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The Unreached Potential of Business Intelligence for Sustainability:

A qualitative study on the utilisation of business intelligence for sustainability efforts in manufacturing organisations.

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ABSTRACT:
The growing importance of organisations becoming more sustainable has reached a crucial point. To aid the journey of becoming more sustainable information systems and specifically business intelligence is an appropriate solution to help manage and measure sustainable development. However previous research suggests the use of business intelligence in the context of sustainability is not as prevalent as it could be. This study examines the use of business intelligence in relation to sustainability and its drivers for utilisation. Through a qualitative approach with semi-structured interviews, this study finds how manufacturing organisations are underdeveloped in their use of business intelligence. Further, the study finds the driver for the use and under utilisation of business intelligence is connected to the strong focus on reporting sustainability instead of focusing on gaining competitive advantages.

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1 Introduction

Sustainability has been a concern for many years. In 1972 the first steps towards addressing environmental issues were made in the UN Conference on Human Environment in Stockholm (Giovannoni & Fabietti, 2013). However, not until the last decade have these issues like environmental and climate change, issues with poverty and social inequalities become a large concern. Policy makers, academics, businesses and institutions have intensified their focus on these issues all across the globe (Giovannoni & Fabietti, 2013). There seems to be a general consensus on the importance of sustainability issues, but when it comes to engaging in sustainability practices many risk of falling short (Dixon & Fallon, 1989; Gray, 2010).

Gray (2010) explains the difficult nature of the dimensions of sustainability since they are accompanied by contradictions and we can attribute some of these contradictions to the "tension between the dimensions of sustainability" (Giovannoni & Fabietti, 2013). For example, a for profit organisation might face a dilemma when trying to maximise profits and address environmental issues, where one often comes at the cost of another. Due to this nature of the sustainable dimensions, most implementations of sustainability and sustainable development do not go beyond mere rhetoric (Giovannoni & Fabietti, 2013). To prevent the economic dimension from dominating, Elkington (1998) devised the triple bottom line approach and thus expanded the traditional economic performance metrics commonly used by most organisations to include social and environmental aspects as well.

The growing worldwide consciousness about sustainability issues is urging a move towards sustainability participation. In the context of Information and Communication Technology (ICT) for sustainability, it's believed that ICT can play a key role in facilitating this shift towards corporate social and environmental responsibility (Zelenika & Pearce, 2013). Watson et al. (2010) argues for the involvement of information systems in promoting sustainability since information systems have been considered to be the greatest driver for productivity since the birth of the computer.

Organisations are increasingly incorporating social responsibility into their mission but these elements remain isolated and fail to be fully integrated with the overarching corporate strategy (Petrini & Pozzebon, 2009). Petrini & Pozzebon (2009) explain that Business Intelligence (BI) could be leveraged to support sustainability practices and management. To go beyond the rhetoric, decisions regarding sustainability participations need to be supported by data and their effects needs to be analysed. According to Cheng et al. (2023) there is a positive relationship between the use of BI and sustainability performance. By leveraging data-driven insights provided by BI tools, companies can make more informed decisions that align with sustainable development goals. Integrating sustainability reporting with decision-making processes is something that is known to be inadequate in organisations (Ahmed & Sundaram, 2012). The term BI covers many tools, solutions, platforms, applications and methodologies in combination and the objective of BI is to enable interaction and manipulation of data, sometimes even in real time (Sharda, Derben & Turba, 2018). BI has its roots in the 1970s and the evolution has been fast in recent years, specifically within its data analytics component, but it requires highly structured data to work efficiently (Sharda, Derben & Turba, 2018).

Petrini & Pozzebon (2009) explain that to be able to monitor sustainable practices and the organisation's advancements in those practices there is a need for performance indicators that are related to sustainability. The authors argue that these indicators can only effectively be implemented with the use of a BI platform. Furthermore, BI is found to be crucial as a means of channelling and spreading information (Petrini & Pozzebon, 2009). According to Seidel et al. (2013) information democratisation is an affordance of information systems that can help in creating more environmentally sustainable business practices. BI can help managers track results related to sustainability and other business objectives. The combination of information spreading and tracking results enables everyone in an organisation to learn, uncover, and share insights about social and environmental initiatives undertaken both within their organisation and by others. The way BI systems provide reflective disclosure is also a way that can let organisations become more environmentally sustainable (Seidel et al. 2013). This feedback is essential to incentivise organisational behaviour to be directed towards socially responsible actions (Petrini & Pozzebon, 2009).

1.1 Problem

Zelenika and Pearce (2013) explains the possible usage of different ICT technologies in order to increase sustainability practices and improvements. The authors emphasise on the opportunity of further research within advanced information technologies and the need for a greater knowledge building within the area. Zelenika and Pearce (2013) means there is a lack of research on different usages of advanced technologies in order to increase sustainability, especially in a collaborative and open source environment.

Further, from the conclusions of the study by Petrini & Pozzebon (2009) we can deduce that the integration of BI platforms with corporate management systems has been lacking, even for those who are leaders within sustainability. According to Cheng et al (2023) it is proven that BI enables manufacturing companies to gain insights, make environmentally friendly choices and adopt more sustainable practices. Even though BI has been proven to have positive effects on organisations within the manufacturing industry there is a limited use of BI for sustainability (Ahmad, 2015). When BI is used, sustainability data is rarely integrated into the financial data to achieve a more balanced priority among the three sustainability dimensions (Menaouer et al. 2022).

In the field of BI, there is a notable research gap in the integration of sustainability issues, and its potential for enhancing sustainability practices in management are still very much unexplored. Despite the development of a conceptual model from Petrini & Pozzebon (2009) that integrates social, environmental, and economic indicators to facilitate sustainability in business strategies, its transferability and effectiveness in different international contexts are not yet fully understood. Ahmad (2015) further supports that the amount of literature on the subject is limited. Menarouer et al. (2022) show that 10 years on, companies still do not utilise the full potential of BI in sustainable development.

An indication of this gap may be first noticed in the search results from the Association of Information systems database. A search made in april 2024 with the combined key words: “Business Intelligence Sustainability” showed less than 30 results and no research relevant to the combined fields that has been published in the Senior Scholars list of Premier Journals since Petrini & Pozzebon´s (2009) mention of the research gap. A search with other keywords

such as “Green IS” gives similar results. Even though Petrini and Pozzebon (2009) and Watson (2010) have previously expressed more research to be needed in the field, a recent study with several authors from the IS field urged for more contribution to sustainability (Watson et al. 2021). Watson et al. (2021) discusses how the IS field needs to contribute more research for sustainability and need to make long-term commitments. By devoting more research focusing on sustainability in IS and journals recognizing the need for a shift towards solutions that are intervention-oriented instead of purely theoretical (Watson et al. 2021).

1.2 Research motivation

The relevance of BI is increasing together with its ever changing environment (Deloitte, 2018. Chen et al. 2012). In a report from Deloitte (2018) they explain how businesses want to do more with their data and the field of BI is moving towards a priority usage of advanced analytics. Within advanced analytics there are use cases of artificial intelligence with machine learning and mining of text and data (Deloitte, 2018). As modern BI is changing and connects with artificial intelligence the relevance of the field is very prevalent. A search for machine learning analysis in the Google Scholar database from 2023 yields over 87 900 results showing the high relevance and upwards trend of the technicalities connected to BI and advanced analytics.

Further, the challenges of becoming sustainable is also arguably the most important challenge for businesses and organisations around the world. Integrating corporate social responsibility (CSR) and sustainability into business strategies and operations has become a challenge for many organisations (Tsalis et al. 2020). CSR and sustainability have led to new global standards and legislations for companies to comply with (Bansal & Roth, 2000). Companies face the difficult task of aligning their operations and strategies with these sustainability goals (Ahmed & Sundaram, 2012). Although there's a growing interest in sustainable practices, putting these practices into place successfully can be quite challenging (Petrini & Pozzebon, 2009). Many companies have treated sustainability as a separate issue, not integrating it with their business strategies or performance evaluations, which are traditionally focused on financial indicators (Nappi & Rozenfeld, 2015; Petrini & Pozzebon, 2009). The requirements to balance financial performance with social and environmental impact demand adjustments in performance indicators to include all dimensions of sustainability (Nappi & Rozenfeld, 2015).

The relevance of the subject of sustainability cannot be underestimated with its multidimensional discourses, its meaning and impact on social and environmental aspects (Giovannoni & Fabietti, 2013). Although sustainability has been a prominent issue for some time, according to the latest report on the sustainable development goals from the UN there is still a lack of progress (United Nations Department of Economic and Social Affairs, 2023). As research has presented, there is also a need to increase usage of different advanced technological solutions in order for businesses and organisations to become more sustainable and tackle the challenges (Zelenika & Pearce, 2013).

In order to have a relevant contribution to the discipline of IS we believe there needs to be research looking to explore the connection between BI and sustainability and focusing on the BI capabilities which may be leveraged in order to manage sustainability measures. As previously outlined there is still a gap within BI in connection to sustainability. Therefore it

seems to be missing research looking at the integration of sustainability and BI (Petrini & Pozzebon, 2009). The field of IS as a whole also needs to shift focus and spend more time on sustainability issues (Watson et al. 2021). Furthermore, this research paper will focus on the specific industry of manufacturing in order to be slightly practical and partly because of the manufacturing industrys high environmental impact (Panagiotopoulou, Stavropoulos & Chryssolouris, 2021).

To summarise the problem and our motivations for this research paper, we have identified a challenge where organisations are not fully utilising BI to enhance their sustainability performance although there is a proven positive relationship (Cheng et al. 2023). Especially within industries like manufacturing that have a significant environmental impact. Organisations are struggling with integrating sustainability data with financial data, preventing them from having a more holistic view of an organisation's performance across all sustainability dimensions. Traditional performance indicators in companies are inadequate for capturing the full spectrum of sustainability, resulting in a need to reevaluate how performance is measured to include sustainability indicators. Finally, adhering to new global sustainability standards and legislation presents ongoing challenges for companies, demanding adjustments in ways organisations traditionally report on sustainability.

Lastly, as there is missing research on this narrowed approach looking at the IS-system of BI and its use case of sustainability, this paper hopes to explore these disciplines in a more practical setting. As authors we believe that this paper will help give insights into how BI currently is used in an industry setting, and identify both problems and opportunities when a business works with its measuring and managing of sustainability.

1.3 Research aim & purpose

By analysing how and to what extent manufacturing companies use BI technologies for their sustainability initiatives, we aim to identify the factors that influence the utilisation of BI in a sustainability context. This research seeks to contribute to the work towards sustainable development by providing insights into why BI is not used more extensively for measuring sustainability performance considering there is a proven positive relationship. The purpose of the research is also to add more to the knowledgebase of information systems and how systems may help organisations become more sustainable.

1.4 Research questions

Because of the intersection of BI and sustainability and the lack of research, looking at the relation of using them in conjunction the research questions want to focus on the what and how. As the management of the BI systems may be complex the objective of the paper is to answer the following research questions in order to understand both social and technological aspects as outlined in our aim of the study:

1. How and what BI technologies are used by manufacturers when measuring sustainability?
2. What drives manufacturers to use BI technologies to measure sustainability?

1.5 Delimitation

The research initially limits itself to the field of BI and looks at certain aspects of the field in conjunction with sustainability as an applied field for the BI systems. The research will not go in depth in a single component that is BI, but rather focus on the technical definition of BI as an umbrella term and look overarching at all components and how they are used. On the contrary, the research limits itself to looking at sustainability only from the perspective of the social and environmental components as these are the components connected to the defined problem. As the research is qualitative and interviews will be conducted within a short timeline there is a limitation to the amount of interviews to be made. Further, the study limits itself to looking at manufacturers and producers. The study also limits itself to only interview companies that operate in Sweden. These limitations are made because the research is being conducted in Sweden which helps the ability to find participants for interviews. This means each manufacturer might end up working in different sectors, which also may be reflected in the findings.

2 Literature review

This chapter is the result of our literature review. It covers the most important subjects of our research by delving into the different areas and fields the research questions are focused on. It gives the reader an introduction to all concepts and goes in depth in certain areas of higher importance to the study.

2.1 Business Intelligence

2.1.1 Business Intelligence Definition, History & Benefits

Business Intelligence (BI) is an umbrella term which combines several different technologies in conjunction (Sharda et al. 2018). It is a content-free expression and may have different meanings to different people, however in this paper we will use the definition made by Sharda et al. (2018) in which BI works as a system with four major technical components. The authors explain that a BI system consists of data sources linked to the first component, a *data warehouse*, second a suite or collection of *analytical tools for data analysis*, third *business performance management* (BPM) for performance monitoring and fourth a user interface for interaction, e.g. a *dashboard*. These components have a relationship, and together they make up the high level architecture of what a BI system is defined as (Sharda et al. 2018). Because of the four components of BI there are many different applications and solutions connected to BI. These applications and solutions can be things such as decision support systems (DSS), visualisations, data mining software, customer relationship management systems (CRM) and more (Negash, 2004). With the use of these applications and solutions the main purpose of a BI system is to provide deeper understanding of an organisation via insights and help the decision process via data analysis (Negash, 2004). This purpose means BI in practice needs to enable access to data, sometimes in real time, the process is on the basis of transformation of data to information, which ultimately leads to decisions and actions (Sharda et al. 2018. Negash, 2004).

