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Supply Chain Analytics for Sustainable Operations

A Case Study on Unilever’s GHG Emissions

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Abstract

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This thesis explores the application of supply chain analytics in improving companies' sustainable operations. It provides an example for all companies to understand, predict, and select actions for their sustainability performance. As international requirements for sustainability continue to increase, it is meaningful for enterprises to realize and optimize their sustainability situations with data-driven approaches.
The study uses supply chain analytics, which includes descriptive, diagnostic, predictive, and prescriptive analytics. The supply chain analytics lifecycle is demonstrated through a case study of Unilever's GHG emission reduction. The six-step analytics lifecycle starts from the specific problem identification. Regarding the problem or metrics, relevant data should be collected and then used to describe the past and current situations. Understanding the description is necessary but not adequate because it is more important to explore the root cause behind the information. The next step should be predicting what will happen in the future. Based on the prediction, we can select the correct actions to influence the future. Finally, the action implementation should be checked and standardized for ongoing improvement.
This research illustrates how firms use supply chain analytics to improve sustainability. To make this study applicable to different companies, the challenges in adopting analytics are also discussed, such as data quality, data scalability, time consumption, and data security. Moreover, a detailed review of existing sustainability standards and KPIs is introduced for measuring a company's sustainability performance. These standards and KPIs guide the direction of a firm's sustainability strategies. Lastly, the study introduces the nonlinear relationship between profitability and sustainability, which indicates the appropriate strategies for different stages of sustainability and explains the importance and process of stakeholder engagement. It can assist companies in balancing their financial and sustainable performances.

Keywords: Sustainability, supply chain analytics, analysis challenges, sustainability standards, profitability

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Glossary

BDPA	Big data and predictive analytics.
CSRD	Corporate Sustainability Reporting Directive. A guide for companies' annual sustainability reports.
ESG	Environmental, social and governance. Three dimensions of sustainability.
ESRS	European Sustainability Reporting Standards. The requirements for EU companies to report their sustainability performance.
GHG	Greenhouse gas. The gases that can aggravate global warming.
GRI	Global Reporting Initiative. An institution that has developed and delivered international sustainable practices for organizations.
GSCM	Green supply chain management.
IFRS	International Financial Reporting Standards. A set of accounting rules for how information should be gathered and presented in financial reports.
ISSB	International Sustainability Standards Board. An organization that develops and approves IFRS.
KPI	Key performance indicator. A quantifiable indicator of progress which is used to achieve an intended result.
PSS	Product-service system. A business model that provides combination of product and service.
SCDDA	Supply Chain Due Diligence Act. A sustainability legislation that pushes companies to practise sustainable and ethical supply chain operations
SCM	Supply chain management. Strategies and control of the materials and information flows during the supply chain.

SME	Small and medium enterprises. The small-sized and medium-sized companies.
SSCM	Sustainable supply chain management. Management of supply chain with taking sustainability into account.

1 Introduction

The supply chain is a complex and interconnected network that encompasses every phase of production, from sourcing raw materials to delivering products to end users. This intricate web not only facilitates the movement of goods but also plays an important role in determining the sustainability of business practices. As environmental and social sustainability issues increasingly come to the forefront, challenges often arise at various stages of the supply chain. Factors such as resource depletion, waste generation, and unethical labor practices can have far-reaching implications, not only for companies but also for communities and ecosystems worldwide. In response to these pressing concerns, governments and international organizations are implementing strict regulations and guidelines aimed at driving businesses toward more sustainable practices. As a result, the demand for transparency and accountability in supply chains is growing, pushing organizations to demonstrate their commitment to sustainability. However, the journey toward sustainable operations is fraught with complexities. Analyzing and optimizing a company’s sustainability performance requires a nuanced understanding of diverse variables, including resource management, waste reduction, ethical sourcing, and social responsibility. Additionally, the integration of new technologies and data sources further complicates the situation but also opens new avenues for innovation.

Therefore, implementing effective supply chain analytics is not only beneficial but also essential for companies striving to thrive in an increasingly sustainability-conscious marketplace. As consumers demand greater transparency and responsibility, organizations that prioritize sustainable practices will not only enhance their reputation but also drive long-term success. By harnessing the power of analytics, companies can not only meet regulatory requirements but also create a competitive advantage in an evolving global economy focused on sustainability.

1.1 Research questions and objectives

This thesis focuses on using supply chain analytics to measure and improve a company's sustainability performance. The research questions are listed below.

1. How can supply chain analytics improve sustainability in operation?

2. What are the challenges and barriers to adopting supply chain analytics for sustainability?

3. What are the main sustainability standards and key performance indicators (KPIs) for supply chain operations?

The first question seeks to understand this method's structure and procedure to handle a sustainable issue. The second one investigates the obstacles organizations face in integrating analytics into their supply chain for sustainability purposes. The third question aims to identify the specific metrics that a company should measure and analyze in the sustainability field. The purposes of this thesis can be structured to systematically address each research question and provide comprehensive insights into the application of supply chain analytics for sustainable operations. The first research objective is to examine the method of supply chain analytics in enhancing sustainability. As per the analysis, an enterprise will deeply realize its sustainability situation and know what to do to optimize its sustainability performance. The second goal is to identify the challenges and barriers to adopting supply chain analytics for sustainability so that firms understand what capabilities they should improve to overcome the difficulties. The third purpose is to recognize sustainability standards and KPIs, which can be crucial since they guide a company's supply chain analytics and provide its sustainability reporting structure and requirements. Based on a detailed and clear standard, firms can correctly report and promote their sustainability performance.

1.2 Scope of the study

The thesis is built on experimental research. Supply chain analytics, which is the experimental design for my topic, discovers patterns and provides insights for information-based judgment (Sekhar, Chandrashekar & Matt 2021: 11). It includes four steps- descriptive, diagnostic, predictive, and prescriptive analytics (Saci 2022). Concerning the methods for data analysis, the study will focus on statistical analysis, root cause analysis, linear regression, and decision trees. The application of supply chain analytics is demonstrated through a practical example of Unilever. The case issue is to analyze and improve Unilever’s greenhouse gas (GHG) emissions situation.

1.3 Methodology

The research method selection largely depends on what and how we collect data. Since the thesis topic focuses on data analysis, which is numerical and mathematical, the data needed for the thesis should be mainly quantitative. Quantitative analysis methods include making straightforward tables or graphs to display how often certain events happen, as well as employing statistical techniques like indices for comparison by identifying relationships between different variables. (Saunders, Lewis & Thornhill 2019: 777). The methods such as data trend charts, comparison charts, statistics of related variables, and rate calculation will be used for the Unilever case in this thesis. The data source for the case is secondary, which is collected from Unilever’s annual sustainability reports and data sharing.

1.4 Structure of the study

It is necessary to realize the study structure so that the research can be effectively understood.

Figure 1. The study structure

Figure 1 demonstrates the complete structure of this study.

2 Literature review

In recent years, the integration of sustainability within supply chain management has become increasingly vital, driven by growing environmental concerns and the need for responsible business practices. In this chapter, I will introduce the topic-related concepts and theories regarding sustainability, sustainable supply chain management, and supply chain analytics. In addition, the research achievements and shortcomings of relevant studies will be discussed. Therefore, this literature review explores the intersection of supply chain analytics and sustainable operations, examining key methodologies, tools, and frameworks that organizations employ to optimize their supply chains in an environmentally conscious manner.

2.1 Sustainability

Sustainability is increasingly becoming a topic of concern in the world. The popular definition of sustainability should meet “the needs of the present without compromising the ability of future generations to meet their own needs” (United Nation Brundtland Commission 1987: 16). The key point of sustainability should be maintaining, which means the situation of using the current resources for a long term so that the future generations still have enough resources for living and developing. Therefore, people should consider the current and future imperatives.

The concept of sustainability has rapidly developed over the past few decades. With the prosperity of the second industrial revolution, western countries were fast developing. The development at that time was accompanied by huge waste of resources and environmental pollution. The western countries began to notice that their industrial and business activities largely influenced the environment and society. In 1968, Garret Hardin’s *Tragedy of the Commons* argued that if people acted independently and focused on the pursuit of their own gain, they would ultimately work against the common benefits of society and deplete the earth’s resources (Hardin 2001). In 1972, the Club of Rome’s *The Limits to Growth* report predicted that economies and societies would collapse by the end of the 21st century if humans did not limit growth. In the same year, at the United Nations Conference on the Human Environment held in Stockholm, the concept of sustainable development received international recognition for the first time (Sustainable Development Commission 2011). In addition, the most recognized definition of sustainable development, as mentioned in the last paragraph, was given in the Brundtland report in 1987. Furthermore, the triple bottom line which was created by John Elkington in 1994 explained that companies should not only care about the profit but also be responsible for the societal impact of firm activity and the environmental impact of operations (The Economist 2009). At this moment, the concept of sustainability, which concerns profit, planet, and people, has become more comprehensive.

2.2 Sustainable supply chain management

A supply chain is a network of connected organizations that cooperate to convert the flow of materials, and information from suppliers into goods and services for end users (Harrison and Hoek 2008: 7). Supply chain management (SCM) is accordingly the strategies and control of the materials and information flow for optimizing the company's operation and reducing its costs. When sustainability is used in the supply chain field, the term sustainable supply chain management (SSCM) was created and has been defined by Carter and Rogers as

> the strategic, transparent integration and achievement of an organization's social, environmental, and economic goals in the systemic coordination of key interorganizational business processes for improving the long-term economic performance of the individual company and its supply chains (2008:368).

According to Carter and Rogers (2008: 365), supply chain management should be based on the triple bottom line (environmental, economic, and social performances) and the four sustainability supporting aspects- risk management, transparency, strategy, and culture, which are conceptualized and indicated in Figure 2.

