuality and train failures. Data is used to assess key performance indicators. The punctuality performance can be seen in retrospect every month or day. But there is still room for improvement regarding a better quantification of risk or identifying new risk by using data.

What kind of data is used at the moment?

Quantitative data sources alone are not sufficient. The context of the quantitative data is even more important. Some signals can be explained without being an warning signal. The data sources are a combination of both quantitative and qualitative. Furthermore, it is possible to collect more data from trains. Key is understanding what data is really needed and how can this data be used. Data needs to be used to improve the capabilities of employees, and to punish them.

This also relates to culture. The mindset on how to deal with mistake and deviations plays a role in the culture. To gain insights in the culture it should be measured. Something it is hard to use quantitative data in qualitative analyses, due to the importance of the context of the

What is the top risk of Connexxion?

Financial and safety risks can be identified. Regarding safety, collisions with persons by suicide the last couple of years. From an perspective of Connexxion the risk lies with the impact is has on personnel. The risk is the loss of personnel due to the traumatic experience they encounter. The second safety is red is stop or red signals passages. With regard to

the business continuity there are also risk. Ending concessions are a risk for Connexxion, but also opportunity because other regional operators are in the same position. Winning does tenders are opportunities for growth. Another risk is the impact of COVID. The effect of working from home are not clear yet.

The risk of COVID are financial risk, less passenger is less revenue. Making sense of the situation is done with scenario that are based on a lot of factors.

What would be the impact on these risk when data-driven risk management is adopted?

It is always good to prevent or reduce risks. The use of data increase the predictive abilities of events and incidents. Furthermore, the use of data can lead to behavioural changes. Also combing data can lead to a better insight of the overall business processes and overall risk assessment. More data leads to more knowledge. Currently, some things are not yet known and can only be analysed afterwards. It is going to be part of the future of Connexxion.

An additional advantage is that data can confirm the gut feeling. This is in particular an advantage for smaller organization with a smaller distance to the operation. It makes the case of the gut feeling stronger when it is also reflected in the data. The focus should lie on improving the capabilities of employees and not to punish them.

To what extent are other risks created by the dependency of data?

It is important to see deviations in context. A braking spike on its own is a risk. However, in the context of an averted collision it is a good signal. Data alone is not the only basis on which risk management should be found. The ability to explain deviations in the data is valuable.

Data is an enrichment for predictive abilities and risk management, but the human touch and the gut feeling can also be useful. Over the years, the amount of data has increased and has added value but a lot is also captured by culture. Employees of small organizations are required to be familiar with the subject matter in various areas. Larger organizations such as the NS are much more specialized. Understanding the entire business and culture is more important for smaller companies, like Connexxion, than larger ones, like the NS.

To what extent can data-driven work enterprise risk management be used in the case of an weather related operational risks of failing infrastructure and a strategic risk of changing competition?

Extreme weather does not have a direct influence to the operation. The simplicity of the operation of Connexxion ensures that not a lot can go wrong. The disruption are caused by the rail infrastructure. A disruption of the infrastructure is an external event, which cannot be influenced by Connexxion but affect the operation. Examples are:, frozen switches or a tree on the tracks. The operation of Connexxion is quite simple, a train from A to B and from B back to A. Increasing the network complexities makes the operation more vulnerable to disruptions. The NS experience the risks of a complex operation, were simplistic operation Connexxion benefit in these kind of situations. After the disruption last winter, Connexxion could start their operation again faster than the NS. Data of winter weather is less important for Connexxion. Instruction whether the infrastructure can be used or not and weather forecasts are the data sources for Connexxion regarding weather. Data-driven work is not of added value regarding this risk and Connexxion. An organization as ProRail benefits more form this kind of data.

However, the number of passenger is a data source which Connexxion monitors. The attractiveness of commuter traffic by rail can be influenced by cancelled operations of Connexxion due rail infrastructure failures. Connexxion uses data to analyse the behaviour of passenger compared with previous years.

The recovery after COVID is an example of this.

*note second interviewees left the interview to attend another meeting.
To what extent can data be used for the strategic risk of changing competition?

> The tenders of concessions are based on lots of data. The party with the most and best data can execute the best analysis. There are two kind of concession for an operator: you want to keep the concessions you already own, and new concessions need to be won. Data of a defensive concession is known from the previous period. A risk of defensive concessions is that it is based on the current situation and that sometimes creativity can be lacking. An organization possess less data for an offensive tender, but the information asymmetry forces to look at competitors and innovation. This is less data based, but more feeling driven. Data is always important for a tender. Client requires data to support claims during tenders.

To what extent is there a difference between private and public owned companies regarding the adoption of data-driven work in their enterprise risk management?