The field of BI has its roots in early reporting systems of the 1970s however the term was first coined by the Gartner Group in the 1990s (Sharda et al. 2018). The BI systems went from being static reporting systems without analytical capabilities to their current versions containing powerful artificial intelligence capabilities within BIs´ analytics component (Sharda et al. 2018). Chen et al. (2012) goes deeper into the history of BI and describes BI as Business Intelligence and Analytics (BI&A) by focusing more on the history of the analytics component of BI. The authors explain how BI&A is constantly evolving and the field has emerged from and relates to database management. BI&A is heavily reliant on technologies for data collection and has evolved from data collection of legacy systems to collection from IoT sensors and mobile data collection which help provide more person- or context centred analysis (Chen et al. 2012).

Benefits of using BI are presented when data is heavily collected (Chen et al. 2012).

The benefits of using BI systems are presented to the decision makers, which is to gain valuable insights which helps make more informed and better decisions (Sharda et al. 2018). The benefits include gaining the insights from data very rapidly, and the intelligence helps organisations to work proactively in their decision making (Negash, 2004). While the benefits of BI are intangible, the system's primary benefits are not connected to efficiency, but rather long term which may help to create big returns for an organisation in the future (Negash, 2004; Sharda et al. 2018).

2.1.2 Business Intelligence & Data Warehouses

Data warehouse is the first technical component of what makes up a BI system (Sharda et al. 2018). A data warehouse is a larger scale predetermined and specially made repository of data and is created to support decision making (Wixom & Watson, 2001). Different from a database, a data warehouse is larger and combines several databases over an entire organisation (Sharda et al. 2018). Data is extracted from different sources which typically include various types of systems, it is then pre-processed with cleaning and transformation and placed in the data warehouse (Wixom & Watson, 2001; Sharda et al. 2018). The common characteristic of the data warehouse is how the data is in a structured form and readily available for analytical processing (Sharda et al. 2018).

From the data warehouse suppliers are responsible for delivering the data to end users of the warehouse and make it available to them through SQL queries or various types of decision support systems. The end users may be analysts and other people of an organisation that can make use of the preprocessed and structured data (Wixom & Watson, 2001). While data warehouses may be hosted locally, there are also various providers that help organisations hold their data warehouses in the cloud, which is a big sector of growth and seen as a benefit of data warehouses as it allows easy access for end users (Sharda et al. 2018). Other benefits of having a data warehouse may include the access to real time data for end users, the inclusion of metadata i.e. data about data and being subject oriented as it is organised in detailed subjects such as products, sales and similar (Sharda et al. 2018). Wixom and Watson (2001) further explain how organisations perceive that they gain benefits from a data warehouse only when the data quality- and the data warehouse quality, is good. This is because the qualities directly impact how data is provided to end users in their decision support systems (Wixom & Watson, 2001).

2.1.3 Business Intelligence & Analytics

The second technical component of what makes a BI system focuses on analytical capabilities and business analytics (Sharda et al. 2018). The word analytics is oftentimes used instead of the word BI and it can be seen as the process of developing actionable decisions or recommendations based on data, in similarity to the BI definition (Sharda et al. 2018). The rise of big data with its large scale data collection has created the possibility of BI and analytics (BI&A) to thrive, therefore BI&A is also closely related to the field of big data analytics. (Chen et al. 2012).

Chen et al. (2012) presents a framework with many different analytical technologies that work as a foundation for BI&A. Some of the authors´ included technologies are data mining, web analytics, statistical analytics and text analytics. These technologies are used in predictive

analytics, where accurate projections of future events are to be made (Sharda et al. 2018). For instance, what's going to happen, what is likely to happen and why it will happen (Sun et al. 2018). There is also prescriptive analytics using simulations, decision modelling and expert systems to find the best possible business decision in a given situation (Sharda et al. 2018) Prescriptive analytics therefore addresses problems related to what an organisation should do (Sun et al. 2018). Finally there is descriptive analytics used to discover new information and explain relationships among entities within big data (Sun et al. 2018). It is used to address questions related to what happened, when and what is currently happening (Sun et al. 2018).

Furthermore, there are other technologies which can be used for analytics. These other technologies are also related to artificial intelligence (AI), for instance the use of machine learning (ML) algorithms which is commonly used when conducting data analysis and data mining (Tsai et al. 2015). ML technologies like these can also help understand meaning from various collected data (Tsai et al. 2015). ML algorithms have a wide use case and can be used for most data analysis problems when it comes to large amounts of data (Tsai et al. 2015). ML technologies can for instance be used in analysis to do different predictions such as classification and regression (Mahdavinejad et al. 2018). Classification and regression problems can for example be solved by using data collected from IoT devices, utilising ML algorithms and technologies and making real time prediction of behaviour and forecasting weather (Mahdavinejad et al. 2018).

2.1.4 Business Intelligence & Business Performance Management

The third component of Sharda et al.'s (2018) BI system structure is business performance management (BPM). BPM is a process which typically leverages BI technologies (or other types of applications), i.e. the previously described data warehouses and analytical applications, but BPM itself is merely a process (Frolick & Ariyachandra, 2006). The BPM process aims to optimise the development and execution of business strategy through different applications and technologies (Frolick & Ariyachandra, 2006). While BPM is not the same as BI, it is typically a part of a BI system, but it can also be a standalone process with other applications that are not considered BI (Frolick & Ariyachandra, 2006; Sharda et al. 2018).

The BPM process can be described as a closed loop cycle where the process is divided into four steps; *strategize*, *plan, monitor* and *act/adjust* (Frolick & Ariyachandra, 2006. Sharda et al. 2018). Each step wants to answer different questions that are connected to each other in order, *strategize*: where do we want to go?, *plan*: how do we get there?, *monitor*: how are we doing? and *act*/*adjust*: what do we need to do differently? (Frolick & Ariyachandra, 2006; Sharda et al. 2018).

In the process of the BPM steps they help identify metrics closely tied to business strategy, key performance indicators (KPI) (Frolick & Ariyachandra, 2006). The KPIs are identified in the *strategy* step, as this step is when an organisation identifies key drivers of business value which then can translate into the KPI metrics and help assess business performance (Frolick & Ariyachandra, 2006). Furthermore the identified KPIs are used in the *monitoring* step in order to follow up on how the previously selected metrics are performing which then ultimately can lead to a response depending on the KPIs (Sharda et al. 2018).

2.1.5 Business Intelligence & Dashboards

The fourth and final component of a BI system is the user interface, or the information *dashboard* (Sharda et al. 2018). A dashboard can be a part of many different systems and are almost always prevalent in a BI system (Sharda et al. 2018). The dashboard is supposed to provide visual displays of important information, for example KPIs, it is also meant to be arranged on a single screen for easy digestion (Sharda et al. 2018). Eckerson (2005) adds to this meaning of the dashboard and describes them as an organisational magnifying glass to help an organisation clearly communicate its strategy. The dashboards function can further be described in three sets: monitor, analyse and manage (Eckerson, 2005). Its purpose is to help monitor critical business processes, analyse the root cause of problems and manage processes to improve decisions (Eckerson, 2005). To create the dashboard organisations use different types of data- or information visualisation such as graphs, charts and different types of visual elements and putting them together with the use of for instance a BI application (Sharda et al. 2018).

The benefits of using dashboards are highly practical and they offer a vast amount of benefits such as: help communicate strategy, increase visibility, strategy refinement, deliver actionable information, increase motivation, increase coordination and user empowerment (Eckerson, 2005) While benefits are prevalent the use of dashboards can be unsuccessful if the applications used are too flat, i.e. Microsoft Excel and PowerPoint (Eckerson, 2005). They can also be unsatisfactory if they are too manual and are not automatically updated. In addition to this they will prove unsuccessful if the source data to the dashboard is too isolated and only appeal to a very small audience (Eckerson, 2005).

2.2 Sustainability

2.2.1 Goals for sustainable development and its challenges

The United Nations has established 17 Sustainable Development Goals (SDGs) as a global blueprint to achieve a better and more sustainable future for all by 2030 (United Nations, n.d.). These goals address the global challenges such as poverty, inequality, climate change, environmental degradation, peace, and justice to name a few. Complying with these goals has become a high priority for many businesses (Tsalis et al. 2020). Although many organisations may want to contribute to all 17 goals in some way or another, corporations face the challenge of adjusting their operations and strategies to align with the SDGs (Ahmed & Sundaram, 2012; Tsalis et al. 2020). A key challenge due to new standards of reporting is ensuring that reports provide valuable, transparent, and accurate information about a company's sustainability practices and performance (Ahmed & Sundaram, 2012; Tsalis et al. 2020). This requires a comprehensive understanding of the goals and how they relate to the business's impact on social, economic, and environmental dimensions. This comprehensive coverage demands significant resources for monitoring, measuring, and reporting activities (Tsalis et al. 2020).

There is an existing gap in integrating sustainability reporting with decision-making processes and business transformation initiatives (Ahmed & Sundaram, 2012). Ahmed & Sundaram (2012) argue that organisations often treat sustainability modelling and sustainability

reporting as separate activities, which leads to uncoordinated efforts and misses the opportunity for these processes to inform and reinforce each other. Ahmed & Sundaram (2012) critique current practices where sustainability reports are prepared without fully integrating them into the business's strategic and operational planning, resulting in reports that might not fully capture or drive the organisation's sustainability efforts. An integrated approach to sustainability modelling and reporting, where insights from sustainability models directly inform reporting processes, can significantly enhance the strategic value of sustainability reports.

2.2.2 Corporations motivations for sustainable development

Corporations are being increasingly concerned with sustainability. Bansal & Roth (2000) identifies three main objectives why corporations are adopting more and more ecological practices or ecological initiatives. One motivating factor is competitiveness; where organisations can pursue ecological strategies such as waste management and reduction in order to reduce cost and thus improve profitability, all in line with the resource based view (Bansal & Roth, 2000; Dangelico & Pujari, 2010). The second motivating factor is legitimation of the organisation. Legitimation in this sense relates to the compliance of regulations and norms. Organisations often adopt a more reactionary approach towards external constraints in order to avoid fines and sanctions (Bansal & Roth, 2000; Dangelico & Pujari, 2010). They tend to adopt a conservative approach, imitating peers and adhering to industry standards to ensure conformity and maintain legitimacy (Bansal & Roth, 2000). Dangelico & Pujari (2010) go beyond just regulatory compliance and argue that environmental sustainable development also enhances an organisation's reputation and thus gaining legitimacy that way. This will in turn lead to competitive advantages. Lastly, Bansal & Roth (2000) identified responsibility as a motivator for sustainable development (Bansal & Roth, 2000). The emphasis on ethical considerations over pragmatic benefits is a hallmark of this motivation, with actions taken out of a sense of duty, responsibility, or philanthropy rather than for direct financial gain. Firms motivated by ecological responsibility often report undertaking their environmental initiatives because it is the "right thing to do" (Bansal & Roth, 2000; Dangelico & Pujari, 2010).

Given that many organisations see compliance towards regulations as one of their top motivations to why they undertake sustainable development indicates that regulations will be a crucial component in the grand scheme of reaching the UN goals of sustainable development by 2030. The European Union recently enacted legislation concerning corporate social responsibility reporting, known as CSRD that stands for corporate social reporting directive (Official Journal of the European Union, 2022). The implications of this legislation is still unknown since the directive came into effect Jan ‘23 and the first companies will have to apply the rules for the first time in the fiscal year of ‘24. However, until adequate research has been published we can assume that the challenges would be similar to what we have seen to date regarding regulations on sustainability reporting. Organisations will be required to report on a broader range of sustainability matters, including environmental, social, and governance (ESG) aspects (Official Journal of the European Union, 2022). This will likely necessitate the collection, analysis, and disclosure of more detailed and comprehensive data than previously required. As per Petrini & Pozzebon (2009), BI tools and processes can play an important role in collecting, analysing, and reporting the vast amounts of sustainability data. Data that now will be required under the new directive. However, one could question its effectiveness for getting closer to the UN SDGs, since there is a disconnect between reporting

and decision making processes, where reporting is treated by itself, as argued by Ahmed & Sundaram (2012).