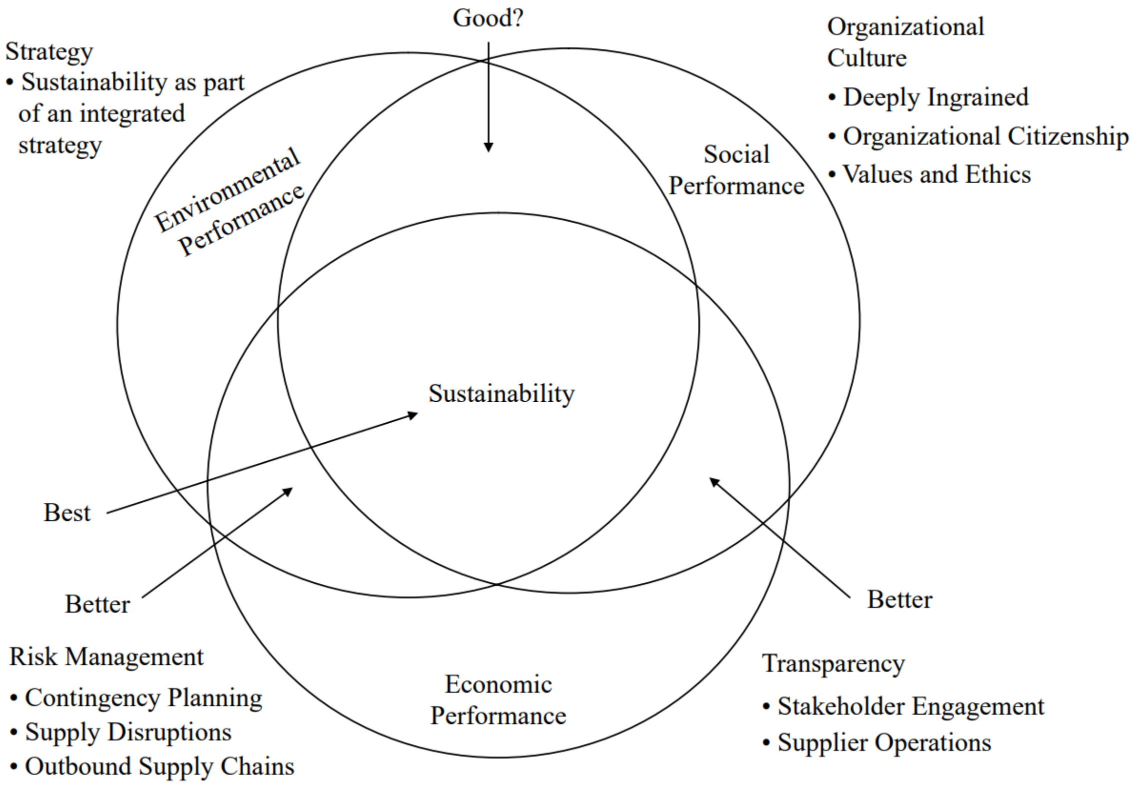

Figure 2. The triple bottom line and SSCM (Carter and Rogers 2008: 369)

The environmental and social strategies must be undertaken with an explicit awareness of the economic objectives of the enterprise (Carter and Rogers 2008: 369). Organizations should carefully select the social and environmental goals related to their supply chains. A comprehensive strategy is required to manage the relationship of the three dimensions for achieving a win-win situation. Thus, SSCM denotes the implementation of effective managerial strategies aimed at safeguarding the environment, fostering societal well-being, and upholding human rights throughout the intricacies of the supply chain network.

Green logistics or green supply chain management (GSCM) is a popular topic relevant to the topic of the thesis. Singh and Trivedi aim to provide the latest and structured insight into the GSCM literature published during the past ten years (2016). Following the literature, Singh and Trivedi (2016) state that firms have moved their attention from the environment to the triple bottom line for adopting and developing their sustainability. Various aspects of GSCM have been studied and discussed, such as supplier selection and analytical models. This study offers a comprehensive understanding of GSCM from different angles, which includes logistics, reverse logistics, performance assessment, production supplier selection, human resource management, and IT systems.

2.3 Data analysis and supply chain sustainability

Big data and predictive analytics (BDPA) are a popular topic in this field. BDPA tools and methodologies use computer algorithms and statistical technologies to produce patterns and insights from huge data sets (Jeble et al. 2018). As Jeble et al. (2018: 515) state, a theoretical model is created to explain the impact of BDPA on the sustainability of business development for an organization. Compared with the previous studies for single sustainable performance, the authors focus on the triple bottom line which includes economic, social, and environmental sustainability. In addition, the BDPA for supply chain sustainability can be used for various aspects including supply chain management, industrial engineering, information systems, and business analytics (IFRS et al. 2016: 592). However, BDPA may not be widely used, because some companies, especially small and medium enterprises (SMEs), do not have big data analysis technologies and capabilities. On the other hand, Sekhar, Chandrashekar, and Matt (2021: 11) introduce supply chain analytics methods, which are descriptive, predictive, and perspective analytics. The study discusses supply chain technology, tools, opportunities, and process applications. The shortcoming of this thesis is that it does not explore diagnostic analysis in depth.

Mangina et al. (2020) use data from over 11 million journeys covering 27 European countries to analyze vehicle utilization, degree of vehicles’ loading, and amount of CO2 emissions. Different algorithms including Horizontal Cooperation, Pooling, and Physical Internet are implemented to analyze efficiency and improve sustainability. This study focuses on the global supply chain, which exhibits data analytics for macro situations but lacks analysis and guidance for individual companies.

Data-driven decision-making is also a crucial concept in supply chain analytics. It not only increases the efficiency of enterprises' operations, but also optimizes their supply chains in the implementing and monitoring of sustainable supply chain management activities (Mageto 2021: 4). Moreover, sustainable supply chain analytics is treated as a collection of data-driven activities and analytic tools to offer suitable solutions and creative vision for complicated supply chain decision-making issues so that the objectives of environmental, social, cultural, and economic sustainability can be achieved (Ülkü and Engau 2021). These studies provide rich theoretical support and textual analytics but lack empirical studies. In addition, Robertson comprehensively discusses using supply chain analytics to enhance supply chain strategy, design, execution, and people processes and gives a DHL study case for decision-making (2021). Even though this study explores various dimensions in depth, it does not integrate supply chain analysis into sustainable development.

Collaboration and circular supply chain are actively discussed in this field as well. Collaboration requires all the stakeholders in the supply chain to work together and share data to improve sustainability. In the view of Bag et al., the companies that deploy BDPA are more willing to share circular economy-related information and build close relationships with stakeholders (2023: 5). Therefore, stronger trust and cooperation, which make contributions to social sustainability, can be built during the supply chain process.

According to the exploration of Brandenburg et al. (2019), many companies face challenges when shifting towards sustainability and need to find the balance between the dimensions of the triple bottom line. However, simply using a win-win perspective to manage the triple bottom line can hardly bring fundamental change in business practice, because it limits the strategic choices to those immediately connected to profit logic. This study highlights the importance of the balance between profitability and sustainability and provides a foundation to explore and improve the issue.

2.4 Global legislation and current situations

Supply chains are the arteries of today's global business. Owing to the large scale and high complexity, the supply chain has been ranked as the biggest challenge to improve sustainability (United Nations Global Compact n.d.). Under this circumstance, the world's demands for sustainability are fully reflected in legislation. The supply chain sustainability-related laws, regulations, and international principles are built to require companies to maintain a more balanced and environment-friendly future. According to Authenticate (2023), the Supply Chain Due Diligence Act (SCDDA) is one of the sustainability legislations that pushes companies to practice sustainable and ethical supply chain operations with the following core standards: transparent supply chain information, due diligence, systematic risk assessment, human rights protection, minimized environmental impact, reporting, auditing and verification by a third party, supplier engagement, and continuous improvement. In addition, new trends for sustainability are emerging. With the Corporate Sustainability Reporting Directive (CSRD) taking effect in 2024, large and medium companies in the European Union market are required to create annual sustainability reports to "disclose their environmental and social impacts, and how their environmental, social and governance (ESG) actions affect their business" (IBM 2024). Therefore, it is obvious that sustainability is becoming increasingly essential in the current and future supply chain.

To meet the growing sustainable demands, mounting companies are pouring efforts to optimize their supply chain practices. Based on the survey from PwC (2023), 86% of corporations have recognized the importance of supply chain operations to improve their strategy of ESG. Moreover, 79% of them agreed that the digital investments in ESG have contributed to their supply chain. However, most respondents have not developed their digital ability to verify and measure supply chain performance that can benefit their sustainability objectives (PwC 2023). Furthermore, the survey of *State of Supply Chain Sustainability 2023* (Correl and Betts 2023) reveals that around 65% of over 2300 global respondents do not have a net-zero carbon emissions goal. Hence, compared with the trends of sustainability, the current situation is still far from meeting the requirements.

Data-driven approaches are playing a critical role in a sustainable supply chain. Companies can track their greenhouse emissions and resource utilization, and measure environmental impact. By analyzing the sustainability-related data, companies will optimize decision-making on supply chain activities. This thesis aims to explain how supply chain analytics can display the companies' sustainability performance and what it can do to improve sustainable operations.

2.5 Supply chain analytics

Supply chain analytics has been defined by Deloitte (2014) as "tools and techniques that harness data from a wide range of internal and external sources to produce breakthrough insights that can help SCs reduce cost and risk while improving operational agility". With the assistance of visual tools such as tables, charts, and diagrams, supply chain analytics can discover patterns and provide insights for information-based judgment (Sekhar, Chandrashekar & Matt 2021: 11). By using supply chain Analytics, companies can accomplish cost reduction, higher efficiency, and less environmental impact through supply chain networks.

Supply chain analytics consists of four steps: descriptive analytics, diagnostic analytics, predictive analytics, and prescriptive analytics (Saci 2022).

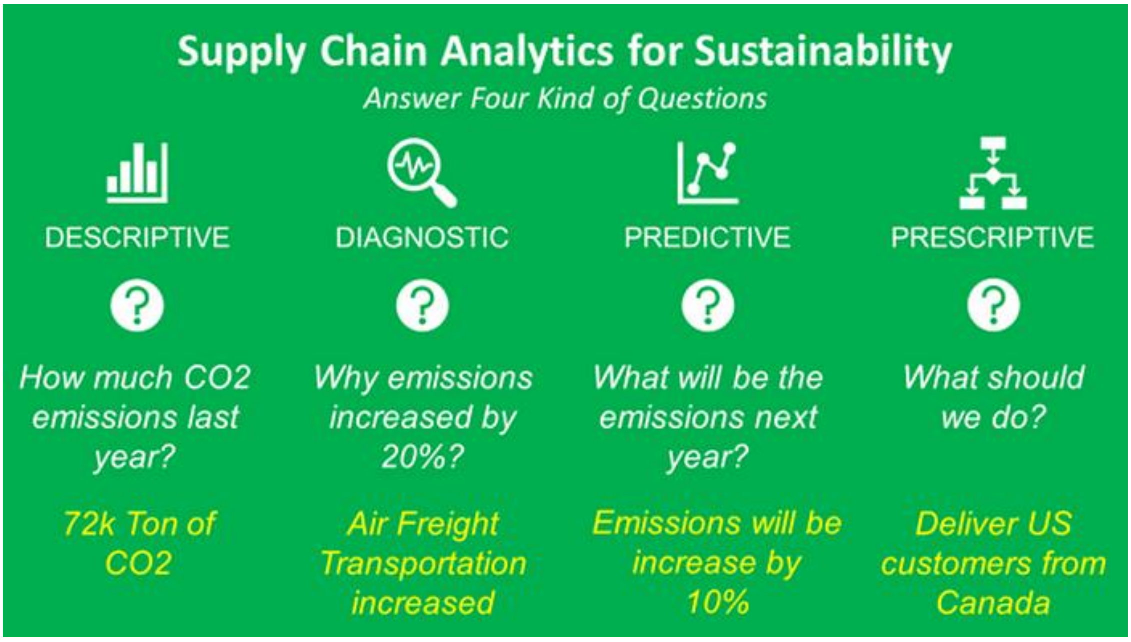

Figure 3. Four types of supply chain analytics for sustainability (Saci 2022)

When they are applied in sustainable fields, a company can build a complete process to reveal its sustainability performances, find out the problems, predict future situations, and design solutions for reducing environmental impact during the end-to-end supply chain operations.