> It is culture-driven the differences, what is safety culture and profile of the organisation. Resources also play a role in this: how much money is available and how many staff do you have. The market position is more important than the public or private ownership. Smaller organisations are more integrated, and larger ones are build up in silos. Data will be of more importance for Connexxion in the future. Meanwhile, data does plays a much bigger role at the NS at the moment. Large organisations have more data, more money, more staff, and more possibilities to do something with it. For sure this creates a difference within the sector

Are profit-driven organisations more focused on innovations to create more revenue compared to public owned organisations?

> An organisation such as NS has the financial resources to innovate. For Connexxion innovation means investing money, when at the same the shareholders demand a profit maximisation. Connexxion does not compete in a tender if it is not profitable for the shareholder. Public owned companies are less profit-driven, and lower profits are less of a problem for them. In addition, the concession of the main infrastructure is still granted without a tender. This makes it harder for an organisation like Connexxion to compete with them.

C.5. Interview 5

What is your role within the organization, and what is your relation with enterprise risk or risk management?

The technology risk department conducts IT audits and investigations aimed at IT risk management. IT risk management audits relate to the risk controls of organizations based on their use of IT.

What is the added value of enterprise risk management compared to traditional risk management?

In recent years, risk management of different silos becoming increasingly intertwined. In the past, enterprise risk management was not applied, or risk management was financially and shareholder driven. Currently, it is more intertwined with the use of IT or chain risks. A holistic approach is becoming more present, which is needed and good

Are you missing the in-depth risk assessment of traditional silo risk management in the enterprise risk approach?

There is always a difference in the level of aggregation. The responsibility of the risks is the question. However, with IT risk they are linked to enterprise or strategy risks. An example in the rail sector is the strategic risk of safety. The responsibility of safety risks is with management, although systems are vulnerable to IT risks. It is a good development that risks are addressed at an organizational level, with the specific risk underneath it.

To what extent does data-driven work influence your work?

The availability of data at companies says a lot about how they deal with IT risks and how big the risks are. Data-driven work can change mindsets. Instead of completely closing of systems with access right you can also choose to keep track of who sees what and what does that person do with the data. Data-driven work is valuable within this field of expertise, and it is applied more often. However, from an IT risk management perspective is a combination needed. It can be too late to intervene when only afterwards log analysis is applied. This is a problem when it comes to personal data.

To what extent is enterprise risk management used by the Dutch rail sector?

The largest rail-related client uses the enterprise risk management approach. Risks that influence the operation are part of the enterprise risks and need to be addressed even at a boardroom level. Cyber security is part of their enterprise risk management model and is discussed on a management and board level. The philosophy of enterprise risk management is also applied by other rail-related organisations. However, there are differences in the maturity of their enterprise risk management adoption. Smaller operators are less far in their enterprise risk management than other operators. The ownership of rail companies in the Netherlands is also interesting. The Dutch government is 100 per cent owner of the NS. Other rail companies have French or German owners. It also depends on whether enterprise risk management is used within these foreign companies this influences the maturity of enterprise risk management within the Dutch subsidiaries.

Are larger rail companies more mature than smaller ones, and why is this?

Larger rail organisations are more mature. Firstly, they have more resources at their disposal. Despite having to comply with the same laws and regulations, they have better risk and compliance departments. Secondly, smaller organisations do not pose these kinds of departments or in limited sizes.

To what extent does an asset manager like ProRail uses enterprise risk management?

No statement can be made about the maturity of ProRail. However, a client within the rail sector is part of the value chain risk management between ProRail and rail operators. This addresses the risks that are present in the entire value chain which needs to be tackled together.

To what extent do your client rail companies use data-driven work?

They work completely data-driven. For example, the check-ins and outs systems send data to TLS for the financial administration. The data of the pillars need to be extracted manually when data is missing. Data-driven work tells them which data is missing. Another example, based on previous travel data it can be predicted where someone checks out when they forget to check out themselves. Data about customer satisfaction rate, punctuality, delays are collected by operators self or provided by ProRail to report it, but also to support the decision to improve these KPI's.

What kind of data is used by rail companies?

Both qualitative and quantitative data is used; it depends on the purpose of the data. For the larger rail organisation, the amount of data ultimately says something about how it works in practice. The punctuality data is a lot of the same every time, and it does not tell you anything on its own. Qualitative data is used by the organization themselves to make specific assessments of trends and deviations.

What are the risks for the daily operations of rail companies of data-driven work?

The daily operations do not really encounter risks because trains can still drive even when data is not present. Check-in and check-out data can be missed for some time, but when it is gone forever it creates a problem with revenues. It is a big risk when check-in and check-out data is missing both digitally as manually. Data about the travel quality is not needed for the operation of rail companies but is something shareholders want to know.