2.2.3 Measuring Sustainability with Performance Indicators & Triple Bottom Line

There are various ways to report on sustainability practices firms undertake towards their stakeholders (Tsalis et al. 2020). Corporate Social Responsibility (CSR) embodies the principle that companies should go beyond profit-making to include social and environmental responsibilities in their operations and relationships with stakeholders (Borglund, 2021). This concept advocates for a business model where achieving economic success goes hand in hand with fostering environmental sustainability and social equity, often described as the "Triple Bottom Line" (United Nations, 2024). Through CSR, companies aim to balance their economic goals with the broader expectations of shareholders and the community.

The triple bottom line approach coined by Elikington (1998) adds social, environmental indicators to the usual economic performance indicators typically used in most organisations (Nappi & Rozenfeld, 2015). Nappi & Rozenfeld (2015) highlights the growing importance of sustainability indicators when there is an increasing interest in the environmental impact of products from consumers. To achieve the goals of becoming more sustainable, managers require updated, precise, and unified performance data for guiding and improving operations, Nappi & Rozenfeld (2015) suggest a Performance Measurement System. This system is a way to create metrics evaluating efficiency and effectiveness. This is not too different from the business performance management mentioned in section 2.1.4. Although business performance management is merely a process and not a system, they are closely related.

Nappi & Rozenfeld (2015) argues that identifying and selecting sustainability indicators involves workshops with a multidisciplinary group of employees to understand current practices and strategic objectives related to sustainability. This highlights the importance of involving stakeholders or subject matter experts (SMEs) in the identification and validation of new performance indicators to ensure that the selected indicators are relevant and aligned with both internal and external sustainability objectives (Nappi & Rozenfeld, 2015). Nappi & Rozenfeld (2015) discuss the possibilities of adapting a PMS system like the Balanced Scorecard and expanding its traditional dimensions to include sustainability concerns. The balanced scorecard traditionally supplements financial metrics with indicators that predict future performance, all of which are aligned with the organisation's goals and strategic direction (Norton & Kaplan, 2006). Originally, the Balanced Scorecard did not include sustainability as a factor and did not explain how to make sustainability a key part of company strategy. However, its ability to look at multiple aspects at once has led to efforts to modify the BSC to include sustainability (Petrini & Pozzebon, 2009).

Petrini & Pozzebon (2009) points towards a major issue where many companies have treated sustainability as a separate concern rather than incorporating it into their core business strategies and performance evaluations, which traditionally focus on economic indicators. Petrini & Pozzebon (2009) stresses the importance of not only defining social and environmental indicators but also understanding how these indicators can be effectively implemented, displayed, and monitored. According to Clarkson (1995) this is crucial for enhancing CSR management as the transparency and accessibility of corporate information become bigger concerns.

2.2.4 Affordances of IS in green transformation

Seidel et al. (2013) argue that information systems play a significant role in facilitating organisational transformations towards environmental sustainability. A business intelligence system is objectively an information system, as they provide the technological basis for monitoring, managing information. For this reason BI systems can facilitate the move towards environmentally sustainable business practices within organisations. Seidel et al (2013) highlights four crucial functional affordances provided by information systems. These affordances aid organisations to engage in sensemaking processes related to emerging environmental requirements and implement environmentally sustainable work practices.

The first affordance is *reflective disclosure* (Seidel et al. 2013). According to Seidel et al. (2013), information systems can facilitate reflective disclosure meaning that organisations can more easily assess and improve their environmental impact. This could manifest itself through data analysis on metrics such as carbon footprint and waste production. Secondly, *information democratisation* expands access to sustainability information within and beyond the organisation, promoting inclusivity and engagement for collective action towards sustainability goals (Seidel et al. 2013). Dashboards are explained in section 2.1.5 and can be used for this purpose as dashboards effectively communicate strategy, offer actionable information and increase motivation (Eckerson, 2005). Cheng et al. (2023) reinforce that due to BIs ability to share knowledge and gain insights encourages environmentally aware behaviour, environmentally friendly choices and make organisations adopt more sustainable practices. The two above mentioned affordances are related to organisational sensemaking (Seidel et al. 2013). The third affordance and fourth affordance are related to sustainable practices rather than sensemaking. These two affordances are not equally manifested in BI. *Output management* leverages information systems to track and manage environmental outputs, such as resource consumption and waste, enhancing sustainable practices by reducing environmental footprints (Seidel et al. 2013). *Delocalization* utilises information systems to become location independent, minimising the need for travel and its environmental impact, thereby supporting a shift towards more sustainable and flexible work arrangements.

2.2.5 Business Intelligence and Sustainability

As mentioned before, one of the main motivators for companies to engage in sustainable practices often stems from regulatory compliance (Bansal & Roth, 2000). This is where the importance of reporting becomes evident. As we have hinted at before, with its roots as a reporting system, BI holds potential as a powerful tool for sustainability. BI systems, as described by Petrini & Pozzebon (2009), have the capacity to address many of the challenges associated with sustainability reporting. The complexity and breadth of data required for comprehensive sustainability reporting fit well with BI's capabilities in data aggregation, analysis, and reporting (Sharda et al. 2018). BI systems can provide detailed performance indicators that align with the Triple Bottom Line approach (Nappi & Rozenfeld, 2015; Sharda et al. 2018).

Moreover, BI possesses at least 3 of the affordances that Seidel et al. (2013) consider important for green transformations. BI offers enhancements to a company's ability to monitor, manage, and report on what could be, sustainability practices and sustainability related data (Sharda et al. 2018; Eckerson, 2005). These affordances include reflective disclosure, which allows organisations to assess and improve their environmental impact

through data analysis; information democratisation, which expands access to sustainability information, fostering inclusivity and engagement; output management, enabling the tracking and management of environmental outputs.

Given the challenges of incorporating sustainability measures into traditional reporting and performance indicators, Petrini & Pozzebon (2009) show that the absence of advanced informational support such as BI systems is considered a significant drawback. Issues arise from not having a unified system, where metrics developed in isolation by various individuals who do not collaborate lead to inconsistencies, such as the same metric displaying different values in different reports (Petrini & Pozzebon, 2009). This fragmentation in information management undermines the reliability of collected data, including indicators related to sustainability, and prevents their integration with other metrics for informed decision-making (Petrini & Pozzebon, 2009). Challenges also stem from the effort required in gathering and validating these indicators, the absence of timely and current data, and a general misunderstanding of the metrics' definitions and purposes due to a lack of clear conceptualization and transparency. Consequently, Petrini & Pozzebon (2009) argue that BI systems are increasingly viewed as a crucial solution, offering a robust, ongoing platform for communication and information sharing that supports sustainability practices across firms.

2.3 Business Intelligence & sustainability in manufacturing

2.3.1 Business Intelligence in manufacturing

Because of the large amounts of data produced in a manufacturing process the use of BI is applicable in the field in order to create some type of value out of the data (Bordeleau et al. 2020). In manufacturing BI&A has emerged with a focus on operations by valuing real time data created in the production process (Bordeleau et al. 2020). However while BI is applicable, real time and integrated analysis is especially difficult for smaller manufacturers (Bordeleau et al. 2020). For BI&A to create operational value for manufacturers there is also a need for collection of both qualitative data on for instance employee engagement and work climate at the manufacturing facility as well as quantitative data from the production process (Bordeleau et al. 2020).

Manufacturers can have a BI infrastructure that connects many of the different systems needed to conduct adequate analysis (Bordeleau et al. 2020). There is a possibility to use centralised and company-wide databases to access data from different business processes (Bordeleau et al. 2020). Manufacturers may use tailormade BI solutions called manufacturing execution systems (MES) that utilise BI technologies such as dashboards, data warehousing and data integration (Koch et al. 2010). MES wants to merge machine and production data collection with energy management in conjunction with simple reporting and analytical capabilities (Koch et al. 2010). With this MES approach a manufacturer aims to create a centralised BI approach of its manufacturing process (Koch et al. 2010). However, MES lacks features that are common in a proper BI solution such as advanced data analysis and elaborate data history via data warehouses (Koch et al. 2010).

2.3.2 Sustainability & sustainability KPIs in manufacturing

In the manufacturing industry there is a need to measure different sustainability concerns in its manufacturing processes and systems (Giret et al. 2015). One major factor which influences efficiency, quality and cost within a production process is the scheduling at the operational level (Giret et al. 2015). Scheduling in manufacturing is to allocate human or technical resources to various tasks within a given time frame (Giret et al. 2015). Scheduling is broad and may also encompass predictive approaches, reactive approaches and real-time control techniques (Giret et al. 2015). Efficient scheduling may help manufacturers to directly impact resource and energy consumption and any type of emission (Giret et al. 2015). One of the most important parts of increasing sustainability in manufacturing processes is to reduce the energy consumption because the processes generally use large amounts of energy (Giret et al. 2015).

Sustainability KPIs in manufacturing are vast and can vary depending on the manufacturer, but manufacturers typically still follow the three pillars of sustainability; social, environmental and economic (Contini & Peruzzini, 2022). The most common KPIs manufacturers focus on in the social pillar are in the following order: health, employee satisfaction, staff training, noise and work accidents (Contini & Peruzzini, 2022). In the environmental pillar the most used KPIs were in the following order: energy, waste, water, raw materials, greenhouse gas and air emissions (Contini & Peruzzini, 2022). Finally in the economic pillar the biggest KPI focus are on: turnover, material costs, quality, sales, labour costs and research and development costs (Contini & Peruzzini, 2022). While these are the most common KPIs in manufacturing there are still more that are measured and the economic pillars are the most diverse in terms of what is most common (Contini & Peruzzini, 2022).

2.4 Literature structure

2.4.1 Summary of the literature review

This literature review explores what previous research has been done in the realm of BI and sustainability. The literature review also tries to account for the use of BI in manufacturing and the common sustainability KPIs within said industry. The selected literature is an examination of BI’s components and shows the evolution from simple reporting systems to more complex systems with predictive and prescriptive analytics. The selection of literature also highlights the: complexities and multidimensionality of sustainability; why organisations might want to be more sustainable; what makes information systems well suited for green transformations.

Considering KPIs are an important part of BI we also wanted to review the research on creating KPIs that measure sustainability performance. By assessing existing KPIs focused on sustainability we can get an understanding of the current state of their BI usage. The literature demonstrates how BI tools can measure and improve various sustainability KPIs across the triple bottom line. Focusing on the manufacturing sector, the review illustrates how BI tools are tailored to enhance operational efficiency and sustainability through real-time data analysis and integrated systems. Practical examples demonstrate BI's applicability in monitoring and enhancing sustainability performance across various dimensions.

We expect this literature to support our empirical research by providing a foundation that illustrates how BI tools can be used in manufacturing to enhance sustainability practices. This will assist in answering our research questions concerning the rationale behind the use of specific BI tools in this sector and their impact on sustainability metrics.

2.4.2 Literature framework

In order to further understand and summarise our literature review a framework is provided below. The framework is also to help show the identified literature, different perspectives, provide an overview and will be further used in the research as a structure basis for empirical data and discussion.

Table 1: Literature framework

Main field	Aspect	Connected literature
Business Intelligence	BI definition, history & benefits	(Sharda et al. 2018) (Negash, 2004) (Chen et al. 2012)
	BI & Data Warehouses	(Wixom & Watson, 2001) (Sharda et al. 2018)
	BI & Analytics	(Tsai et al. 2015) (Sharda et al. 2018) (Chen et al. 2012) (Mahdavinejad et al. 2018)
	BI & Business Performance Management	(Sharda et al. 2018) (Frolick & Ariyachandra, 2006)
	BI & Dashboards	(Sharda et al. 2018) (Eckerson, 2005)
Sustainability	Reporting	(Ahmed & Sundaram, 2012 (Tsalis et al. 2020)
	Motivations	(Bansal & Roth, 2000) (Dangelico & Pujari, 2010)
	Affordances	(Seidel et al. 2013)

	CSR & Triple bottom line	(Borglund, 2021) (Elkington, 1998) (Tsalis et al. 2020)
	Sustainability KPIs	(Nappi & Rozenfeld, 2015) (Petrini & Pozzebon, 2009)
BI and Sustainability in Manufacturing	BI in Manufacturing	(Bordeleau et al. 2020) (Koch et al. 2010)
	Sustainability & sustainability KPIs in Manufacturing	(Giret et al. 2015) (Contini & Peruzzini, 2022)

3 Research methodology

This chapter covers our research methodology. It explains our decisions and choices of philosophy and various methods used to conduct our research. It also delves into ethical aspects and quality standards set for our research.

3.1 Research philosophy

As this study's objective is to understand the what and the how within a field we as researchers have adopted interpretivism as the most suitable research philosophy for this study. Goldkuhl (2012) makes the case that interpretivist methodologies, which concentrate on the understanding of people's subjective experiences and meanings, are suitable for examining the adoption and utilisation of information technologies in organisational contexts. Interpretivism was therefore an appropriate philosophy as our study aimed to learn more about the utilisation of business intelligence to manage and measure sustainability performance.