2.5.1 Descriptive analytics

Descriptive analytics refers to the process of using information to describe past and present situations, which is usually the first stage of supply chain analytics. It answers the questions about what has happened and what is currently happening by collecting and recapitulating “the source data to a human-understandable format” (Sekhar et al. 2021: 17). The questions can be, for example, how much carbon emission was produced last year, and what were the transportation costs in the first quarter of this year. Thus, descriptive analytics should be the objective reflection of the raw information. In addition, descriptive analytics always applies various statistical methods such as means, standard deviations, distributions, ratios, and summations, which can produce significant insights for future analysis (Robertson 2021: 34). The results of descriptive analytics can be visualized by different kinds of chart tools, which presents an intuitive reporting way for easy understanding.

Descriptive analytics, as the first level of supply chain analytics, is crucial for the data-driven decision-making process because it builds the foundation and determines the direction of future data analytics.

2.5.2 Diagnostic analytics

Realizing what has happened is essential but not sufficient for the whole analysis purpose. The second analytics stage, diagnostic analytics, answers why it happened behind the objective situations. Since the current strategy and implementation cannot be perfect, it is important to understand why the performance did not achieve the goals. With the assistance of the results of diagnostic analytics, a company can make more experienced data-driven decisions through “finding patterns, correlations, making assumptions on things” (Morrow 2023). In this analytics step, the questions that can be mentioned are, for example, why the CO_2 emission increased by 10% this year, and why the inventory cost increased by 15% last month.

Diagnostic analytics, which explores the deep reasons based on descriptive analytics, creates meaningful insights for future problem-solving requirements.

2.5.3 Predictive analytics

Predictive analytics aims to answer what could happen in the future. Since it is impossible to predict a 100% accurate future, the probability of prediction is exactly significant in this stage (Robertson 2021: 34).

According to Sekhar et al. (2021: 18), both qualitative and quantitative methods can be used to analyze past and current information for making predictions in the supply chain. Therefore, linear regression analysis, which “is used to predict the value of a variable based on the value of another variable” (IBM n.d.c), plays a powerful role in this field. The variable that is used to predict another variable is the independent variable (x), while the variable that we need to predict is called an independent variable (y).

Based on the view from AWS (n.d.), the following three types of regression analysis are especially suitable for handling complex datasets.

Table 1. The three regression analysis types that suit predictive analytics

Type	Explanation	Application
Simple linear regression	$y= \beta_0 * x + \beta_1 + \varepsilon$ β_0 and β_1: regression slope ε (epsilon): error term It aims to describe a linear correlation between x and y.	Relationship between two variables: e.g. age and height of children
Multiple linear regression	$y= \beta_0 * x_0 + \beta_1 * x_1 + \beta_2 * x_2 + \ldots\ldots \beta_n * x_n + \varepsilon$ It includes a single dependent variable and multiple independent variables.	Multiple variables and their impact on the dependent variable (outcome): e.g. wage growth and inflation on home loan rates
Logistic regression	It analyses the probability of an event happening based on the input data. The prediction is presented as a number between 0 (unlikely to occur) to 1 (maximum likelihood).	0-1 possibility: e.g. the probability of passing or failing a test

Understanding the fundamental knowledge of linear regression greatly contributes to predictive analytics, since it indicates the trends of the predictor factor based on the known information.

2.5.4 Prescriptive analytics

Following the various judgments from previous steps of analysis, prescriptive analytics, which answers the question of what actions should be taken to influence the most possible future, is the final stage of supply chain analytics and largely builds the success of making decisions (Sekhar et al. 2021: 19). In addition, prescriptive analytics assists in providing the most correct choice which “best meets predefined objectives (i.e. provides the best response)” (Robertson 2021: 35). Therefore, decision analytics is essential in this stage. When determining which action or model should be selected, the method of decision trees can be used to make a more accurate choice among multiple alternatives.

The decision tree is a tree-structured, hierarchical “non-parametric supervised learning algorithm, which is utilized for both classification and regression tasks” (IBM n.d.a). According to the opinion of Pourabdollahi et al. (2014: 61), the decision tree explores and analyses the relative situations that build a dataset and identifies logical relationships of the variables in the dataset. In a decision tree structure, the analysis starts from a root node and then feeds into two internal nodes. Based on the known features, both of the internal nodes are evaluated to form homogenous subsets, represented by leaf nodes or terminal nodes which are all the possible outcomes in the task (IBM n.d.a).

Here is an example of the decision tree for a cocktail party.

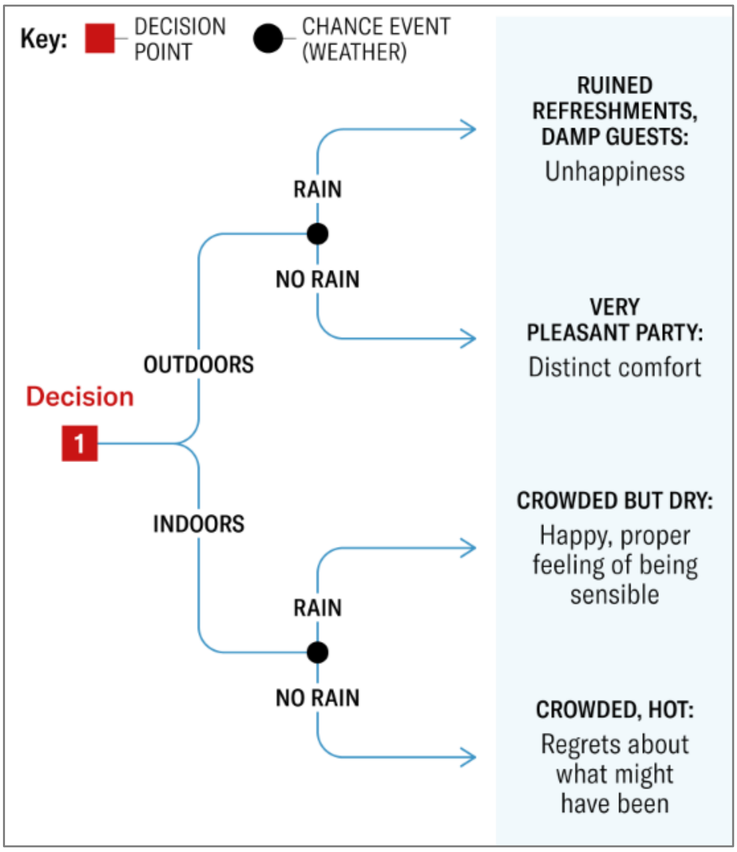

Figure 4. Decision tree example for a cocktail party (Magee 1964)

The root node in this example is Decision which can also be presented as a question like How we host a cocktail party. The internal nodes, which extend two branches from the root, are OUTDOORS and INDOORS. Since the unique feature is the weather, the four leaf nodes based on the weather display all the possible results that are related to advantages and risks in this case.

3 Research methodology

3.1 Case study introduction

In this research, the theories of sustainability and supply chain analytics will be practiced through a case study about Unilever's sustainability performance during its supply chain. Unilever is one of the largest consumer goods companies in the world, which owns hundreds of well-known brands such as Dove, OMO, and Ben & Jerry's (Unilever n.d.b). Unilever has a complex global supply chain network that is flexible and effective. It is interesting and challenging to study its sustainability situation during the network. The results and findings must be greatly meaningful for many companies to improve their supply chain management.

The specific point that will be explored in this case study is a main aspect of sustainability- greenhouse gas (GHG) emissions. GHG emissions are measured in three types: Scope 1, 2, and 3. Scope 1 refers to the direct emissions from assets that are directly controlled by the company, and Scope 2 is the indirect emissions from purchased electricity. Scope 3 refers to the other indirect emissions from the sources such as logistics, business travel, and employee commuting. This case study will use the methods of supply chain analytics to analyze Unilever’s GHG emissions performance from 2018 to 2023.

3.2 Data sources and collection

Unilever has made significant commitments to sustainability and has been recognized for its efforts in this area. It has collected and organized detailed information about GHG emissions and environmental performance, which is reported in annual sustainability reports. In addition, Unilever published separate Excel data on Scope 1, 2 & 3 emissions which can be immediately collected and used for analysis. Since some related variables should also be analyzed in this research, some other information from Unilever is indispensable.

Table 2. The information sources used for the study case from Unilever

	Documents	Years
1	Unilever Annal Report and Accounts	2018- 2023
2	Unilever At a Glance	2024
3	Climate Transition Action Plan	2024
4	Unilever Sustainable Performance Data_ Climate	2023
5	Unilever's Supply Chain	2022

Table 2 displays all the information sources from Unilever that are used for this case study. The data that I collected is related to Scope 1 and 2 GHG emissions from operations (e.g. manufacturing facilities, offices, and warehouse) and energy use, as well as Scope 3 GHG emissions from raw materials, packaging materials, retail ice cream freezers, etc. Some data on relevant elements that affect emissions such as energy use, supplier count, waste generation, and purchased materials costs are necessary for predictive analytics.

To make the research more comprehensive and fair, information from other sources should be included. First, CDP is a nonprofit organization that provides a global disclosure system for companies, cities, and investors to manage their environmental impacts. Its standardized reporting framework is based on extensive and comprehensive datasets of corporate actions (CDP n.d.). CDP's score for Unilever's sustainability performance can be involved in this case study as reliable information. Second, Morningstar Sustainalytics is a leading company in ESG research and data. Its ESG Risk Rating is "a multi-dimensional assessment of a company's exposure to industry-specific material

ESG risks and its management of those risks" (Morningstar Sustainalystics n.d.). All in all, these third-party evaluations of Unilever's environmental performance can make this case study more objective.

3.3 Research methods and process

The application method of supply chain analysis for sustainability should be the supply chain analytics lifecycle, which is a complete process of implementing supply chain analytics in a continuous business improvement way (Robertson 2021: 30).