To what extent can data-driven work be used in the risk management of rail companies?

They should use data-driven work for risk management to identify and assess risk areas companies should look at the data they have, both internal and external data sources. However, in this way the use is still limited. Data is given a prominent place regarding the risks of cyber-attacks. The increasing number of attacks and threats helps to assess the cyber risks and map them.

To what extent can data be used for issue management, such as weather?

In practice, weather data is used to prepare for disruption and the arrangement of replacement transport.

What are the opportunities and risks of data-driven enterprise risk management?

An opportunity is that a large amount of available data can be used to predict risk development and trends. In the next step of risk management, data can be used to come up with measures to control the risks. A disadvantage is that you cannot management unknown risks. Missing data does not mean that those areas do not contain risks. It can have a misleading effect. Another challenge is data is needed throughout the entire chain, the exchange of data between parties. The exchange and reliability of this data are essential for the creation of good and useful decision-supporting data.

What are the added risks of data-driven work compared to non-data-driven work?

People are vulnerable to see data as leading and base their decision on it when there is a lot of data available. The tendency is to focus on areas with a lot of data and that areas with mainly qualitative knowledge are less included in the decision-making process, but they can also contain risks. This is a pitfall compared to a situation when there is no data available.

How is the processing capacity an issue for data-driven enterprise risk management?

That is also a risk. It is a question of what data do you collect and what can you do with it? The quality of the data determines everything before you can deal with it. This risk is always there. The more data, the greater the chance to lose the overview. It will not increase with the availability of more data.

Do you oversee challenges regarding the correctness of the data?

That is where the biggest risks lie because organizations assume too easily that the data they use and the reports they have are correct. During audits, this can be seen very often. Deviations and remarkable differences are often noticed. However, a more professional work process needs to be applied, in order to guarantee the correctness of the data and reports.

To what extent can data-driven work enterprise risk management be used in the case of weather-related operational risks of failing infrastructure?

It is of great importance because things have to be arranged in advance if certain weather occurs. Trains can be made better and infrastructure more reliable, but it will cost a lot of money and are long-term projects. Until the rail sector is improved significantly, backup arrangements are still needed. Furthermore, it can be used to predict travel movements and crowds for the future. The combination between weather and the future use of the rail infrastructure is of importance to assess. It is easier to use one very robust train daily than in the Dutch context with trains arriving every ten minutes. Including weather forecasts in risk management is essential, but expecting trends are also important.

To what extent can data-driven work enterprise risk management be used in the case of the strategic risk of changing competition?

It certainly plays a role during the tenders for the concessions. During tenders, parties need to prove how they score on passenger KPI's, punctuality and customer satisfaction etc.

To what extent is there a difference between private and public owned companies regarding the adoption of data-driven work in their enterprise risk management?

It does not necessarily have to be different. NS is a private company with the Dutch State as its owner. Therefore it is a semi-public organisation. They work more data-driven than smaller private organisations. The reason for this is the scale of the organisation and the departments. There are, however, visible differences in real government sectors. Governmental bodies use a lot of data, but it lacks slightly behind and is slower to professionalise compared to large private organisations.

What is the reason why there is a difference?

The financial resource is one reason. Within the government, everything is arranged with budgets. Private organisations can independently decide to invest. The second reason is bureaucracy. Governmental organisations make decisions on multiple levels. Private organisations provide more freedom to the employee with some boundaries. Furthermore, private companies have incentives to increase efficiency to make a profit. An organisation like NS lacks this incentive in a way the government helps the NS out if necessary.

C.6. Interview 6

What is your role within the organization, and what is your relation with enterprise risk or risk management?

Our internal audit department definitely deals with ERM. The department audits the organizations to test whether departments or projects control their risks. The audit areas are based on the strategy of the NS. The task of the audit department is to check whether the NS controls the risks the strategy faces. The audits of the departments are enterprise-wide.

What is the added value of enterprise risk management compared to traditional risk management?

The NS uses the three lines of defence theory. The third line is the NS audit, and the risk department is the second line of defence. The risk department is closer to the operation. As a result, they are more involved in solving the risks. The audit department is at a greater distance from the operation so that objective and independent audits can be carried out. The audit department does not help solve risks but reflects on the status of the risk controls.

But what is the added value of the enterprise risk management methodology to the organisation according to you?

Of course, there is added value. The risk teams help so the issues. The internal audit looks independent of the risk controls. It gives the board an objective perspective on the risk profile on which they can create strategies.

To what extent do you experience that the NS uses an ERM methodology?