The subjective experiences from our respondents differed from each other and our aim was to understand the meaning of their answers through the process of interpretation (Goldkuhl, 2012; Lee, 1991). In our case, interpretivism as an approach helped us understand the respondents in their specific setting. Furthermore, adopting a interpretivist philosophy meant we as authors and interviewers had to interpret the empirical reality from the conducted interviews by understanding the human behaviour of the respondents, and to which the subjective meaning the behaviour had (Lee, 1991). In the context of our study, this meant that we had to understand how our respondents used BI systems and what that meant in relation to our research aim. Our interview questions were therefore also influenced by phenomenology, meaning that we wanted to understand how BI systems were utilised through the lived experiences of our respondents.

One may argue positivism would work as an approach since positivists use formal logic to eliminate propositions that may be a researcher's own subjective opinions (Lee, 1991). We authors disagree with the positivistic approach due to its focus on natural science methods and attempts to quantify social reality. Such methods are not suitable for this research, as our research question is not easily quantifiable by nature (Lee, 1991). This led us authors to choose interpretivism as our philosophical approach.

3.2 Research approach

As we seeked non numerical answers such as experiences, opinions, and analysis of our observation, qualitative research was particularly well suited for this cause (Patton, 2015; Recker, 2012). Qualitative research encourages the development of conceptualizations based

on the data collected with an interpretive inquiry rather than a statistical one (Recker, 2012). The qualitative approach consequently aligned well with our interpretivist philosophy as it enabled us to gain insights into the informants' experiences by interpreting their rich responses.

Quantitative instruments, as argued by (Patton, 2015), are most suitable for standardised questions where responses often fall into predetermined categories. Since there was no vast literature regarding the utilisation of BI systems for sustainability at the time of this study, we believe that we would be unable to create said predetermined categories for statistical inquiry. By conducting qualitative research we had the opportunity to create categories of analysis of our own and come across unexpected results that challenged our former perceptions on the matter (Patton, 2015). As we looked for details and a deeper understanding of the subject at hand, qualitative research was the most appropriate research method (Patton, 2015). Since the answers to the questions we posed were unique from one respondent to another, the answers would therefore be difficult to quantify, and by trying to do so we would lose much of the depth. Instead, we chose to embrace a qualitative approach which helped us uncover reasons organisations might underutilize BI for sustainability. This method also allowed us to gain a deeper understanding of the organisational context in which BI resides.

Qualitative methods enable the collection of in-depth information and lets us understand not just the decision, but the reasoning behind them. This aligned with our objective of understanding the rationale associated with utilisation of BI and sustainability. By employing these methods, we were able to engage directly with participants, eliciting comprehensive explanations and personal insights that reveal not only what decisions are made but also why they are made. Qualitative methods also let us examine the use of BI from different angles and gather a comprehensive and detailed picture which we argue is appropriate for capturing its role in the multidimensional nature of sustainability, i.e. economic, social and environmental (Recker, 2012).

Realising the weaknesses of qualitative research methods in regards to generalizability and validity we nonetheless argue that qualitative research is the most appropriate research method for the questions this paper aims to answer (Patton, 2015; Recker, 2012). We also acknowledge that the credibility of this research hinges to a greater degree on our skills as researchers, our competence and the rigour of our research (Patton, 2015).

3.3 Literature review approach

In order for us to gain a deeper understanding of the different subjects this paper examines ,a thorough literature review has been conducted. While both of us authors have experience from master level courses in the field of sustainability and BI we are still not experts in any of these fields. Because of this we needed to go over literature relevant for the study, for both the sake of us authors but also for the readers' understanding. The literature review helps to convey our frame of reference, clarifying the informational basis for our interview questions and how we interpret the results. The literature review was conducted by searching for key search terms we perceived as relevant for the study in LUBSearch, Google Scholar and AIS eLibrary. The literature was then selected based on our judgement of relevance to the different subjects brought up in the study.

While there was no strict search criteria, we aimed for each article to be peer reviewed, we also prioritised articles with higher number of citations, more known and cited authors and articles published in the Senior Scholars' List of Premier Journals in order to maintain a higher quality of our literature. We did not prioritise recently published sources in our literature mainly due to the fact that the nature of our question does not aim to uncover anything new in BI nor sustainability. The question of our study rather focuses on existing and already prevalent components of BI and sustainability and how they can work together, meaning newer sources regarding the respective fields will not necessarily add anything of value to the preexisting literature. While we have these prioritizations it does not mean all our articles meet the priority criteria. Further, some of the literature was taken from the course literature of BI and Sustainability courses us authors previously attended.

For us to narrow down our search results to be as relevant to our research as possible, operators such as AND and OR were used with selected keywords. OR encompassed similar definitions, while AND identified concepts that we wanted to look at in conjunction. Consequently, the following keywords were determined for the literature search.

Business Intelligence, Business Intelligence AND Sustainability OR Green IS, Data Warehousing, BI AND Sustainability, Sustainability Reporting, Sustainability Manufacturing, Business Intelligence AND Manufacturing.

3.4 Sampling

Our information to this study was purposefully sampled. As Patton (2015) describes, what would be considered bias in statistical sampling becomes a strength in qualitative research. Random and statistical representative sampling enables for generalisation to a larger population (Patton, 2015). However, we seeked information rich cases where we could gain more in-depth knowledge about the issue we wanted to understand. Purposeful sampling enabled us to do this. We cannot expect to gain deep knowledge about BI and its use for sustainability unless we go out and purposefully find the people with the right knowledge.

We used a hybrid approach to purposeful sampling for this research. Our approach combines elements from the snowball sampling method, the intensity sampling approach, and the homogeneous approach. Due to time constraints, we were not able to implement each strategy in its entirety. Instead, we selectively adopted components from each strategy. Due to the limitations of our professional connections in the field of BI the snowball approach is appropriate for finding relevant and information rich informants. The snowball approach helped us get closer to the right participants through the referencing of others (Patton, 2015). For instance we utilised our social network, asked our friends and colleagues, who we believed had connections within the sustainability departments of manufacturing companies, to identify potential interviewees. Our sampling was also homogenous as the informants we seeked had similar types of roles within their respective organisation and with similar experiences in the field. Intensity sampling is the sampling of information rich cases that exhibit the phenomena we want to understand (Patton, 2015). The word intensity refers to the degree to which the phenomena presents itself. We would not want to research cases where the phenomenon is not manifested enough since this would not help us get closer to answering our research question. In order to maintain a high degree of intensity and homogeneity we searched on LinkedIn for keywords such as sustainability, business intelligence or data

scientist to find the right people for our study. The participants could be of either 2nd or 3rd degree connection. After having received recommendations on who to contact, a request was sent out via LinkedIn and Email asking whether they would be willing to participate in our study.

In table 2.2 below our respondents are displayed in conjunction with their role and type of organisation. Respondents 6-8 was a group interview in which several people with various roles from one organisation participated. All interviews except with respondent 2 were held online through video chat. All respondents work with sustainability and data in some manner and were able to answer almost all our questions.

Table 2: Respondents

Designation	Organisation/Industry type	Role	Length	Date
Respondent 1	Industrial consultancy	Sustainability consultant	59 min	10 April 2024
Respondent 2	Industrial machine production	CFO & Head of sustainability	55 min	17 April 2024
Respondent 3	Tobacco production	Senior Lead Engineering & Sustainability	52 min	19 April 2024
Respondent 4	Mining industry	Business development manager	52 min	24 April 2024
Respondent 5	Furniture manufacturing	Senior Business- & Product developer	58 min	25 April 2024
Respondents 6-8	Stainless Steel production	Senior Sustainability Engineer; Environmental Engineer; Energy Engineer	58 min	26 April 2024

3.5 Data collection method

3.5.1 Interviews

The data collection was conducted through interviews, where we were able to see things from the other person's perspective (Patton, 2015). The interviews were mostly conducted online via video call, however one interview was made in person. The fact that the interviews could

be conducted online simplified the interview process by making it easier to schedule, requiring less time and effort from the interviewee and thus increased the likelihood of actually securing an interview. After the sampling of our participants, we gave a brief introduction of the topic and the aim of our research, so that the person being asked could determine themselves if they were fit for an interview. The participants were also informed that the interview would be approximately 1 hour long.

We chose semi-structured interviews as our main method of data collection. This method of data collection was appropriate as it offered us a blend of questions that can be formulated ahead of time and questions that may arise as the interview progresses (Recker, 2012). The questions formulated ahead of time acted as our framework for the interview, ensuring we covered the essential topics related to BI and sustainability. Given that we are unsure of the interviewee's proficiency in both BI and sustainability beforehand, a semi-structured interview lets us adapt our questions so that we could extract the most out of each interview. During the interviews, we often found that the interviewees preemptively answered many of our questions. The use of semi-structured interviews allowed us to adapt our questions dynamically, ensuring the conversation flowed naturally.

The existing knowledge in this field is still evolving, meaning that the conventional theories that typically guide research questions in research are not as developed or comprehensive (Recker, 2012). We argue that this lack of a well-established foundation would mean that if we had to rely too heavily on predetermined questions that could have been overly restrictive, hindering us from uncovering aspects that later proved to be important for us. This approach enabled us to probe deeper into areas that proved to be significant, but were not immediately apparent or well-defined in the existing literature, during the course of the interviews (Recker, 2012).

Semi-structured interviews encouraged two-way communication that lead not only to interesting answers but also to underlying reasons behind them (Recker, 2012). As we aimed to understand how and what factors influenced the utilisation of BI a semi-structured interview was particularly appropriate. However, alongside these benefits, we were also aware of challenges associated with the process of interviewing (Recker, 2012). These challenges could have included issues of reflexivity, where interviewees could have responded in a way that aligns with the interviewer's expectations, leading to biassed responses. In our case this could have manifested itself when the respondents answered questions regarding sustainability practices. They could have claimed to do one thing but actually do something else, just to portray themselves in a positive light. This is something that we had to be wary about.

3.5.2 Interview guide and design

Four of our interviews took place on Zoom, one in person and the last interview took place on Microsoft Teams. For the interview in person, we recorded using the recording software application built in on our phone. For the interviews on Zoom we were able to download the audio recording from the program. Regarding the last interview on Microsoft Teams, since this was hosted by the respondents, we need to ask for the host to send it to us. For all interviews we were very thorough in not uploading the data to the cloud, making sure it was stored locally on our computer’s hard drive.

In table 3 you will find our interview guide. This guide helped us structure our interview and made sure we had a clear focus. It also ensured that our questions were grounded in the literature, increasing the legitimacy and relevancy of our questions. Once again, we conducted a semi structured interview, which means we were able to go on a tangent if we deemed it necessary. Some questions that are not listed in the interview guide arose such as follow up questions and clarifications. There was no set order that these questions were asked. If the respondent touched on a question that was meant to be asked later on in the interview, we took the opportunity to ask it right away to create a natural flow in the interview.

While the questions are displayed in English it is translated from Swedish as all the interviews are made with Swedish respondents. The entire interview was also held in Swedish since both us interviewers and the participants were Swedish. Conducting the interviews in the participants' mother tongue we hope would let the participants express their thoughts, feelings, and experiences more precisely and comfortably. The interview guide has four columns. A theme, which is the main subject at hand, together with a category which is based on the subheadings of each theme and finally the connected literature which the questions are based on.

Table 3: Interview Guide

Theme	Category	Literature	Questions:
Introduction, background, ethical aspects and formality	-Introduction -Background	Checklist of things to cover before the interview starts.	- Is it ok that we record the interview? - We will only store the audio file until we have finished transcribing. Once transcribed all recordings will be deleted. - You have the right to be excluded from the study at any point. - You will be anonymous. - We will not disclose your name. - We will not disclose your company name. - We will only mention your role and type of industry. - What is your role and what does your organisation do? - What sort of customers do you have?
BI	Definition of BI & Sustain-ability	Sharda et al. 2018; Negash, 2004; Chen et al. 2012	- When we talk about BI, we refer to the following definition… - Does the definition of BI correspond with your definition? - If not - why/how? - What is your definition of sustainability? - Do you have a sustainability framework?