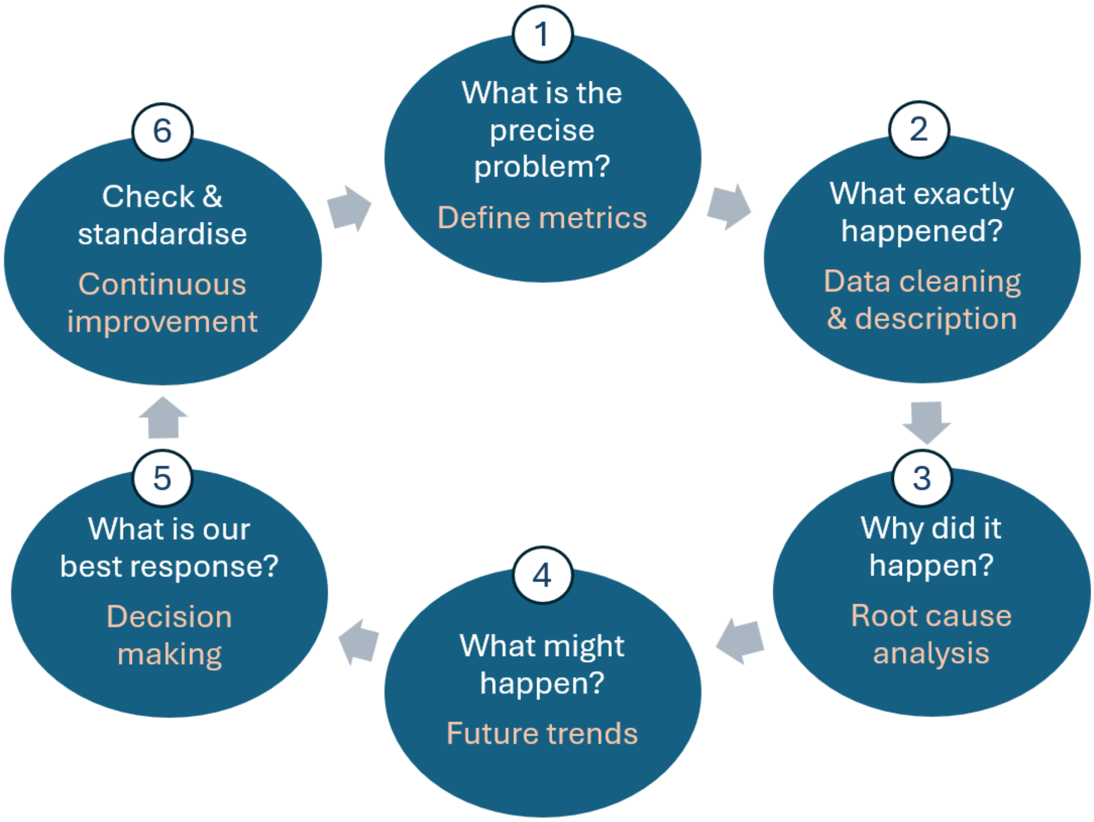

Figure 5. Supply chain analytics lifecycle (Robertson 2021: 31)

The six-step analytics lifecycle begins with the crucial phase of specific problem identification, which sets the foundation for the entire process. In this initial stage, it is essential to clearly define the problem or the metrics that need to be addressed. Once the problem has been articulated, the next step involves collecting relevant data. This data serves as the backbone of the analysis, which describes the past and current situations comprehensively. (Robertson 2021: 30)

Understanding this descriptive data is vital, yet it is only the starting point. A deeper exploration into the root causes behind the information is necessary to uncover the underlying factors contributing to the observed trends. This root cause analysis allows analysts to move beyond surface-level symptoms, providing a clearer picture of the complexities involved. (Robertson 2021: 31)

Following the exploration of root causes, the next step in the lifecycle is prediction. This involves utilizing statistical models and forecasting techniques to anticipate future events based on historical data and current trends. Making accurate predictions is key, as it informs the subsequent phase of action selection. (Robertson 2021: 31)

Based on the prediction analytics, various strategies should be considered to influence future outcomes positively. The decision-making process must involve a careful evaluation of each potential strategy, weighing the risks and benefits associated with every point. (Robertson 2021: 31)

Once the appropriate actions have been selected, the final step is action implementation. However, this phase does not conclude the process; it is essential to continuously monitor and evaluate the effectiveness of the implemented actions. Establishing a feedback loop allows for ongoing improvement and refinement of strategies, ensuring that the organization can adapt to changing conditions and maintain its competitive edge. (Robertson 2021: 31)

4 Unilever case study

In this chapter, Unilever’s sustainability performance will be analyzed by the method of supply chain analytics.

4.1 Problem identification

In the first step, we should determine a clear, brief, and relevant statement of a problem generally including five W's and one H, which are the abbreviation of who, what, where, when, why, and how (Robertson 2021: 30). The analysis can be started more smoothly with a comprehensive and clear problem statement. Besides, the key sustainability metrics, which are involved in the statement, could include carbon emissions, water usage, waste generation, ethical labor practices, and so on.

The problem statement I would like to define is how Unilever's GHG emissions performed from 2018 to 2023 in the aspect of the supply chain. It is obvious that the key sustainability metrics are GHG emissions.

4.2 Data cleaning and description

In the second stage, we should describe what has exactly happened. This step involves collecting relevant information, data, and specialists' opinions if necessary (Robertson 2021: 31). The data should be gathered across a company's supply chain, which might include internal data from operations, and external data from suppliers, transportation partners, as well as other stakeholders. After collecting the data, it is crucial and necessary to clean and integrate the raw data. According to Tableau (n.d.a), data cleaning, also known as data scrubbing or data cleansing, refers to "the process of fixing or removing incorrect, corrupted, incorrectly formatted, duplicate, or incomplete data within a dataset". The objective of data cleaning is to improve the quality of data for future analysis. The methods and techniques for cleansing data may vary depending on the different data types, while the basic way to accomplish that can follow these 5 steps (Tableau n.d.a):

- Remove the unwanted data: duplicate or irrelevant observations.
- Fix the structural errors.
- Eliminate the outliers.

- Deal with the missing information.
- Validate the dataset.

After removing the unnecessary data and correcting the mistakes, the dataset can be checked whether it aligns with the validation rules that we have predefined (Hillier 2023). If all the requirements are achieved, we receive the cleaned and qualified data which can be used for descriptive analytics.

In the case of Unilever, As per the sustainability performance data published by Unilever (n.d.a), a large range of data on planet, society, and people has been provided for deeper delving. I used climate action data (see Appendix 1 and 2), combined the variables regarding Scope 1, 2 & 3 GHG emissions from 2018 to 2022, and unified the numbers' units for this case analysis. After cleansing the data, I can describe the performance of Univeler's GHG emissions during the five years.

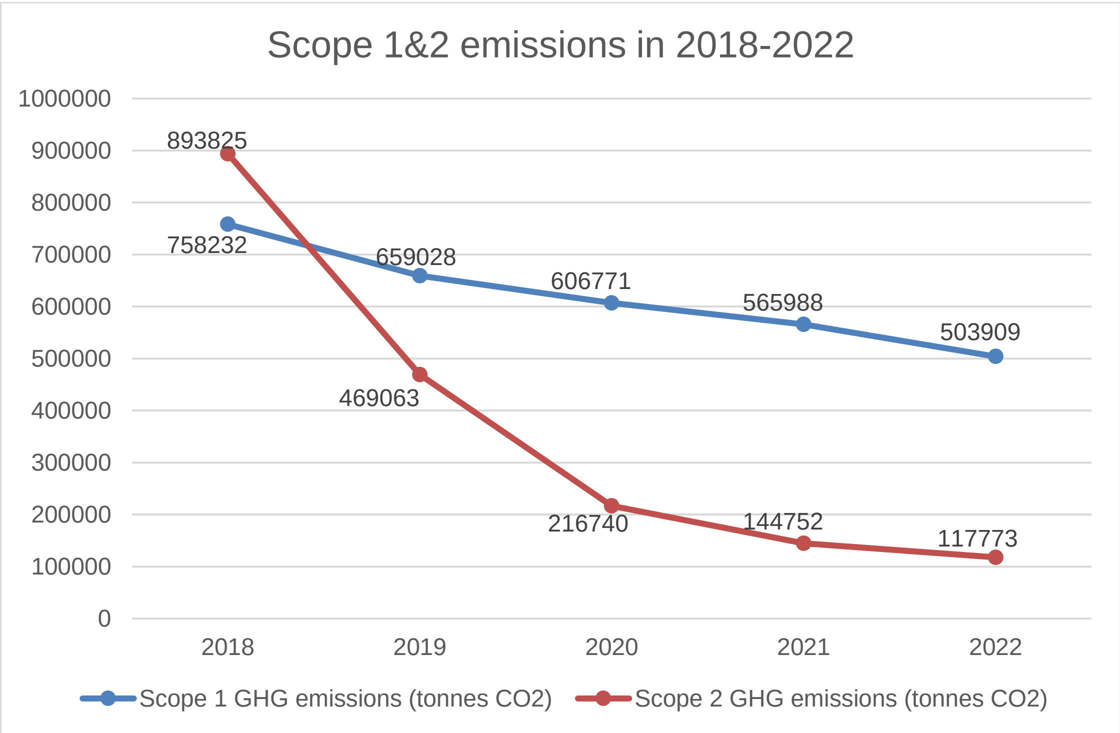

Figure 6. Unilever Scope 1&2 emissions from 2018 to 2022

Unilever has demonstrated a strong commitment to reducing its greenhouse gas emissions, particularly evident in the trends observed in its Scope 1 and

Scope 2 emissions. The trend of Scope 1 emissions indicates a stable and smooth reduction during the five years. It maintains decreasing around 10% each year, which demonstrates Unilever's continuous efforts on climate action. This consistent decline underscores Unilever's sustained efforts and strategic initiatives aimed at minimizing its direct environmental impact.

On the other hand, Scope 2 emissions, which are indirect, have experienced a more dramatic change. Scope 2 emissions of Unilever dropped sharply from 2018 to 2020, with a 76% reduction in 2018 compared to that in 2020. This sharp decline indicates that Unilever has likely adopted significant energy efficiency measures and possibly transitioned to more renewable energy sources to power its operations. Moreover, it has maintained a steady decline since 2020. It is obvious that Unilever has implemented effective methods to decrease Scope 2 emissions.