The internal audit works for the board, and the focus is on the entire enterprise and its strategy. This also applies to the risk department. Although, with the risk department there is a division of specialities amongst the team members. With the organisation, you notice that some frameworks and guidelines apply to the entire organisation, e.g. security and privacy policies. The guidelines are enterprise-wide, but teams can adjust them to their context.

What is the ERM maturity of the NS?

Different frameworks are used to create a framework that suits the NS organisation the best. The NS does not work with one framework and follows it strictly. This is not in the interest of the NS to use multiple frameworks and apply the relevant parts.

Do you know whether other rail organisations also apply the ERM methodology?

This is a difficult question. I do not know how the work processes of other rail organisations look like. I think that they are on an equal level of maturity. Rail organisations are not the most mature organisation, to be frank. We cannot be compared to organisations within the financial sector. Banks and insurers are far more matured than the rail sector. The reason for this is that they have more regulations regarding ERM and these regulations have been around for a while now in the financial sector. ERM related regulation applies to a lesser extent to the Dutch rail sector.

What is the added value of data for the NS and especially for the risk management function of the NS?

Data-driven work is very important for the NS. The NS have a strategy for data-driven work. This strategy focuses on the internal transformation to a data-driven organisation of the NS. The aim is to base all decision-making processes on data by analysing all kinds of data. The NS depends a lot on data, e.g. the planning of the time schedule, operating the time schedule, planning maintenance, The train are great sources of data with all their digital systems. Data is used in every aspect of the organisation. The commercial department uses data to analyse patterns of passengers.

The data sources you mention are meanly quantitative of nature but is qualitative data also used, e.g. data from a camera?

Cameras are used to analyse safety situations, e.g. AI is used to analyse backpack abandoned backpacks at train stations. In addition, drones are used to inspect train stations whether maintenance is needed. Qualitative data is also used for rail safety data from cameras is analysed to identify objects on the rail tracks.

How far is the NS with the implementation of the strategy for a data-driven organisation?

At the start. The goals to realise a data-driven organisation are determined. In addition, a maturity model is developed to test how far along each department is with the implementation of data-driven work. At the moment, the first results of the maturity analyses are collected.

What is the added value of data-driven?

The added value is that there is always insight into how things are going. Hence, the decision-making processes are supported by the least information. For example, planning maintenance of trains will not be based on time indicators but on the data that indicates the condition of the equipment.

What is the added value of data-driven work for the risk management of an organisation?

Risk is probabilities times impact. Data-driven risk management is better in identifying risks with higher probability and impact levels. The real-time data ensures a better assessment of the risks and enables a more precise risk prioritisation. Data-driven work provides a better risk prioritisation within your risk management.

What are the challenges or risks of data-driven work?

The challenge is to have the means to collect the data. The employees need to have the right skills to work with data-driven processes. Besides, data-driven work creates a lot of data, finding the right data is a challenge. A risk of data-driven work is that you cannot see the wood for the trees. Filtering relevant data from junk is important. The wrong output data can lead to wrong decisions.

What is the added value of data-driven enterprise risk management in the case of weather-related operational risks of failing infrastructure?

The NS can use different data sources to anticipate on the effect of weather events, e.g. combing weather forecast, The NS can use different data sources to anticipate the effect of weather events, e.g. combing weather forecast, maintenance status of the trains, time schedules of employees and expected passengers flow data. The NS can use these combined data sources to inform their passenger when the operating capabilities decrease due to weather events. In addition, data-driven ERM enables a quicker response to weather events so that the NS can adjust its timetables more quickly. The advantage is that the communication towards passengers is quicker and more precise due to data-driven ERM. The effect of the weather events can be determined by data-driven ERM.

What is the added value of data-driven enterprise risk management in the case of the strategic risk of changing competition for the NS?

When a competitor develops the capabilities to perform better than the NS due to data-driven work it poses a risk for the NS.

Is it really a risk to the NS because the main rail track concession of 2024 is already granted to the NS?

The performances of the NS are in the spotlight because the NS is close to a monopolistic organisation. Data-driven work can increase and decrease the competitive position of the NS. The NS is granted the concession under the condition that they meet their performance indicators. Data-driven work is critical to achieving the targets of the Dutch State.

To what extent is there a difference between rail companies regarding the adoption of data-driven work in their enterprise risk management?

It is a difficult question to answer. I hope that your research will provide these insights. The subsidiary, Abellio, also adopted the holistic approach of ERM for their risk management.

Is there a difference in the data-driven maturity of rail organisations in the Netherlands?

I do not know if Connexxion or other organisations use data-driven work. I think that they use data-driven work to analyse passengers flows.

What could explain the differences between the organisations?

NS's monopolistic positions are putting more pressure on governments and stakeholders.