Sustainable development		Tsalis et al. 2020; United Nations, 2024	- What sustainability goals do you have? - How would you like to be more sustainable?
Motives for sustainable development		Bansal & Roth, 2000; Dangelico & Pujari, 2010	- What motivates your organisation to work with sustainability? - Competitive advantages, regulatory compliance and/or altruism?
Alignment with sustainability goals and compliance with regulations	-SDG & EU	Ahmed & Sundaram, 2012; Bansal & Roth, 2000; Tsalis et al. 2020	- Does your sustainability work align with the UN Goals? - Has CSRD changed the way you work?
BI	-BI&DW	Wixom & Watson, 2001; Sharda et al. 2018; Seidel et al. 2013	- Do you use a data warehouse? - Or how is the data stored? - How is the data made available to the different parts of the organisation? - Who has access to the data?
BI	BI&A	Chen et al. 2012; Mahdavinejad et al. 2018; Tsai et al. 2015; Sharda et al. 2018	- How is the data that you store analysed? - Do you use any special tools or as such in your analysis? - Do you make use of any AI/ML in your data analysis?
BI	-BI & BPM	Nappi & Rozenfeld, 2015; Petrini & Pozzebon, 2009	- How are KPIs identified? - What does the process look like when evaluating sustainability performance/KPIs? - Do you have a framework when identifying KPIs? Balanced scorecard? - What KPIs do you have in relation to your sustainability goals? - What stakeholders are included in identifying what KPIs are needed?

BI	-BI & Dashboard	Eckerson, 2005; Sharda et al. 2018	- How are dashboards used and in what context? - What do these dashboards contain? - What tools are used to build and/or present dashboards?
BI & Sustainability in conjunction		Ahmed & Sundaram, 2012; Tsalis et al. 2020	- What kind of BI tools are used in conjunction with sustainability data? - What sustainability data are you gathering and storing? - Has CSRD changed the data that you manage? - What does the process look like when choosing sustainability data? - Who decides what data to gather?
BI, sustainability + manufacturing		Giret et al. 2015; Petrini & Pozzebon, 2009	- Are you obtaining any qualitative data? For example in health and safety, or is it just quantitative? - Is there any real-time analysis of the data? - What do you aim to achieve from your data analysis? - What advantages do you see when using BI in conjunction with sustainability? - Are you using BI more for other applications?
Other			- Is there anything that you think we should look more into in our research? - Is there anything we have missed that you consider important in the context of BI & Sustainability?

3.6 Data analysis methods

After data collection we transcribed the recorded interviews. To transcribe the data used the open source software Whisper developed by OpenAI. Whisper is an automatic speech recognition (ASR) model (Radford et al. 2023). After gathering the transcription provided by the speech recognition program we cross-checked the transcription with the audio recording. This makes sure that the ASR has not hallucinated, made any errors or missed crucial parts. Going over the transcription provided by the ASR program also allows us to remove some of the interjections such as “Mhm” and “Ok!” in order to make the transcription more readable.

Sometimes during the interview words were repeated several times, providing no additional information. Consequently, for the sake of readability, we added punctuations where we saw fit and sometimes removed repeated words. Furthermore, the transcription created by the ASR program is divided into rows, where each row contains a maximum of a few words. In order to structure it easily and make it readable in a table we joined the rows where the respondent speaks, then put the joined part as a paragraph in the table. Respondents are displayed as plain text and us interviewers are marked with **bold text** for better readability.

In order to fulfil the aim of the paper, the collected qualitative data must be thoroughly analysed in relation to the research question (Patton, 2015). For this research we conducted 6 interviews before we started to see information saturation in the answers provided by the respondents. Each interview was around 1 hour long, this in turn created large amounts of data. Recker (2013) describes large amounts of data as a key attribute of qualitative research and suggests techniques to analyse large amounts of qualitative data. We used coding as our data analysis technique, which is the most suitable for our study since it is commonly used in qualitative research and aligns with our entirely qualitative data (Recker, 2013).

Coding is used to categorise and organise data around key concepts or ideas. Given our comprehensive literature review, we opted for selective coding. This method allowed us to focus on pre-identified key categories informed by the literature, ensuring a more targeted and efficient analysis of the interview data (Recker, 2013). For findings that did not directly relate to any specific key concept, we still coded it with the theme it fitted with the most. As all findings relevant for the study somehow could relate to the themes we saw this as the best way to help structure our findings.

Furthermore, we also used deduction as a method for analysis in conjunction with coding. Deduction is an attempt to test patterns or concepts of theory with empirical data (Recker, 2013). In our case, as explained, we used our literature review as a foundation, we then compared the empirical data collected and coded it to the existing literature on the subjects of research to find any anomalies, similarities and new findings.

Table 4 displays the coding made when analysing the empirical data. Each category is connected to a colour and each more specific aspect of the category has an ID connected to it. The relevant text in the transcription tables will then be coded with colour and an ID connected on the right hand side of the table.

Table 4: Coding

Bin/category	Colour	Aspect	ID
Business Intelligence	Blue	BI definition	A1
		BI & Data Warehouse	A2
		BI & Analytics	A3
		BI & BPM	A4
		BI & Dashboards	A5
Sustainability	Green	Sustainability reporting and goals	B1
		Motivators	B2
		Affordances	B3
		KPI	B4
BI & sustainability in manufacturing	Red	BI & Manufacturing	C1
		Sustainability KPIs in Manufacturing	C2

3.7 Ethical considerations

Ethical considerations cannot be ignored when conducting research because of the direct relation to the integrity of the research study and field of discipline (Bryman, 2012). Bryman (2012) presents different ethical considerations, three of which we deemed relevant for this qualitative study. First consideration is whether or not consent has been informed, second if there may be an infringement of integrity and third if there may be some type of deception (Bryman, 2012). To maintain these ethical considerations into our study we contacted the participants with some information before the interview started. We asked everyone for permission from each participant to interview, record and store the recordings. This permission was asked for verbally before the recording was started and therefore it also is not included in the transcription. Given that we used the ASR from Whisper, we were able to store the information and run the ASR locally on our computers. Due to the fact that we were able to store the audio recordings locally on our computers, we made sure that we did not share information to any third parties such as cloud storage providers at any time. We as authors understand that the ASR software tool is not free from mistakes, i.e. hallucinations. We therefore manually checked the automatically generated transcriptions and looked for any discrepancies between the recording and the transcription. This ethical consideration is in

place so that the interviewee is not being misinterpreted. The participants were also informed of the possible publishing of the interviews on the Lund University website and they were also informed of the main topics the interview would be about.

Further, we informed the participants that neither their names nor the company names will be used in order for them to remain anonymous, however they were also informed that we will mention the industry/organisation type and their type of role in the organisation. Each participant was also informed of the possibility to contact us and withdraw their responses at any time. In order to live up to these ethical measures we also decided to blank out our respondents names, any mentions of people within their organisation or network and any names of their organisations with "XXXX".

3.8 Scientific quality

In order to maintain high scientific quality, this research addresses various mechanisms, such as validity and reliability. Validity describes whether the collected data represent the constructs set out to be measured and is both internal and external (Recker, 2013). Internal validity is whether the study being conducted is reflected in the social phenomenon which is studied and whether it is influenced by other factors, meanwhile external validity is how the research results may be generalised to other contexts or situations (Bryman, 2012). In order to increase the internal validity of this qualitative study we had to make sure the respondents were aware of any possible concerns. For example we acted transparently and mentioned who has access to the interviews, and provided information about what the interviews will be focused on. Further, interpretation of data was documented to increase overall validity. A high external validity however is difficult to maintain in this qualitative study, as the specific situations and the results this study provides may be hard to replicate and apply to other contexts and situations (Bryman, 2012).

Another mechanic to help us maintain a good scientific quality is reliability. If a study is repeated in the same setting and yields the same results, it is made in a reliable way (Recker, 2013. LeCompte och Goetz, 1982). Internal reliability is the degree of which other researchers may agree with each other on the matching of data and constructs (LeCompte och Goetz, 1982). In this research in order to increase reliability we conducted the research together, including the interviews and data analysis to make sure we interpreted the data in the same way. External reliability is how well a study may be replicated (LeCompte och Goetz, 1982). We used an interview guide to conduct the semi-structured interviews to keep them consistent to a certain extent, making it easier to replicate and thus maintaining higher external reliability (LeCompte och Goetz, 1982). However, since the interviews are semi-structured some questions may not easily be replicated as they are dependent on the respondents answers which as explained by Bryman (2012) is common, since a high external reliability is difficult to achieve in qualitative research. But the interview guide works as a basis to increase the reliability as well as possible.

4 Empirical findings

The chapter covers the empirical results from the interviews. The qualitative data is structured in similar fashion as the literature framework in order to make it easier to navigate. The citations are translated from Swedish to English.

4.1 Usage of Business Intelligence

4.1.1 Business Intelligence overview

Respondents had different views on what BI is and how it is used in their respective company. The first literature related question brought up by us authors was whether our BI definition matches each respondents perception of BI in their respective role. Respondent 1 agreed with the definition and explained it's easy to forget the data warehouse component of BI and rather only focus on dashboards (Appendix A, 4).

> *"I am happy that the whole Data Warehouse part is present. Because generally we see many people talk about BI but then they mean dashboards to 95%."*(Appendix A, 4).

Meanwhile, respondent 5 also agreed on the definition entirely and explained how important data is in conjunction with BI (Appendix E, 4). Respondent 2 also mentioned how the underlying data modelling is easy to forget, but meant BI in their organisation was focused on analytical aspects in conjunction with dashboards (Appendix B, 10). However, respondent 3 explained they did not use the term Business Intelligence and rather focused on dashboards as the most used terminology (Appendix C, 6). Respondent 6-8 explains that BI is a recent addition to them, via monthly sustainability reports (Appendix F, 8)

4.1.2 Usage of Data Warehousing

Data Warehousing was discussed during the interviews and the results show that it is not widely used by some manufacturers in regards to sustainability, while some use it to a certain extent. Several respondents also would like to see an automation of data distribution.

Respondents 1, 2 and 3 all mention how they collect and use data but then it is stored and further distributed in different ways (Appendix A, 14; Appendix B, 10; Appendix C, 8). Respondent 1 mentioned how some industries that are ahead tend to use a data warehouse, but that most companies seem to not use it for their sustainability data (Appendix A, 14). The respondent also adds by saying that there are only a few organisations that have a completely integrated approach towards BI where the data is stored in a data warehouse automatically which can be fetched and analysed at any time, and that most organisations input numbers manually and have a static approach towards reporting (Appendix A, 14). Respondent 5 mentioned that they use a data warehouse for their sustainability data and that users access it via a repository which they need access to (Appendix E, 14,16). Respondents 2 and 3 both explain that they do not use data warehouses for their sustainability data, respondent 2 means that the source data is not stored in the data warehouse but they use it in other scenarios

(Appendix B, 10; Appendix C, 16). Respondent 3 mentions how there is a way to distribute the data further from a production system where the collected data is made available (Appendix C, 18). Respondent 2 and 3 both mention how data also is distributed manually via excel files through mail (Appendix B, 26; Appendix C, 18). Respondent 6-8 mentions that data is distributed in different ways and via different system because of the data sources are different (Appendix F, 8)

4.1.3 Usage of Analytics

In the interviews the BI analytical component was brought up where respondents' answers varied to the degree it is used, although most respondents do not use AI in their analysis.

Respondent 1 explains how Power BI is the most common tool to help conduct analysis (Appendix A, 22). Respondent 5 explains that they use data analysis of their sustainability data for example for predictions and to measure their sustainability impact (Appendix E, 21). Respondent 6-8 explains they manually analyse data in excel sheets (Appendix F, 34)

Respondent 1 also discusses how AI is not prevalent in the manufacturing industry to conduct analysis of sustainability data (Appendix A, 22). The respondent explains this is due to there is no need to implement ML or AI as they usually already know the outcomes of where the technology is applicable, making it unnecessary (Appendix A, 22). Respondent 2, 3 and 4 further explains that they do not use AI in any analysis of their sustainability data, and that they have not reached the possibility to do it yet (Appendix B, 30; Appendix C, 26; Appendix D, 47). Respondent 4, however, says pilots are being made to use different AI tools (Appendix D, 47). Respondent 6-8 also mentions they are testing the use of AI (Appendix, 38). In contrast to this, Respondent 5 are the only ones currently using AI and explain that they use AI for data analysis (Appendix E, 25). Respondent 1 mentions that predictive models in relation to ML probably will be more used in the future, but very few make use of the technology at this moment (Appendix A, 22).

4.1.4 BPM practices

Respondents work with BPM in different ways, some are familiar with it while others are not. However, all respondents mentioned that they work with KPIs, but there are differences in how they are identified and similarities how often they are updated.

Respondent 3 says they are not familiar with the BPM component of BI and that they do not use data in that manner (Appendix C, 6,8). However, respondent 3 mentions that they work with KPIs but they are defined by themselves on what seems feasible and are looked at on a yearly basis (Appendix C, 34,36). On the contrary, respondent 2 is familiar with BPM and mentions that the BPM part is more and more forthcoming (Appendix B, 10). Respondent 2 also explains that the KPIs are defined based on laws and regulations (Appendix B, 42). Respondent 1 also says KPIs may be defined based on sustainability CSRD regulations (Appendix A, 30).