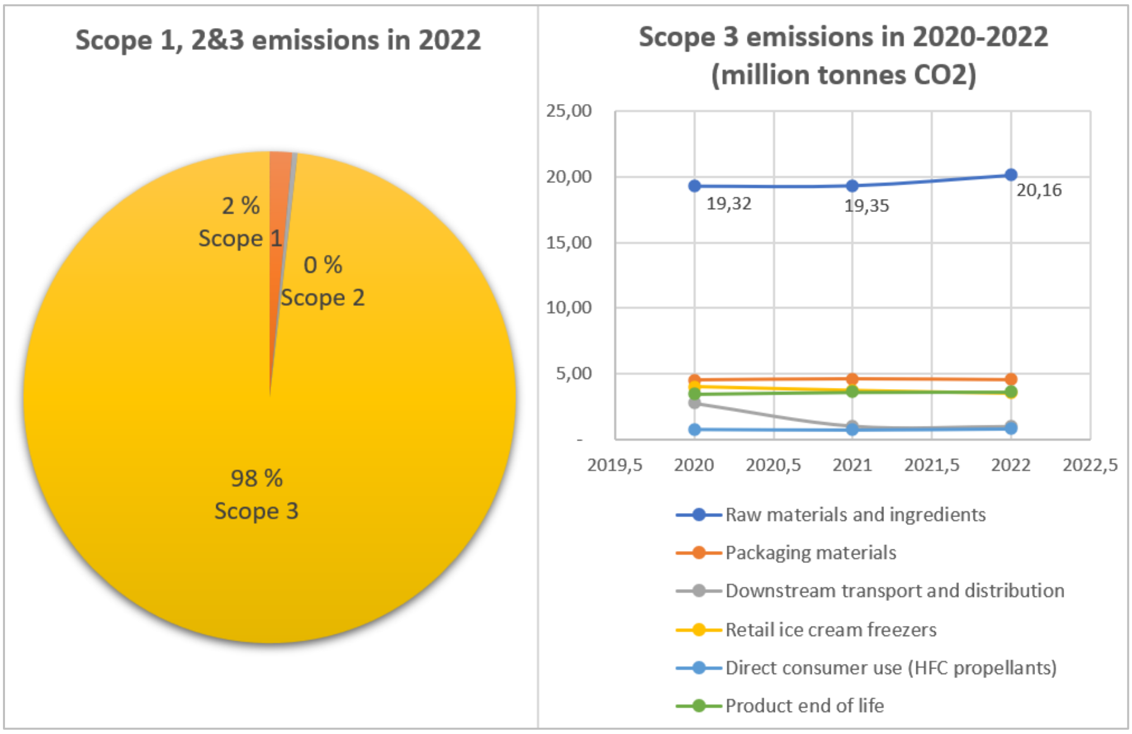

Figure 7. Situations of Scope 3 GHG emission in Unilever operations

The line chart on the right side of Figure 7 provides a detailed breakdown of the Scope 3 emissions from 2020 to 2022, measured in million tonnes of CO_2. It reveals that Scope 3 emissions (only operational aspects considered) accounted for up to 98% of Unilever's total GHG emissions in 2022. This overwhelming percentage underscores the critical role that Scope 3 emissions play in Unilever's overall carbon footprint, making them the predominant contributor to the company's environmental impact. In contrast, Scope 1 emissions make up only 2%, while the proportion of Scope 2 emissions is negligible and displayed as 0%.

According to the line chart in Figure 7, Scope 3 emissions have not effectively decreased from 2020 to 2022. This is particularly concerning given the significant proportion they represent. In fact, the largest source, raw materials, and ingredients produced 20.16 million tonnes of CO2 in 2022, which is 0.81 million tonnes more than the previous year. This rise highlights a growing challenge for Unilever, as reductions in other areas are overshadowed by the persistent and even increasing emissions in their supply chain. Other contributors to Scope 3 emissions include packaging materials, downstream transport and distribution, retail ice cream freezers, direct consumer use (HFC propellants), and product end of life. Although these categories have shown relative stability, they still represent substantial emission sources that require targeted reduction strategies.

Consequently, the biggest challenge for Unilever in reducing GHG emissions is how to effectively lower Scope 3 emissions.

4.3 Root cause analysis

The third stage in the supply chain analytics lifecycle is diagnostic analytics, which explores the reasons for the problem. Root cause analysis (RCA) refers to “the quality management process by which an organization searches for the root of a problem, issue or incident after it occurs” (IBM n.d.b.). As stated by Tableau (n.d.b), RCA operates on the belief that it is better to proactively address underlying issues rather than simply dealing with surface-level symptoms. It involves a range of principles, techniques, and methodologies aimed at pinpointing the fundamental causes behind an event or pattern. By delving deeper than immediate cause and effect, RCA reveals where breakdowns in processes or systems occurred, leading to the issue at hand.

The techniques and methods for RCA are numerous, such as the 5 Whys, change analysis, Pareto chart, and fishbone diagram (IBM n.d.b). The 5 Whys approach is one of the most common techniques for implementing RCA, which requires a team to continue asking “why” questions of a problem until the root cause is identified (Tableau n.d.b). Generally, a team should prepare 2 to 50 whys for achieving the correct answers (Tableau n.d.b). Regarding the Unilever case, the 5 Whys approach can be used as shown in Table 3.

Table 3. 5 Whys approach for exploring the root cause of Unilever's problem

Whys	Answers
1. Why have Scope 3 emissions increased these three years?	1. Because Unilever can hardly control Scope 3 emissions.
2. Why can Unilever hardly control it?	2. Because the sources of Scope 3 emissions lie outside Unilever’s direct operation.
3. Why do the sources of Scope 3 emissions lie outside Unilever’s direct operation?	3. Because the sources are the companies cooperating with Unilever, not being owned by it.

Therefore, since Scope 3 emissions are from stakeholders that are outside Unilever’s immediate control, it is greatly difficult for Unilever to reduce Scope 3 emissions.

4.4 Predictive outcomes

Both quantitative and qualitative methods can be effective for predictive analytics. The regression models, which have been explained in Chapter 3 Table 1, are common and powerful quantitative methods. In contrast, qualitative analytics, which deals with non-numeric data, provides rich insights into complex phenomena and a deep understanding of the underlying motivations, reasons, and behaviors. Unilever has focused on reducing its overall environmental footprint, including Scope 3 emissions, which constitute a significant portion of its total emissions. This part uses both quantitative and qualitative analytics to predict the future trajectory of Unilever's Scope 3 emissions by analyzing various data sources.

Unilever has formulated policies and guidelines for sustainability. The Climate Transition Action Plan (CTAP), which is the science-based target set by Unilever, consists of the 1.5°C temperature goal of the Paris Agreement, and aims to achieve net zero emissions by 2039 (Unilever 2024: 7). It covers Unilever's entire value chain, including Scope 1, 2, and 3 emissions (excluding indirect consumer use emissions). In addition, another standard, the near-term GHG reduction targets, requires a 42% absolute reduction of Scope 3 energy and industrial GHG emissions by 2030, and a 30.3% absolute reduction of scope forest, land, and agriculture GHG emissions by 2030 (Unilever 2024: 11). These two targets together contribute to preventing climate change. Furthermore, Unilever launched the Supplier Climate Program in 2021, which is committed to "accelerating the transition of key suppliers to a position of climate leadership" (Unilever 2024: 19). Since Scope 3 emissions are generated from the outside cooperators where suppliers play a significant role, the program would effectively build the suppliers' climate capability for the unified sustainability objectives. On the other hand, reformulating products is one of Unilever's most important strategies to decrease emissions. The key actions include increasingly using lower-GHG and plant-based ingredients, and reducing the usage of palm oil in soap bars (Unilever 2024: 20). Besides, Unilever improves climate impact through expanding usage of electric energy and renewable packaging material, as well as enhancing the efficiency of the logistics network (Unilever, 2024: 27).

To significantly enhance the accuracy and robustness of the predictive analytics, I incorporate several external factors impacting Scope 3 emissions, such as the number of suppliers, costs of purchased goods, global energy use, and waste generation, into the predictive analytics. All the data are collected from Unilever's annual reports from 2020 to 2023.

Table 4. Unilever climate data and related variables

Year	Total Scope 3 emission (million tonnes CO2)	Supplier count	Purchased goods costs (€ million)	Total global energy use (kWh)	Waste generation (tonnes)
2020	60,39	56000	20,40	7037674000	584038
2021	55,34	53800	21,80	7002482000	652296
2022	52,82	52000	26,36	6609692000	571284
2023	52,13	57000	25,08	5971759000	504286

Table 4 demonstrates that less energy use, supplier streamlining, and recycled products contribute to the reduction of Scope 3 emissions. On the other hand, the total Scope 3 emissions are inversely proportional to purchased goods costs, which indicates that renewable materials generally command more payments. As per Unilever's annual report (2023: 39), the GHG emissions have decreased 74% in 2023 compared to 2015 levels. Moreover, Scope 3 emissions keep a slight and steady reduction (1.3% to 4.6%) from 2021 to 2023. These achievements prove the effectiveness of Unilever's sustainability tactics and actions.

According to Table 4, the Scope 3 emission reduction rate can be calculated as follows.

- 2020 to 2021: (60.39 - 55.34) / 60.39 * 100% = 8.36%
- 2021 to 2022: (55.34 - 52.82) / 55.34 * 100% = 4.55%
- 2022 to 2023: (52.82 – 52.13) / 52.82 * 100% = 1.31%
- The average annual Scope 3 emission reduction rate: (8.36% + 4.55% + 1.31%) / 3 = 4.74%

Under this trend, future emissions can be estimated.

- 2024: 52.13 * (1 – 4.74%) = 49.66 million tonnes CO2
- 2025: 49.66 * (1 – 4.74%) = 47.31 million tonnes CO2
- 2026: 47.31 * (1 – 4.74%) = 45.07 million tonnes CO2
- 2027: 45.07 * (1 – 4.74%) = 42.93 million tonnes CO2
- 2028: 42.93 * (1 – 4.74%) = 40.90 million tonnes CO2
- 2029: 40.90 * (1 – 4.74%) = 38.96 million tonnes CO2
- 2030: 38.96 * (1 – 4.74%) = 37.11 million tonnes CO2
- 2030 emission compared to 2023: (52.13 – 37.11) / 52.13 * 100% =29.06%

Thus, Unilever may achieve a 29.06% reduction in Scope 3 emissions by 2030, which is lower than its near-term GHG reduction targets.

According to CDP's scores on climate change of Unilever plc, Hindustan Unilever, PT Unilever Indonesia Tbk, and Unilever Nv Cva from 2018 to 2023, all of the four companies received scores A from 2018 to 2022, and scores A- in 2023 (CDP 2024). It reveals that Unilever's GHG emission performance in 2023 was not as good as in previous years. In addition, Morningstar Sustainalytics's ESG Risk Raking is 23.5 (Medium Risk) for Unilever plc, 21.5 (Medium Risk) for Hindustan Unilever Ltd. and 18.2 (Low Risk) for PT Unilever Indonesia Tbk (Morningstar Sustainalytics 2024). It demonstrates that Unilever in the United Kindom and India still faces medium-level ESG risk, which may affect its future performance.

In summary, even though Unilever has detailed strategies and ambitious targets for climate change, the prediction analytics for its GHG emissions is not quite optimistic, finally resulting in a 20% to 25% reduction by 2030.

4.5 Decision making

Prescriptive analytics involves using data-driven insights to recommend specific actions or strategies to achieve desired outcomes. For Unilever to reduce its Scope 3 emissions, decision-making analytics can provide meaningful and feasible recommendations based on predictive and diagnostic analytics.

The Scope 3 emissions are the results from the upstream and downstream in Unilever's value chain where the key influencing factors can be identified. According to Figure 7, the largest contributor to Scope 3 emissions could be raw materials and ingredients. Thus, Unilever should take action by purchasing more recycled materials and ingredients, prioritizing suppliers with lower carbon footprints, and pushing the existing suppliers to perform more sustainably. Furthermore, packaging materials and retail ice freezers are the main factors of Scope 3 emission. Unilever can use renewable packaging materials and services, as well as minimize packaging size and weight for less emissions. It is also necessary for Unilever to develop new technology for improving the ice freezers to reduce emissions. Besides, transportation routes and modes can be optimized for decreasing fuel consumption.

By leveraging decision-making analytics, Unilever can develop a strategic, data-driven approach to reducing Scope 3 emissions. This involves not only identifying the main emission sources but also implementing optimized, actionable strategies to achieve significant reductions in their environmental impact.

4.6 Continuous improvement

The actions and strategies, which have been established based on prescriptive analytics, should be checked, standardized, and improved in the continuous implementation. This stage "involves collecting performance results and assessing them against the desired levels" (Robertson 2021: 32).

Reviewing and modifying the strategies and actions can be implemented through several aspects. First, a detailed action plan should be developed for precisely executing the prescriptive recommendations, including timelines, required resources, and people in charge. Second, the key performance indicators (KPIs) should be established to measure the progress of Scope 3 emission reduction and evaluate whether the solutions are proven to be efficient. The KPIs can be metrics such as GHG emissions per unit of product, supplier sustainability scores, and percentage of recycled materials usage. Third, Unilever can develop a real-time data platform for tracking the efficiency of the strategies and make adjustments accordingly. Finally, Unilever should communicate and report the progress regularly to the stakeholders so that all the value chain members can work together for unified goals.

Monitoring, reviewing, and optimizing in the stage ensures the practical application of recommendations. The continuous improvement cycle assists in refining strategies and developing the most suitable practices. On the other hand, the regular evaluation can highlight the areas where innovative solutions can be applied to further GHG emission reduction.

5 Findings and analysis

The Unilever case study reveals several important findings. Firstly, it identifies that reducing Scope 3 emissions is crucial for lowering the company's overall GHG emissions. Secondly, the study highlights that raw materials and ingredients are the largest contributors to these Scope 3 emissions. The third finding emphasizes the challenge of reducing Scope 3 emissions, as they stem from stakeholders outside of Unilever's direct control. Lastly, the study predicts that Unilever could achieve a 20% to 25% reduction in Scope 3 emissions by 2030. Based on these findings, key actions for addressing the issues and driving improvements have been identified.

The Unilever case can be an example for all companies to understand, analyze, predict, and determine actions for their sustainability performances. Enterprises can produce their own research results according to the Unilever case study steps and methods. However, the application of data analytics can be challenging for many companies. The variety of sustainability standards and KPIs may also confuse companies when measuring sustainability. Moreover, the cost of sustainable inputs may affect the company's profitability, causing it to lower the priority of sustainability in its operations. Thus, these factors greatly influence the use of supply chain analytics for sustainable operations. To make the research results applicable to the different situations of most companies, I will discuss the challenges in the analyzing process, the standards used for sustainability measurement, and how data-driven approaches can balance sustainability with profitability in supply chain management.

5.1 Challenges for supply chain analytics

During the process of supply chain analytics, a company may encounter various problems and challenges. It is critical to recognize these challenges so that firms can address them promptly. According to Arunachalam, Kumar, and Kawalek (2018: 430), the challenges in data analytics can be divided into two categories, technical challenges and organizational challenges.

5.1.1 Technical challenges

The first technical challenge should be data harvest. Data is growing at an unprecedented rate, doubling every 18 months, due to broader access to customer data, new information gleaned from online communities, and newly deployed smart assets (Bughin, Chui & Manyika 2007: 7). The explosive growth of data has made it difficult for conventional systems to collect and deal with data. In addition, data has various types, such as texts, numbers, graphs, videos, audio, weblogs, and GPS location information. Hence, different technologies and devices are required to store and handle the different types of data (Tan et al. 2015: 224), which can be challenging for corporations to own various equipment. Moreover, the complexity of the supply chain can obstruct the data harvest and measurement for sustainable metrics. Lack of comprehensive expertise can be the first organizational challenge, for the fact that a predictive analytics initiative requires abilities and knowledge in various disciplines, such as data engineering, statistics, project management, business, and supply chain (Blackburn et al. 2015: 424). Hence, supply chain analytics involves specialists with different points of view on a problem. For instance, a data analyst may focus on the reduction of waste generation, while a sales manager must care about the profit. Therefore, how to bridge the gaps and achieve overall success can be complicated and challenging.

Data quality, which can be the foundation of the analytics, and determines the effectiveness of outcomes, is another technical challenge. Data quality is greatly required to guarantee meaningful analytics and further decision-making. Since data is intangible and complicated because of its implementation and diverse origins, collecting comprehensive and qualified data is difficult. Furthermore, the data might be incomplete, inaccurate, inconsistent, or unrelated, which can hinder effective analytics activities (Sekhar, Chandrashekar & Matt 2021: 23). Besides, Hazen et al. (2014: 73) classify data quality dimensions into two categories: intrinsic (objective properties inherent in the data), and contextual (depending on the context where the data is observed and used) dimensions. The measurement of contextual data highly relies on quantitative metrics such as surveys and questionnaires (Batini et al. 2009), which may vary widely due to their subjective design.

Another problem can be the insufficient data resources. The supply chain stakeholders' ability to share data in real time may vary largely due to their different technology resources and capabilities (Arunachalam, Kumar & Kawalek 2018: 430). Because of this, data-driven analysis can not effectively cover the entire supply chain network. Meanwhile, insufficient data in certain supply chain links may lead to biased analysis results.

Data scalability poses a significant challenge for supply chain analytics. As Sekhar et al. (2021: 23) explain, many systems are unable to transition effectively from traditional limited databases to more advanced distributed or cloud-based databases. This limitation can severely impact the quality and accuracy of insights derived from data analytics. Without the ability to scale, these systems may struggle to handle large volumes of data, leading to incomplete or inaccurate analyses. Furthermore, the inability to leverage distributed or cloud-based solutions can result in slower processing times and reduced overall efficiency. Consequently, organizations may find it difficult to make informed decisions based on their data, ultimately hindering their ability to optimize supply chain operations and achieve competitive advantage. Addressing this scalability issue is crucial for harnessing the full potential of supply chain analytics.

The lack of technologies and procedures is a problem to properly exploit the data deluge. In demand forecasting technology, for example, only endogenous time-series variables are focused on but lack consideration of exogenous variables and information sources (Meixell and Wu 2001). This obviously demonstrates that more advanced data management capabilities and methods for forecasting demand should be developed to enhance supply chain operations. Particularly for medium and small companies, limited access to advanced technologies can impede the analysis process.

5.1.2 Organizational challenges

Data security and privacy are crucial for all the stakeholders in the supply chain. The data privacy laws are usually strict, and generally different based on the various locations. Richey et al. (2016: 724) propose concern about it and argue that multinational data sharing, especially consumer data sharing, is hindered by antiquated regulations of privacy and data security protection, which can be one of the main obstacles in supply chain analytics.

The individualized trace data, such as real-time data, plays a significant role in data analytics. Using real-time data can generate not only opportunities but also challenges. For instance, decision-makers might overreact to normal fluctuations in real-world systems when relying heavily on real-time data. This overreaction can increase supply chain risks, such as the bullwhip effect, where small variations in demand lead to significant swings in inventory levels and order quantities as they move up the supply chain. Such reactions can also result in higher inventory costs, as companies may hold excess stock to buffer against perceived instabilities (Tachizawa, Alvarez-Gil & Montes-Sancho 2015: 239). Therefore, the behavioral issues can be an organizational challenge in data analytics. Decision-makers must balance the immediacy of real-time data with a strategic understanding of market dynamics to mitigate risks such as the bullwhip effect and increased inventory costs.

Achieving benefits from supply chain analytics is challenging, primarily because it heavily relies on the downstream employees who execute the necessary tasks (Arunachalam et al., 2017: 430). Even if managers accept the analysis results, these insights cannot be transformed into profits unless the employees responsible for the actual work agree with and implement the recommendations (Davenport et al., 2001: 132). Thus, the alignment and engagement of all personnel involved are crucial to realizing the full potential of supply chain analytics.

A survey conducted by Schoenherr and Speier-Pero (2015: 123) indicates that several potential barriers exist in the implementation of supply chain analytics. These include a lack of integration across different systems and processes, which hinders the smooth flow of information. Additionally, many organizations face challenges due to inexperienced employees who lack the skills to utilize analytical tools effectively. There is also a notable shortage of suitable predictive analysis solutions, which limits the ability to make accurate forecasts. Time constraints further complicate efforts, as organizations struggle to allocate adequate resources. Finally, change management issues, such as resistance to new technologies and processes, pose significant obstacles to successful implementation.

5.2 Standards and KPIs for sustainability

Clear and detailed standards and KPIs are necessary to measure how organizations work for sustainability and determine the contents and directions of analysis. The sustainability standards that Unilever follows include the World Economic Forum and International Business Council (WEF IBC), the Global Reporting Initiative’s (GRI) guidelines, and the Sustainability Accounting

Standards Board (SASB) (Unilever 2022). It is also critical for all companies to realize the main standards that work in different regions.

5.2.1 Sustainability reporting standards

Sustainability reports are a significant way for organizations to publicly communicate their environmental impact, practices, challenges, and opportunities with their stakeholders so that they can understand the sustainability situations and make informed decisions (brightest 2024a). According to the Survey of Sustainability Reporting 2022 by KPMG, 96% of the G250 companies have reported their sustainability performance in 2022, and the reporting rate has continued increasing during the past eight years. In the survey, the G250 refers to the largest 250 companies based on the *2021 Fortune 500* ranking in the world, and the N100 is a sample of the top 100 companies by revenue in 58 countries and jurisdictions (KPMG 2022), which stands for the dominating companies all over the world. The sustainability report has become “the fastest-growing type of non-financial reporting over the last ten years” (brightest 2024a). Unlike financial reporting, sustainability reporting has more than 600 standards, guidelines, and frameworks based on the different industries, locations, and company sizes (brightest 2024a). Here are several most widely recognized sustainability standards that should be explained in this chapter.

GRI is an institution that has developed and delivered international sustainable practices for organizations to “communicate and demonstrate accountability for their impacts on the environment, economy and people” with over 14,000 participants in more than 100 countries (GRI n.d.a). GRI Standards are a modular system that consists of three standard series: the GRI Universal Standards, the GRI Sector Standards, and the GRI Topic Standards (GRI n.d.b: 2).