Respondent 5 explains that they use a KPI-tree to visualise how the KPIs are built up from the roots (Appendix E, 27). Respondent 3 says they base their KPIs or goals by themselves based on what they deem feasible (Appendix C, 34). Several respondents say there are small

changes or refinements in the KPIs and they usually are evaluated yearly (Appendix D, 31; Appendix E, 27; Appendix B, 48; Appendix C, 36).

4.1.5 Usage of Dashboards

All respondents use dashboards in relation to sustainability, some more than others, but many respondents' dashboards contain similar types of information.

All respondents mention that their dashboards contain KPIs (Appendix A, 26; Appendix B, 34; Appendix C, 42; Appendix D, 27; Appendix E, 35; Appendix F, 40). Respondent 1 says that dashboards are generally used to show trends and changes on a high level and as a type of descriptive communication and that it is typically shared on a sharepoint or similar (Appendix A, 24). Respondent 3 also explains they look at trends and that mostly just numbers are presented (Appendix C, 42). Respondent 2 also mentions that BI can be used to find trends, however not explicitly mention dashboards (Appendix B, 58).

Respondent 1 means dashboards can be used for controlling data, not just presenting. Respondent 1 also says it is used for descriptive communication (Appendix A, 24). Respondents 2, 3 and 4 use it for reporting various sustainability information (Appendix B, 8; Appendix C, 40; Appendix D, 51).

Respondents 6-8 utilise dashboards to closely monitor energy usage and material consumption in their daily operations at the steel mill. Specifically, they track energy consumption per production batch and material usage, which lets them gauge the use of scrap to optimise resource efficiency (Appendix F, 50, 54, 54).

4.2 Sustainability Results

4.2.1 Sustainability reporting and goals

There is a general consensus that regulations imposed by various regulatory bodies such as the EU are a key concern in the near future (Appendix A, 8; Appendix C, 10; Appendix D, 49, Appendix F, 42, 52).

Respondent 1 specifically points out that CSRD will put even more weight on data management and respondent 4 says it will be a question of strategy (Appendix A, 8; Appendix D , 49). Although respondent 2 company resides outside the EU they too have sustainability frameworks as guidance (Appendix B, 12). Specifically respondent 2 uses the UN Global Compact which, according to the respondent, is quite similar to CSRD (Appendix B, 14). Every respondent we have talked to is very much aware of the CSR directive on sustainability reporting imposed by the EU (Appendix A, 8; Appendix B, 14; Appendix C, 10; Appendix D, 49, Appendix F, 12). For respondents 2 and 3 the decision on which framework to use or on what sustainability goals to set resides at group-level rather than the subsidiaries (Appendix B, 16; Appendix C, 10). The same is true for respondent 6-8 (Appendix F, 12). Respondents 6-8 say that they have adopted five of the SDGs and that they have sustainability goals from the

EU (Appendix F, 14). Respondent 4 and 6-8 both use something called CBAM (Appendix D, 49; Appendix F, 14).

Respondent 4 mentions that reporting requirements may also come from customers (Appendix D, 49). The respondent then continues by drawing the connection between BI and sustainability reporting. Where the respondent addresses that data surrounding a product will need to be processed, such as the carbon footprint (Appendix D, 49). Respondent 4 mentions the "planet-positive" framework as guidance in deciding if new products are worth developing or not (Appendix D, 13). When asked about frameworks, it was evident that many of our respondents had multiple frameworks that they work with (Appendix B, 12; Appendix D, 49; Appendix F, 12). These frameworks do not have to be imposed by regulations, but can instead be frameworks that the organisation sees fit (Appendix B, 12; Appendix C, 10).

Respondent 1 mentions "carbon tunnel visions" as a concept where there is a sole focus on carbon emissions (Appendix A, 37). However, Respondents 1,2 and 3 all point out that there is substantial data gathering when it comes to the social aspect of the triple bottom line. Respondent 4 mentioned that due to the risk of injury and death in their work environment, they have a substantial focus on the health and safety of their employees (Appendix D, 69). Because of this their social aspect of sustainability is as large or if not larger than the environmental aspect and the same division that is responsible for health and safety is also responsible for the overall sustainability matters (Appendix D, 9).

Many respondents do not see regulations as a major hindrance since most of them are already ahead of the regulations (Appendix B, 12; Appendix D, 15; Appendix E, 47).

"*Take a large company like XXXX, [they] have been involved in driving the agenda, they are pretty well prepared for the directives that came, I think you're also well prepared in having the data in place*." (Appendix E, 47)

Respondents 6-8 would also not consider regulations a major hindrance in their work, they are however concerned with the increasing complexity and volume of sustainability reporting requirements. According to one respondent many of the requirements imposed by different governing bodies use much of the same data. But due to a lack of standardisation they need to manage and report environmental data across various formats and standards required by different regulatory bodies. This process leads to significant manual data handling and inefficiencies. A major concern is that these requirements demand more detailed and frequent reporting, adding to the workload (Appendix F, 42).

4.2.2 Motivating factors for sustainable development

As mentioned in the previous section, respondent 1 explains that there will be more weight on the data regarding sustainability reporting. However, respondent 1 also points out that many companies have a journey ahead of them where they need to become CSRD compliant (Appendix A, 8).

Respondents can also see other motivating factors for sustainable development such as competitive advantages. All respondents see competitive advantages in engaging in sustainable development (Appendix A, 12, 18; Appendix B, 19; Appendix C, 58; Appendix

D, 2, 48; Appendix E, 12; Appendix F, 16). The respondent also mentions new requirements on CO2 emissions has increased the demand for recycled materials. (Appendix F, 22)

Some respondents also mention altruism as a motivating factor for sustainable development (Appendix A, 12; Appendix B, 22; Appendix C, 58). Respondent 1 specifically mentions that more has been done in the last four years compared to the previous 15 years. They attribute this to regulations and reporting whereas before the motivation came almost exclusively from altruistic reasons (Appendix A, 12). Respondent 2 and 4 challenges this perception of solely regulatory motivations by explaining how they have been at the forefront of sustainability and never had to adapt to new regulations, meaning that they have been ahead of the regulations (Appendix B, 12, 18; Appendix D, 15). Respondents 6-8 mention that they have had goals in place before new regulations came into place (Appendix F, 18, 26).

"...if you listen to customers and colleagues who have worked with it much longer [than I have], more has happened in these four years than it did in the fifteen years before [...] my analysis is that it was because there were more altruistic reasons before." (Appendix A, 12)

"I believe we have always been ahead of the regulations, due to us having put up net-zero goals" (Appendix B, 12)

Although respondent 5 acknowledged altruism as a motivation for sustainability development the respondent emphasises competitive advantages as a main motivating factor (Appendix D, 12). Respondent 5 says that regulations and competitive advantages can be intertwined and that large scale companies can utilise their size for lobbying. Respondent 5 mentions that organisations can gain competitive advantages by putting stricter requirements onto themselves. The respondent explains that when your own organisation meets the requirements put up by yourself you lobby for the same requirements to be applied to your competitors who may be unprepared for them. Thus, you are able to modify the landscape of requirements and regulations (Appendix E, 12).

"These organisations are so big, so you can lobby based on that too [sustainability]. And then you can even create competitive advantages by setting tougher requirements on yourself, and then those requirements are transferred to your competitors who actually need to fulfil them as well." (Appendix E, 12)

Respondent 4 supports the notions of competitive advantages as being the biggest motivator for sustainable development (Appendix D, 15). They too have been ahead of regulations but have seen an increase in demand from customers. Although respondent 4 mentions that they also have to conform to regulations they do not necessarily see it as a motivator for sustainable development but rather as a motivator for sustainability reporting (Appendix D, 49). According to respondent 4 altruism is more relevant concerning health and safety (Appendix D, 71).

4.2.3 BI as an affordance for sustainability

Respondent 1 says that the sustainability metrics organisations use are rather centralised and underdeveloped. Reflective disclosure mostly covers a KPI or two that is somewhat analysed before presenting it to the management team. Suggesting that information democratisation also lacks in this department. However, respondent 1 previously mentioned that the data is

gathered and visualised in dashboards, which are then analysed and discussed at the managerial level. Respondent 2 supports this notion that information is shared with the help of dashboard technology (Appendix B, 28). All respondents that we have talked to say that they use dashboards for organisational sensemaking of sustainability practices with varying amounts of intensity (Appendix B, 28; Appendix C, 40, Appendix D, 21; Appendix E, 17; Appendix F, 50 & 52).

"...all the sites have a reporting so they get a dashboard of how the trend looks and so forth and they have someone responsible who analyses it and then it is presented to the management team." (Appendix A, 16)

Dashboards are the main tool for information democratisation and KPIs are the main way to assess outcomes, i.e reflective disclosure regarding sustainability data. Respondent 5 adds by saying that not all information is available to everyone and could be subject to request. Not everyone has access to all data, however there is a substantial amount of data that is publicly available (Appendix E, 19).

"You get access to what you should have access to, otherwise you can apply for access. Then there is publicly available data" (Appendix E, 17)

However BI for output management seems to take the form of tracking KPIs and they can vary from organisation to organisation depending on the BI maturity (Appendix A, 31). Respondent 3 says that they measure water and electricity consumption and waste (Appendix C, 30). The way they measure this is put in relation to their production volume. Another example of how BI is used for output management is carbon footprint (Appendix E, 11).

"If you've made significant progress in your journey [in PMS], then you're steering towards underlying forces rather than outcomes. You aim to find a KPI that you can utilise for management. You must find a way to steer so that you're relatively certain that this is the best approach for our organisation and the value we create for investors." (Appendix A, 31)

Respondents 6-8 are currently looking at Energy Management Systems as a way to streamline data access and improve efficiency. These information systems are seen as possible tools to address the challenges of data fragmentation across different facilities and countries. By consolidating data the respondents aim to enhance the democratisation of information, making it readily accessible and interpretable across various departments and locations. The respondents hope that it will also lead to reflective disclosure i.e. organisational sensemaking(Appendix F, 10, 12).

4.2.4 Measuring sustainability with KPIs

All respondents that we have interviewed have answered that they have sustainability related KPIs (Appendix A, 16; Appendix B, 40; Appendix C, 30; Appendix D, 31; Appendix E, 29; Appendix F, 16)

Respondent 1 explains how new regulations will trigger the creation of multiple KPIs but as for now the sustainability related KPIs are only a few (Appendix A, 16, 30). The respondent continues to describe how all KPIs that are imposed by regulations will not be used strategically and may be less prioritised (Appendix A, 30). Meaning some KPIs will be used

strictly for reporting purposes and others that are used for the decisions making and performance management (Appendix A, 30). When asked about a framework for identifying KPIs, respondent 2 says that KPIs are to a large degree driven by regulations and is confident that organisations will use the same KPIs that will come out of the CSR directive. If anything, they will have to try to delimit themselves from using all of the data points listed in the directive (Appendix B, 41, 44).

When talking about KPIs respondent 3 mentions two types of KPIs, them being the operational KPIs and the long term KPIs (Appendix C, 30, 32). The operational KPIs are put in place by themselves and often put sustainability data in relation to e.g. production volume or turn-over. The more long term KPIs are related to specific projects within that organisation and to more long term goals on a 3 year plan (Appendix C, 30, 32, 34). Respondent 2 mentions a KPI where they strive for 0-ton emissions within scope 1-2 and a 50% decrease in scope 3 (Appendix B, 40). The respondent also highlights that this is not in relation to turn-over. These KPIs are in absolute terms.

"We have said that we will have zero in scope 1 and 2 by 2030, and we will reduce scope 3 by 50% by 2030. And this is absolute, it should be zero emissions. It should not be relative to the turnover or anything like that." (Appendix B, 40)

Respondent 4 say they use KPIs as a tool to gauge their performance compared to previous years (Appendix D, 27).

When asked about the selection of KPIs respondent 5 says that the selection largely depends on two main factors: regulatory requirements and the potential value the data can bring to the organisation's performance and reputation. The respondent says that this involves identifying and utilising readily available data that can provide immediate benefits or insights into the company's sustainability performance (Appendix E, 51). This principle of utilising readily available data is supported by Respondent 4 (Appendix D, 32).

Respondent 5 continues by explaining that their organisation has aligned its sustainability efforts with benchmarks such as Greenpeace ratings, aiming to achieve certifications like the Green Leaf. The respondent also mentions the use of tools like the Balanced Scorecard in their efforts of identifying sustainability KPIs (Appendix E, 29 & 31)

When asked about how organisations identify KPIs respondent 1 answered that the process of identifying KPIs involves SMEs from relevant departments. The respondent describes the approach as a data science team tasked with providing the necessary insight. These teams then often rely on SMEs for expert knowledge. The identification of KPIs often originates from requests or 'orders' from departments that recognize a need to address specific issues (Appendix A, 33).