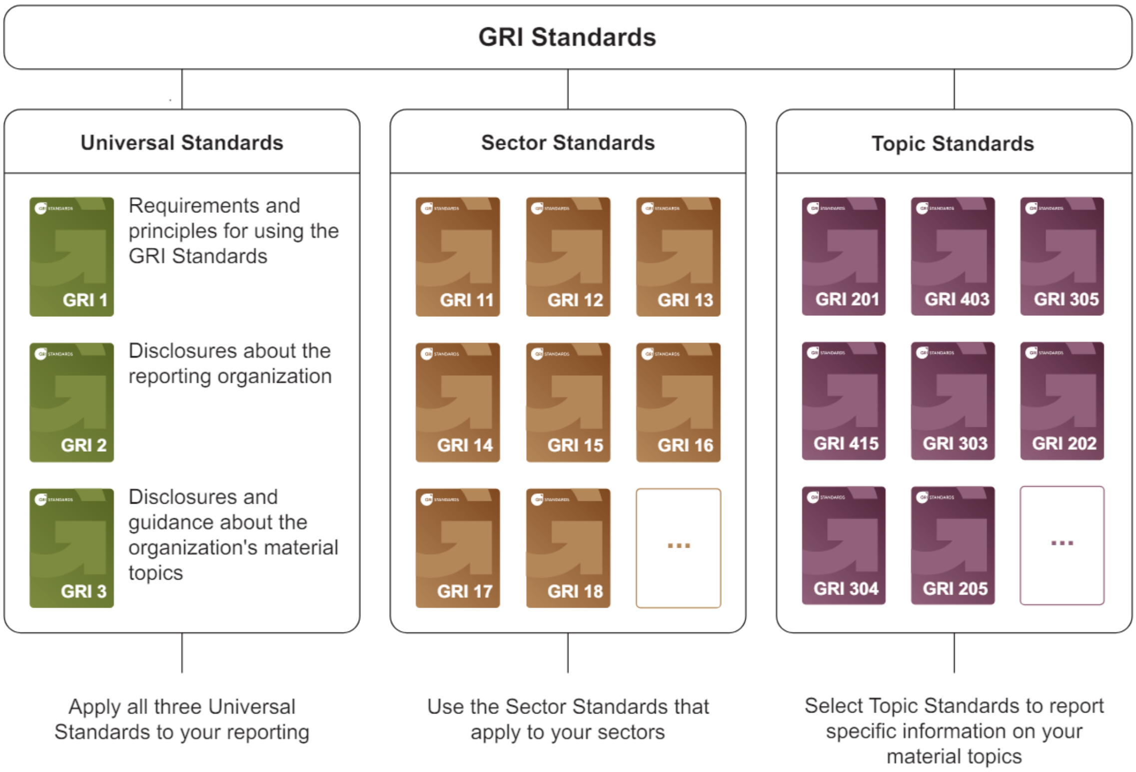

Figure 8. GRI Standards: Universal, Sector, and Topic Standards (GRI n.d.b: 3)

The introduction to GRI Standards explains the requirements (the information that an organization must report), and recommendations (the certain contexts that are encouraged to have in the report but not mandatory) for companies to report their sustainable performances. According to Figure 8, the Universal Standards which comprise Foundation 2021 or GRI 1 (purposes of GRI Standards, critical concepts and usage of the Standards), General Disclosures 2021 or GRI 2 (details on a company's structure, activities, employees, and stakeholder engagement), and Material Topics 2021 or GRI 3 (the steps of identifying the most relevant topics to an organization's impacts), are necessary to sustainability reporting (GRI n.d.b: 2). Moreover, the Sector Standards include 40 sectors, which are likely to be the industries covering most organizations, such as mining, fishing, automotive, and airlines (GSSB 2022: 3). Each sector can guide an industry's companies to determine their main contexts for sustainability reporting. Besides, the GRI Topic Standards "contain disclosures for providing information on topics", which can be tax, waste, safety, and occupational health (GRI n.d.b: 4).

The EU Corporate Sustainability Reporting Directive (CSRD), as an update of the Non-Financial Reporting Directive, amends and enhances the rules regarding environmental and social information for organizations’ reporting (European Commission 2024). The EU CSRD-based reporting is required for large European companies, some of the SMEs, as well as international companies with over 150 million euros on the EU market (European Commission 2024). These corporations have to report following the European Sustainability Reporting Standards (ESRS), which comprehensively cover the environmental, governance, and social impacts, such as climate change, biodiversity, and human rights (European Commission 2023).

To comply with EU CSRD, companies should follow the specific framework of ESRS and take the following actions since 2024 (brightest 2024b):

1. The large EU organizations must prepare and submit ESRS reports in early 2025 based on their sustainable performance in 2024. The SMEs and international companies need to execute it in the later years.

2. Track and publish all the sustainability-related information on the impacts, opportunities, and risks as per applicable ESRS, such as sustainable strategy and governance, materiality evaluation process, ESG performance implementing measures, and metrics.

3. In a company’s financial and management statements, the sustainability context must be tagged following the digital taxonomy specified in the ESRE regulations.

4. The ESRS sustainability reports are required to be assured by a neutral, credible, and experienced third party who will review the data.

The EU CSRD is designed to make organizations' sustainability reporting more standardized and common like financial reporting (brightest 2024b).

The two IFRS (International Financial Reporting Standards) Sustainability Disclosure Standards are also widely used standards. They were issued by the International Sustainability Standards Board (ISSB) in June 2023, which include IFRS S1 General Requirements for Disclosure of Sustainability-related Financial Information and IFRS S2 Climate-related Disclosures (IFRS n.d.).

IFRS S1 requires a company to disclose all the information regarding risks and opportunities in the sustainability field, which can impact the company's cash flow and its access to financing or capital costs so that the report users can make reasonable decisions when they provide resources to the company (IFRS 2023a). Thus, IFRS S1 stipulates how companies should report their sustainability-related financial disclosures, which comprise the sustainability strategy, governance process, implementation steps, and performance of sustainability-related situations (IFRS 2023a). Moreover, IFRS S2 enumerates the requirements for enterprises to reveal their climate-related opportunities, as well as physical and transition risks, which affect their financial reporting (IFRS 2023b). Like IFRS S1, the structure of IFRS S2 also involves four key sections: governance, strategy for risks and opportunities, detailed process, and metrics and targets (Chan 2023). Hence, IFRS S2 can guide entities to use climate-related scenario analysis to identify climate-related risks and opportunities, as well as help them reduce GHG emissions (Chan 2023).

5.2.2 Sustainability KPIs

Incorporating sustainability KPIs into supply chain analysis can not only help companies improve environmental performance, but also gain competitive advantage, reduce costs, and ensure regulatory compliance while building a positive reputation among stakeholders. In the Unilever case, the used KPIs include the three scope emissions, energy consumption, supplier count, and waste generation. In this section, some main sustainability KPIs will be discussed.

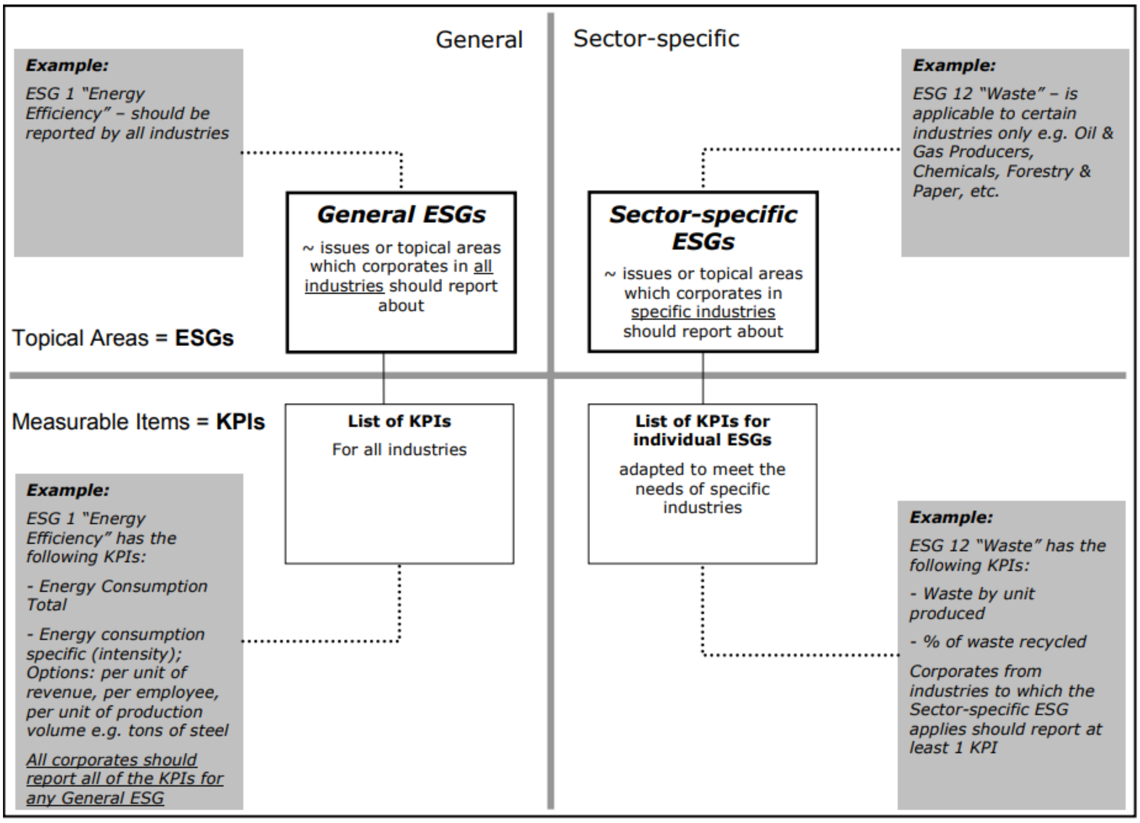

Figure 9. How ESG and KPIs related (EFFAS 2009: 17)

DVFA, the organization of all the German investment experts, identifies 9 General ESGs and respective KPIs that should be used by companies in all industries, and be reported on those that represent "the generally binding minimum requirements" (EFFAS 2009: 16). On the other hand, DVFA also stipulates sector-specific ESGs and KPIs for some specific industries (EFFAS 2009: 17), so that the sustainability reporting can be more reasonable and comprehensive. Generally, the sustainability KPIs for supply chain operations can be divided into three groups based on the ESG standards: environmental, social, and governance KPIs.

The environment in ESG standards represents the maintenance of the renewability of natural resources and the long-term maintenance of the basic functions of the environment; therefore, it covers the fundamental role of natural resources, their application, as well as reduction of material degradation of non-renewable materials (Hristov and Chirico 2019: 7).

Carbon footprint, for example, might be the most common metric for a firm to measure its sustainability performance. It indicates the GHG emissions produced by the company’s supply chain activities, usually expressed in carbon dioxide equivalent. Energy consumption is another common KPI, which tracks the amount of energy use (including fuel and electricity) in transportation, production, warehousing, and so on. Managing energy usage can help corporations reduce pollution and improve efficiency (The Impact Investor 2024). Furthermore, waste generation is a crucial KPI that monitors the waste produced throughout the supply chain, such as liquid, hazardous, and solid waste. It displays “the effectiveness of waste reduction, reuse, and recycling policies” (The Impact Investor 2024). Moreover, sustainable materials can be an increasingly popular environmental KPI in the supply chain, which evaluates the percentage of raw materials that are eco-friendly, reusable, or can be recycled. It encourages companies to enhance the circular economy.