For respondent 3, it is the factory's management team that is responsible for overseeing and making decisions regarding KPIs. Proposals for KPIs can originate from various departments within the organisation. These proposals are typically based on identified projects, development opportunities, or new parameters that the departments believe should be monitored. Once identified, these proposals are brought to the management team, which then makes the final decisions (Appendix C, 38).

4.3 BI & sustainability in manufacturing & other findings

4.3.1 Manufacturer specific BI

Real time data and analysis is not commonly used by the respondents. But some want it implemented. Centralised systems are not either commonly used, but several respondents express how they would like their system to work.

Respondents 2, 3, 4 say they do not do real time analysis while respondent 5 is unsure whether they do it or not. Respondents 6-8 say they use some real time data for measuring chemicals, but it is only used for daily management (Appendix B, 54; Appendix C, 56; Appendix D, 59; Appendix E, 55; Appendix F, 47).

Respondents 6-8 explain they also would like to have a way to use real time data more quickly to make decisions (Appendix F, 48).

"... the dream scenario would be ..let's say you could see water emission and we see an increasing trend before it exceeds a value… then we can react at a very early stage and notice we have a potential disruption"(Appendix F, 48).

Respondents 6-8 then go on by saying that with real time data they would also be able identify an energy surge that could indicate that something is wrong or need fixing (Appendix F, 48). Respondent 3 similarly explained they would like to have more data available earlier for at least daily use so they can react more rapidly. Respondent 3 also expresses a desire for an integrated production management system where they can earlier access analysis (Appendix C, 56).

Respondents 6-8 have identified an issue in which there is a lack of holistic system concerning their sustainability data. Respondent 6-8 says there are inefficiencies in the current use of Energy Management Systems within the steel and mining industries, particularly concerning their limited scope and integration capabilities. According to the respondents there lies a challenge in integrating broader environmental data, such as emissions, which are used for environmental monitoring and reporting as well as predictive and prescriptive analytics (Appendix F, 10).

Respondents 6-8 can also witness that there is a widely recognized problem in the steel production industry, where there is a heavy reliance on manual data handling. The respondents say that this is detracting them from the ability to effectively analyse data and trends (Appendix F, 12). Respondent 2 explained that there would be a need for specifically a centralised system that has all BI capabilities made for them for BI to properly work for them (Appendix B, 66) Some of the data collection also happens to be via email from suppliers. Many respondents mention scope 3 data and the challenges related to collection of this data (Appendix B, 28; Appendix C, 20).

4.3.2 Manufacturers specific sustainability

Respondents measure similar KPIs and focus on similar things in their manufacturing processes related to sustainability, but what to measure is also dependent on the industry.

Respondent 1 says they measure a lot at emission data (Appendix A, 26). Similarly respondent 2 explains that they measure their CO2 footprint and have set goals which they measure and follow up on (Appendix B, 38). Respondent 4 looks at water consumption and also their CO2 footprint (Appendix E, 31) Respondent 3 looks at gas consumption in their manufacturing process (Appendix C, 20). Respondent 5 mentions that they measure material usage and see it as a big part of their organisation (Appendix D, 29).

All respondents say they deal with qualitative data, and five of the respondents says the answer surveys about their health, wellbeing, work environment and safety (Appendix A, 39; Appendix B, 52; Appendix C, 52; Appendix E, 57; Appendix D, 53; Appendix F, 44).

Respondent 4 highlights “planet positive” products within their product range as a KPI. The “planet positive” framework is applied during the product development phase, requiring that a product meet specific criteria to earn this designation. According to the respondent, all initiated projects must pass through these criteria, which are stipulated in the “planet positive” guidelines (Appendix D, 13, 31). The KPIs can measure both the number and revenue of planet-positive products sold. This measure is tracked annually, emphasising the growth in sales of these products relative to total revenue. Additionally, the environmental savings provided to customers through the use of these planet-positive products are evaluated, such as reductions in water and CO2 footprints (Appendix D, 31).

5 Discussion & Analysis

The following chapter will analyse the empirical findings and connect, compare and discuss it in relation to the literature.

5.1 Lack of Business Intelligence for Sustainability

5.1.1 The underdeveloped usage of Business Intelligence

As outlined in the literature review, BI is vast and covers many different technologies in order to create a system that helps provide data driven insights (Sharda et al. 2018). Our results however, showed little usage of the various BI technologies except for the dashboards, which all respondents used extensively. Already in the first question of the interviews, findings show that there is a small usage of BI, as several respondents did not use, or were familiar with all the various components of BI which were identified in the literature (Sharda et al. 2018).

Respondents seemed particularly underdeveloped in their usage of data warehouses and data analysis when it comes to sustainability. For instance, as respondents 2-4 and 6-8 mentioned that they do not store the data in a structured data warehouse and they manually send data via excel files which we think is surprising. We think these findings are surprising partly because data warehousing as a technology is not new, as described by Wixom and Watson (2001) and Sharda et al. (2018). It is also surprising because there is a need for high quality data in order to get most out of BI and be able to conduct appropriate analysis, meaning a data warehouse is necessary for the next step of BI, which would be data analysis (Wixom & Watson, 2001; Sharda et al. 2018). This means that the findings indicate that organisations may not have the proper foundation needed to conduct appropriate analysis and measure their sustainability in a way that gives them most value. According to Sharda et al. (2018), the lack of data warehouses significantly limits the opportunity to access real-time data. This is reflected in our results, as respondents without a data warehouse either had limited access to, or did not use real-time data at all.

In the data analysis aspect of BI only one respondent had adapted to using AI for analysing sustainability data, while the rest were looking into it or were currently not even close to using it. As we previously discussed this can be due to the fact that the respondents do not use data warehouses. However, no specific data analytical techniques were mentioned in the findings that were brought up in the literature by Chen et al. (2012) which we believe to be an indication of a lack of data maturity by manufacturers. Respondents 6-8 even answered that they do data analysis manually and directly in excel spreadsheets, which we believe to show they have not yet integrated much BI into their sustainability processes as even BI dashboard tools can be used for data analysis (Sharda et al. 2018).

As explained by (Frolick & Ariyachandra, 2006) the BPM component is mostly focused on a process, but only respondent 5 seemed to have a proper process or structure for defining KPIs and measurements via their KPI-tree structure and balanced scorecards. As for the other findings, it shows how manufacturers generally did not seem to go through a specific process

for defining KPIs or how to measure sustainability, but rather they were predefined and rarely updated. This further adds to the case of manufacturers being underdeveloped in their use of BI, as they do not properly manage their performance in any specific way similar to the description by Frolick and Ariyachandra (2006).

The empirical findings further suggest that many of the sustainability KPIs used by the manufacturers appear to be serendipitously determined rather than strategically crafted. This observation arises from our respondents' common organisational practice of selecting KPIs based on the convenience of data availability and the ease of measurement. Rather than developing KPIs grounded in a deliberate strategy as explained by Frolick and Ariyachandra (2006) the manufacturers often default to sustainability metrics that align with readily accessible data. We believe this approach risks prioritising what is measurable over what is meaningful in their specific setting. Not only are KPIs based on what is readily available and easily measurable, they are also determined by what might be mandated by the governing bodies and its regulations. If all the metrics imposed by regulations do not align well with the organisation's operation, we believe this too can contribute to the metrics being bad in reflecting the performance of sustainable development.

As previously mentioned the results also show that dashboards were the only BI component all respondents actively used and were the most familiar with. The findings show that manufacturers mainly used it for monthly reporting of various sustainability KPIs, and only respondents 6-8 explained how it was used on a daily basis to make decisions in different manufacturing facilities. Most respondents used it in order to monthly look at KPIs and follow up on them, not necessarily using them to communicate strategy or help analyse root causes of problems which is how they are best used according to Eckerson (2005). We believe this to be a very underdeveloped way of BI usage and we can draw similarities from these results to older BI versions when BI was merely a reporting system (Sharda et al. 2018). The findings shows however that manufacturers use and have appropriate BI applications such as PowerBI instead of Excel or PowerPoint for presenting their dashboards, which shows they at least have the possibility to present data in a non-flat way (Eckerson, 2005; Sharda et al. 2018). Further, while the findings show how they gather data about health issues and work environment, BI is not used to further analyse the data or present it in any way.

5.1.2 Low perceived value of BI systems for sustainability

Because of the findings showing how underdeveloped manufacturers are, we believe the manufacturers lose all or most of the benefits that may arise with BI. As Negash (2004) and Sharda et al (2018) suggest, benefits of BI are long term, and a complete BI system will provide valuable insights to help decision makers make informed decisions. However, since the findings show manufacturers lack the proper BI structure the long term benefits must be close to non-existent. Without a properly structured and functioning BI system, management may not fully understand its potential value until it is fully developed and used over time. This lack of understanding may also cause stakeholders and management to perceive BI as not worth investing in, particularly in the context of sustainability. Consequently, this perception may contribute to the continuing underdevelopment of BI in the manufacturing sector.

5.2 A longing for better Business Intelligence for Sustainability

5.2.1 The need for a centralised system & better Business Intelligence

Even though the findings show how the manufacturers are underdeveloped in their use of BI, most of the respondents also are not satisfied with the current structure of their BI solutions and explain how they want better processes and systems. For instance, because several respondents had a lot of manual work by transferring data either via email, extracting excel spreadsheets or because of having to extract data from several different systems they expressed that change was needed and how they wanted a better system. Similarly the findings show that they wanted systems that work in the same way as the MES explained by Bordeleau et al. (2020) and Koch et al. 2010 which contained several different BI capabilities.

Since a MES is a tailor made centralised system with integrated data collection, centralised storage, easy data access and can do real time data analysis it ticked many of the boxes of which the respondents sought after (Bordeleau et al. 2020; Koch et al. 2010). Respondent 2 specifically mentioned how they believe that a tailor made system is needed in order for BI to be worth it in their case. Other respondents also mentioned how they wanted data more readily available, which would be possible with a MES.

These findings further show how there is an understanding of their underdevelopment of BI and that there is a longing for better BI in relation to sustainability. The people working closely to the systems are expressing a desire to create better solutions to help them work more efficiently with sustainability measurement and management. The respondents who are closely involved in sustainability practices and mostly not top level management in BI therefore want to improve the systems and believe they can get more value out of it. It also shows how there are existing systems that can fulfil the needs of the manufacturers but even if investments into improving BI would be made we believe there are more problems connected to the way the manufacturers use BI for sustainability as well.

5.3 Factors of underutilisation of BI tools

5.3.1 Problem in data handling

As earlier discussed in section 5.1.1, many of our respondents lack a data warehouse with integrated data collection. There is a lot of manual processing via excel, and they wish for more automated processes. Although many see the advantages of leveraging the capabilities of a BI system for handling large amounts of sustainability data we still see our respondents not taking full advantage because of what we believe to be some technical problems which we have identified in the empirical findings.

One problem we identified in the findings that need to be resolved in order to become better at using BI to measure and manage sustainability is in the foundation, the data. The manufacturers need to become better at using high quality data. As mentioned before by Sharda et al. (2018) there is a need for good data to gain full benefit of BI. Further, because of their lack of process for identifying KPIs and what to measure, we believe it may also be difficult for them to know what data to collect and what to measure in order to create some sustainable value in their organisation.

The findings also show that sustainability data may come from diverse sources in the case of these manufacturers and therefore may be difficult to integrate into existing data systems used for other business functions as specifically mentioned by respondent 6-8. This lack of integration may be seen as another major hurdle regarding data for the manufacturers to fully implement BI for sustainability data. Organisations might find it challenging to justify the cost and effort required to unify these systems without clear immediate benefits which adds to the previously discussed argument in 5.1.2 of why BI is not used to its full potential in the results. Especially since BI results and benefits are mostly displayed in the long term (Negash, 2004).

5.3.2 Recognizing the need but missing the mark

Although our respondents recognize the need for more effective solutions, they have not fully leveraged BI's potential to enhance sustainability. Respondents 5 and 6-8 acknowledged the benefits of information democratisation and reflective disclosure provided by BI systems. All respondents use dashboards to some degree, indicating that they all benefit from BI systems making sustainability information accessible across the organisation. The respondents' identification of a need for easily accessible data aligns with the study of affordances for green IS by Seidel et al. (2013). As mentioned before, most of our respondents are not utilising the full potential of BI tools, which offer capabilities for data aggregation, analysis, and real-time information processing (Sharda et al. 2018). This underutilization results in time-consuming and manual report creation processes. For instance, some manufacturers rely on manual data collection, where personnel physically read machine gauges and enter data into Excel sheets. Respondents 6-8 expressed concerns about the excessive human resources devoted to handling sustainability data for reporting activities. Respondents 6-8 also expressed a desire to shift their focus from reporting to predictive and prescriptive analytics.

Both the literature and our empirical findings suggest that enhanced BI systems could provide the necessary support to our respondents for managing complex sustainability data and reporting requirements (Petrini & Pozzebon, 2009). This again raises the question of why they have not made more effort to leverage BI tools. One possible explanation is that organisations may not view sustainability data as critically valuable to their core operations as other business data. If sustainability is seen primarily as a compliance requirement rather than a strategic asset, there is less incentive to invest in sophisticated BI tools to manage this data. However, our findings challenge this view, as all respondents mentioned seeing competitive advantages in sustainable development. Which indicates there is another problem that is keeping the manufacturers behind.

We think the larger problem associated with BI and sustainability lies in how manufacturing organisations work with sustainability. Although our respondents recognize that sustainability efforts can bring competitive advantages, the findings show how the main drivers for working with BI and sustainability are not for creating more profit but rather something else.

5.4 Sustainability regulations as a driving force

5.4.1 Sustainability goals and regulations drive BI utilisation

As the literature suggests, regulations and sustainability goals are highly prioritised by businesses, and there is a large focus on adhering to these goals (Tsalis et al. 2020). However, imposed regulations, both new and existing, create challenges in reporting activities. To determine whether goals and regulations are met, organisations must engage in some form of organisational sensemaking. As most of our respondents follow different regulations and goals for sustainable development they also need to put a lot of resources into sustainability reporting. The notion of conforming to sustainability reporting placing significant demands on organisations is also supported by the literature (Ahmed & Sundaram, 2012; Tsalis et al. 2020).

As our findings show, many of our respondents have practices in place long before new regulations come into force. However, the respondents further stated that there is an increasing demand from governing bodies for sustainability reporting and that reporting is becoming more challenging. This leads us to believe that the main challenge for our respondents lies not in implementing sustainable practices but in fulfilling the extensive reporting requirements imposed by both new and existing regulations. Our respondents are looking at ways to overcome these challenges and most have turned to BI. Furthermore, the findings show that most of our respondents use some sort of readily available framework for their sustainability goals and that they use BI for reporting the progress towards these goals. As mentioned in the empirical section, all organisations use some form of BI tool in their organisational sensemaking and for their sustainability development and reporting. This leads us to believe that sustainability regulations drive BI utilisation for sustainability reporting.

5.4.2 Too focused on reporting

Because the findings show how sustainability reporting for goals and regulations is such a powerful driver of BI utilisation, we believe this means that for manufacturers, sustainability development is almost solely focused on reporting to adhere to overarching sustainability goals and regulations. This means working on other various sustainability practices, including collecting and measuring other data not related to the overarching goals and regulations, are not a priority. Although measuring data in relation to goals can be useful, our empirical findings suggest that these goals often originate from a broad framework. This leads us to believe that the goals are too general and not sufficiently tailored to the organisation's specific operations, reducing their effectiveness in driving meaningful improvements. This is similar to Ahmed & Sundaram (2012) findings that show how companies have difficulties in aligning their operations and strategies with these sustainability goals created by global standards and legislations. An example of this is the utilisation of KPIs. KPIs are rarely updated, and they are usually defined based on what goals and regulations that manufacturers are trying to follow and reach. Because our respondents KPIs are mostly predetermined on overarching sustainability goals and regulations they might not align well with the organisation's operation. This is an example of how goals and regulations can create bad business performance management. The fact that regulations might drive misaligned business performance management may deter organisations from further investing in a more comprehensive BI utilisation. While organisations are capable of meeting regulatory standards, the effort to maintain this compliance, especially in documenting and reporting, is the dominant activity. This focus overshadows initiatives to advance sustainability measures beyond the minimum requirements.

Because of this reporting thinking, manufacturers seem to use BI solely for reporting as previously discussed. Even though BI is great for sustainability reporting, this means they do not focus on other benefits for sustainability which BI may provide the manufacturers, despite our respondents being aware of potential areas of improvement in their BI infrastructure (Nappi & Rozenfeld, 2015; Sharda et al. 2018). The main driver for using BI for measuring sustainability is therefore reporting, which we believe is to undermine the larger potential of using BI to measure and manage sustainability. The necessity to focus heavily on compliance and reporting diverts attention and resources from actual sustainability initiatives.

5.4.3 Other motivations for sustainable development

Following how the manufacturers work with sustainability it means that reporting and decision making is treated somewhat separately regarding sustainable development, making Ahmed & Sundaram's (2015) study still relevant today. While the literature shows how motivating factors for working with sustainability can be competitiveness and it can be seen as something to help increase profits (Bansal & Roth, 2000; Dangelico & Pujari, 2010). Our findings show that manufacturers seem to be aware of this and that they see how sustainable development may create competitive advantages. Interestingly however, they do not seem to act on it particularly much. Although respondent 6 has been using recycled steel in their production for many years they have not until recently started to leverage this as a marketing strategy indicating that they have identified a way to leverage their sustainable practices into something more.

The findings show that manufacturers rather seem to focus on what is described by (Bansal & Roth, 2000; Dangelico & Pujari, 2010) as legitimation, which is once again a focus on regulations but also on norms. The findings also show how many manufacturers want to work with sustainability because altruism is a motivating factor. While we think this may be a good reason to work with sustainability, in order to have a true and meaningful impact we think that the main factor should be competitiveness, since all these manufacturers are for-profit organisations in a competitive environment.

If competitiveness actually was the main driver for sustainability, it would also mean more focus would be on how to improve their manufacturing processes through different solutions where we think BI would have an even bigger impact. If the manufacturers then used all BI technologies in a developed way they could focus on identifying new sustainability data to collect, analyse it and present it, giving stakeholders possibilities to make highly informed decisions every day (Sharda et al. 2018). This could lead to lower energy consumption, waste, CO2 emissions and water saving through for instance better scheduling (Giret et al. 2015. Contini & Peruzzini, 2022).

5.4.4 The wide issue of BI and sustainability summarised

Because of the large focus on measuring sustainability as something to report and not utilising BI in a sustainability context to gain competitive advantages it leads to BI being underdeveloped and not used properly. Yet, as the findings display the manufacturers and its workers are aware. They also have a desire to improve processes and want to work more with sustainability, but the main focus of each organisation's sustainability measurement and KPIs is on just reporting in order to follow rules and regulations. While BI is good for sustainability reporting, they miss the bigger picture of BI where the system provides so much more than just being a reporting tool (Petrini & Pozzebon, (2009).

5.5 Discussion summary

To help summarise what has been discussed and its structure figure 1 below displays the discussion structure. The figure displays how the problems are correlated and how it turns into a vicious loop where BI stays underdeveloped because of the focus of sustainability.

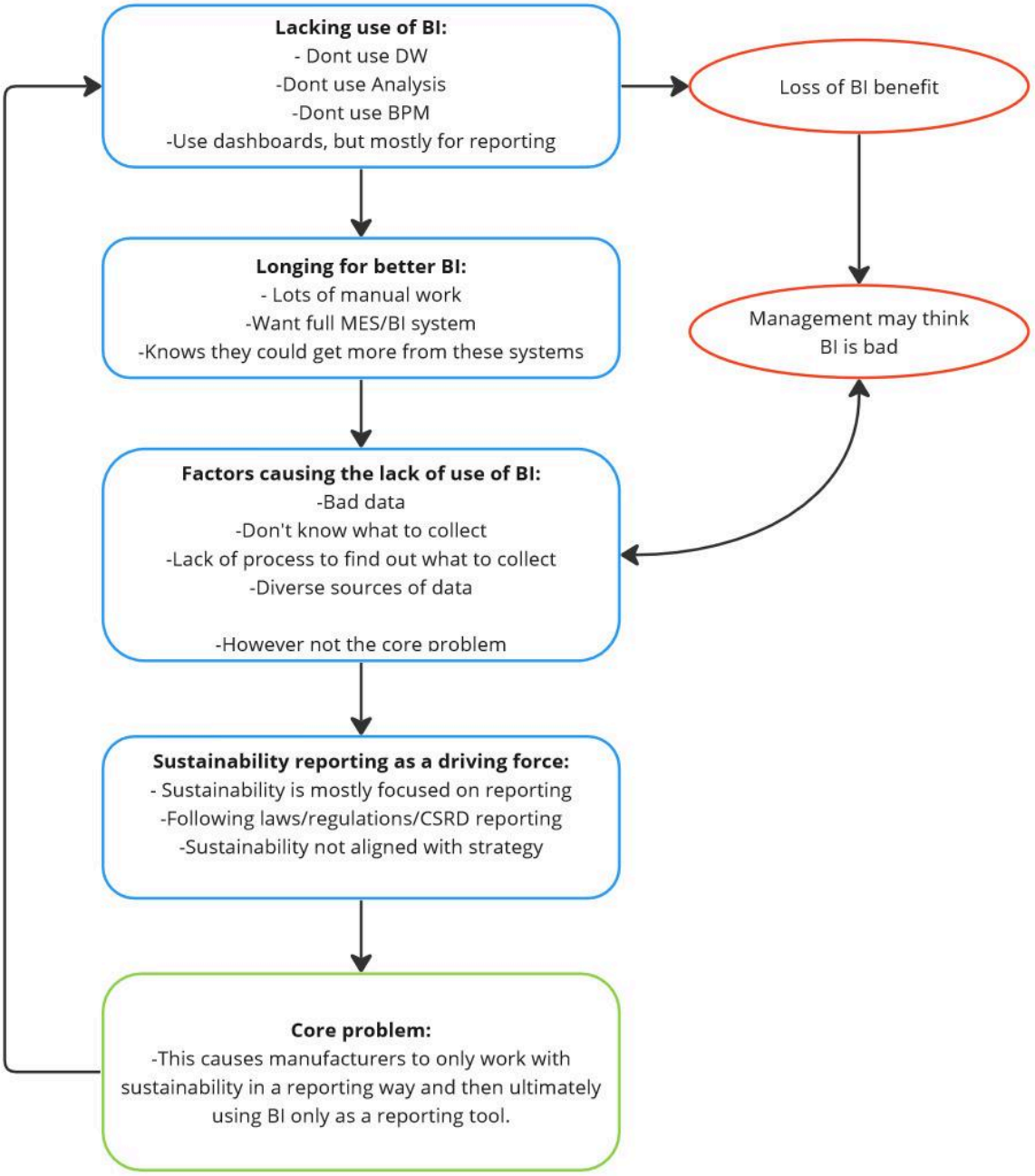

Figure 1: Discussion Summary

6 Conclusion

6.1 Research conclusion

The purpose of this study was to identify the factors that influence the use of BI in a sustainability context which lead us to looking at two different and correlated research questions.

The first research question this study aimed to answer was how and what BI technologies are used by manufacturers to measure sustainability. We have clearly identified the BI technologies that manufacturers use, with the main one being dashboards. We also identified how they are underdeveloped in their usage of BI other BI technologies even though their awareness of better systems existing together with what we believe to be the reasons for their underdevelopment.

The second research question this study aimed to answer was what drives manufacturers to use the BI technologies that they use for sustainability. The main driver we found were regulations and sustainability reporting which led to manufacturers mostly using BI only for these purposes. This is also a possible reason why the BI solutions were underdeveloped.

The answers to the questions were larger than anticipated, as they show the complexity of sustainability and how sustainable regulations and focus affect organisations. The study in its entirety also shows how difficult it may be to use BI effectively within manufacturing organisations as there are many moving parts to consider and things that may affect how and what BI components that can be used.

We believe that this study greatly contributes to the field of Information Systems and the key area of Business Intelligence by its analysis as to how BI and sustainability currently are used. It also contributes by identifying the problems that need to be solved by management and organisations to make sure they identify KPIs that matter for their competitiveness and then utilise BI to become even more sustainable. Furthermore the study paves the way for future research regarding these problems.

6.2 Future Research

For future research, we suggest studies looking into why the sustainability focus of manufacturing organisations are mostly about reporting, even though the organisations recognize other reasons to work with sustainability. We also suggest doing similar studies as this one to find if there are other reasons as to why BI is underutilised for sustainability. These reasons could for example be the badly perceived value creation of BI tools in regards to sustainability efforts that we touched upon in this study. Another suggestion for future studies could be exploring organisational capabilities or human competencies of BI tools in a sustainability context. By doing so research will help answer some of the questions which appeared in our discussion and will also take another step into examining how BI can best be used and applied within the context of sustainability.

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AI Contribution statement

We have used ChatGPT to discuss ideas of inspiration and as a sounding board for our study to help refine our research question(s). ChatGPT has occasionally aided us in formulating our sentences in a way that makes them proper and easy to understand.

We have used OpenAI Whisper for transcription of the interviews.