Another sustainability dimension in ESG theory is social performance, which displays “the capacity of providing for citizens’ welfare with equal distribution among different classes” (Hristov and Chirico 2019: 7). In the view of Guerci et al. (2015: 330), stakeholders are the core of social KPIs. Diversity and inclusion metrics represent the percentage of different demographic groups within a corporation’s workforce and management, involving age, gender, and ethnicity (The Impact Investor 2024). This KPI can enhance companies’ creativity and attract diverse talent. Moreover, staff turnover rate is a meaningful KPI that calculates the percentage of employees who leave the corporation during a certain time due to retirement, resignation, etc. (ESGVoices 2024). The turnover rate can be calculated as (number of leavers/ total staff) x 100. A relatively low employee turnover rate reflects a stable workforce, which results in “better knowledge retention, improved morale, and potentially higher productivity” (ESGVoices 2024). In addition, customers’ satisfaction with sustainability is an important metric that measures how customers perceive organizations’ work on sustainability and how these views impact on their satisfaction and loyalty (DigitalDefynd 2024). The information can be collected through social media, questionnaires, and feedback channels. For instance, a cosmetics company that opposes animal testing and uses eco-friendly ingredients can increase satisfaction and loyalty among sustainability-conscious customers (DigitalDefynd 2024).

Governance KPIs in the ESG framework are crucial for evaluating management practices, ethical standards, transparent reporting, and compliance situations. These indicators help ensure a company's transparent and accountable management, aligning with both regulatory requirements and stakeholders' expectations. Board composition and independence are significant metrics that indicate the management of a company. Board composition, which measures the diversity of the board in a firm regarding gender, race, and expertise, indicates whether the company can implement a wide range of perspectives in the decision-making process (The Impact Investor 2024). On the other hand, board independence tracks the percentage of board members without affiliations or interests in the company (The Impact Investor 2024), which can reduce conflicts of interest and enhance objectivity. Besides, pay equity is considered a common governance KPI, which calculates the salary gap between different groups, such as the highest-paid and lowest-paid employees, men and women on average (EcoCart 2024). Monitoring pay equity contributes to employees' fair compensation regardless of ethnicity, gender, or other personal characteristics. It also improves a company's reputation and ensures compliance with legal requirements. Another key metric of governance should be ethics violations or complaints. According to ESGVoices (2023), this KPI is expressed as "the number of reported incidents related to ethical misconduct or breaches of the code of conduct". Tracking ethics violations or complaints helps ensure that organizations maintain high ethical standards and address any unethical behavior promptly so that organizations can safeguard their values and foster a culture of integrity (ESGVoices 2023).

5.3 Balance between profitability and sustainability

As the world's demand for sustainability significantly strengthens, companies are no longer simply looking to make profits but are integrating sustainability into their development goals. The perfect situation is that organizations can simultaneously achieve business and sustainability goals. However, while reducing waste and pollution is consistent with traditional operation management, not all sustainable practices save costs, and some can even increase costs, especially in the short term (Wu and Pagell 2010: 578). Thus, it is critical to consider the balance between profitability and sustainability when implementing supply chain analytics to achieve sustainable operations.

Matos and Hall argue that, when dealing with sustainable development, some complexity can be expected, as it involves several interacting parameters (i.e. economic, environmental, and social) (2007: 1804). In Walley and Whitehead’s opinion, when companies look beyond the “low-hanging fruit” such as minimizing energy consumption and waste, and move to explore deeper issues like business models and supply chain design, they will realize that advancing their environmental initiatives will necessitate substantial investment, drastic alterations in operational procedures, and a complete overhaul of their current supply chains (1994: 48).

Therefore, balancing profits and sustainability is a key challenge faced by modern business, which includes integrating economic, environmental, and social factors into corporate strategy. The objective is to achieve long-term financial success while minimizing negative impacts in the dynamic, complicated, and uncertain setting.

5.3.1 Strategies for sustainability and profitability

Kohtomäki et al. (2023: 3) illustrate that a company’s strategy on sustainability indicates a nonlinear negative correlation with its profitability.

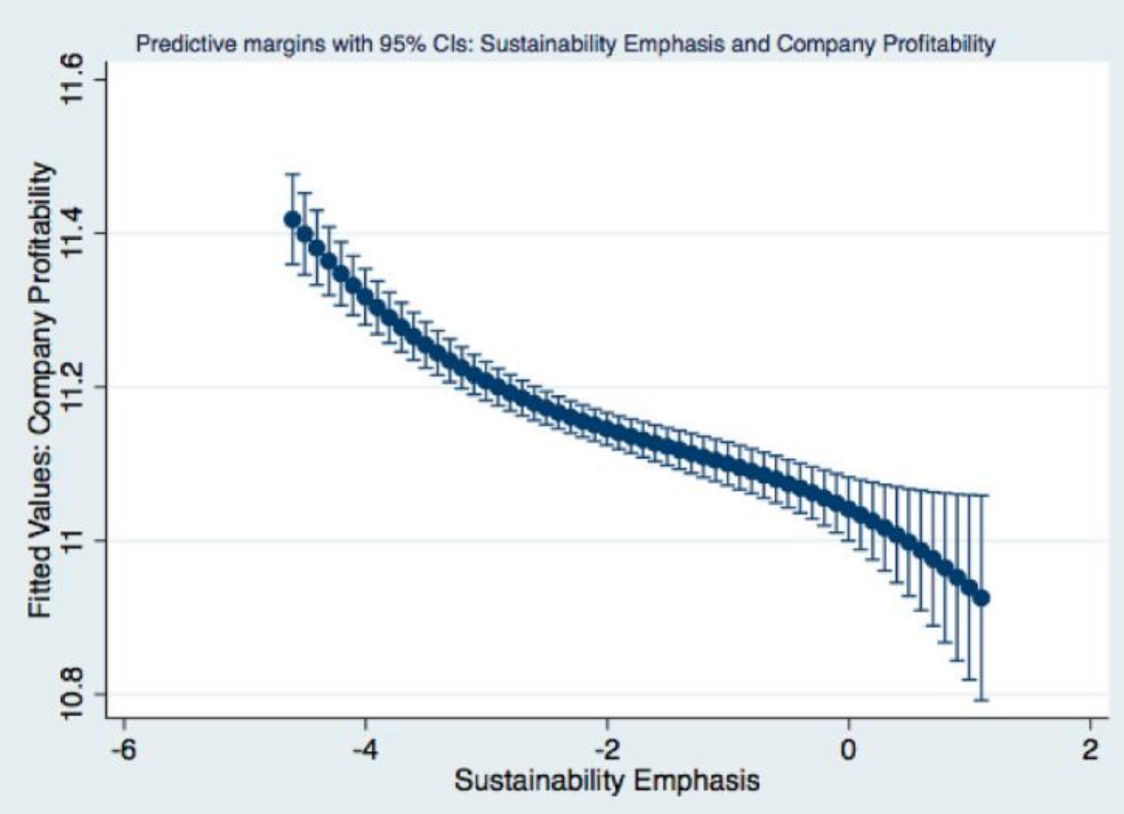

Figure 10. Nonlinear impact of sustainability emphasis on profitability (Kohtamäki 2023: 7)

This nonlinear relationship between sustainability and profitability can be inspected across three levels, which include low to low-moderate, low-moderate to moderate-high, and moderate-high to high levels, referring to "the degree of sustainability emphasis and servitization" (Kohtomäki et al. 2023: 3).

Companies usually start their sustainable development efforts with the most achievable and profitable strategies. This initial phrase is recognized as the lower level of sustainable efforts and servitization. Under the condition of low to low-moderate level, the increased sustainability achievement should be proportional to the company's profit (Kohtomäki et al. 2023: 3). At this stage, companies incorporate basic sustainability development strategies into their services, focusing on complying with environmental regulations and making appropriate improvements to existing products and services. Here are some examples of sustainability practices at this level.

- Eco-friendly packaging: Use reusable and degradable packaging materials to reduce packaging costs and waste.
- Energy efficiency: Develop production methods that consume less energy, so that companies can save energy costs and reduce carbon footprint.
- Recycling products: Implement take-back and recycling programs for products at the end of their life cycle.

These actions promote companies' sustainable performance and decrease their costs. At this level, firms can achieve a win-win situation of sustainability and profitability.

In the low-moderate to moderate-high level, companies integrate more advanced sustainability strategies into their decision-making process and align their business models with sustainable practices more comprehensively. Kohtomäki et al. demonstrate that "the profitability starts to decline when sustainable servitization reaches a moderate to high level" because the advanced sustainable practices require significant investment which greatly increases the cost (2023: 4). This situation puts the company in a dilemma that sustainability is inversely proportional to profitability. Thus, more developed services and business models are needed to resolve this dilemma, so that companies can generate revenue while investing in sustainable capabilities.

- Life cycle analysis: Manage the entire lifecycle of a product, from design, resource, production, and use, to disposal. Identify opportunities to reduce environmental impact and improve efficiency.
- Product-service system (PSS): Integrate "products and services in one scope for planning, development and delivery" (Sakao and Lindahl 2009: 4). Instead of selling products and services separately, companies sell determined results, system usability, or functionality to add value (Sakao and Lindahl 2009: 5). It involves maintenance and upgrade services to extend product life.
- Eco-design: "Considers environmental aspects in design and development intending to reduce adverse environmental impacts throughout the life cycle of a product" (ISO 2020). It requires a company to take a broader view of its environmental impact across the entire supply chain and make the "eco-design of products as a normative element of the environmental management systems" (Lewandowska and Matuszak-Flejszman 2014).

During this stage, companies will experience the most challenging situations. The profitability begins to decline because of the increasing investment. Therefore, strategic decision making is crucial to promote sustainable servitization and capabilities (Kohtomäki et al. 2023: 4). The strategies like life cycle management and eco-design require investment in new technology, production, and expertise, so companies have to improve their business model and management for adopting new strategies.

Companies fully integrate sustainability into their core business strategies and service offerings at the moderate-high to high stage. The profitability may highly increase when sustainability reaches moderate-high to a high level (Kohtomäki et al. 2023: 4). These strategies usually contain systemic changes and innovations that create huge environmental, social, and economic benefits.

- Circular economy: Develop and implement the circular economy model that products are designed for reuse, remanufacturing, and recycling, which builds a closed-loop supply chain during the process of material, manufacturing, distribution, using, recycling, and back to manufacturing.
- Digital twin technology: "A contextualized software model of a real-world object...[which] means that the behavior of the physical object can be replicated in software" (Crespi, Drobot & Minerva 2023: 4). Digital twin enables real-time monitoring and predictive maintenance, reducing downtime and resource use (Tao et al. 2019: 2409).
- Green Financing Service: The green finance programs (such as green loans and eco-investment advisory services) generally include more affordable terms for climate purposes, which enhance banks' capacity and increase investments in sustainable technologies and practices (Park and Kim 2020: 21).

These strategies reflect high integration of sustainability into business models and service offerings, which require innovation and substantial commitment for the entire supply chain to achieve significant success in both sustainability and profitability.

5.3.2 Stakeholder engagement

Balancing sustainability and profitability is not only a company's issue but also the stakeholders' responsibility, because stakeholders influence and are impacted by a company's financial and sustainable performance. The main stakeholders should include internal stakeholders such as executives and employees, as well as external stakeholders like suppliers and customers. In the Unilever case, the external stakeholders play a crucial role in reducing Scope 3 emissions.

A six-step process for stakeholder engagement created by Bal et al. offers a comprehensive method for firms to develop sustainability with their stakeholders (2013: 703).

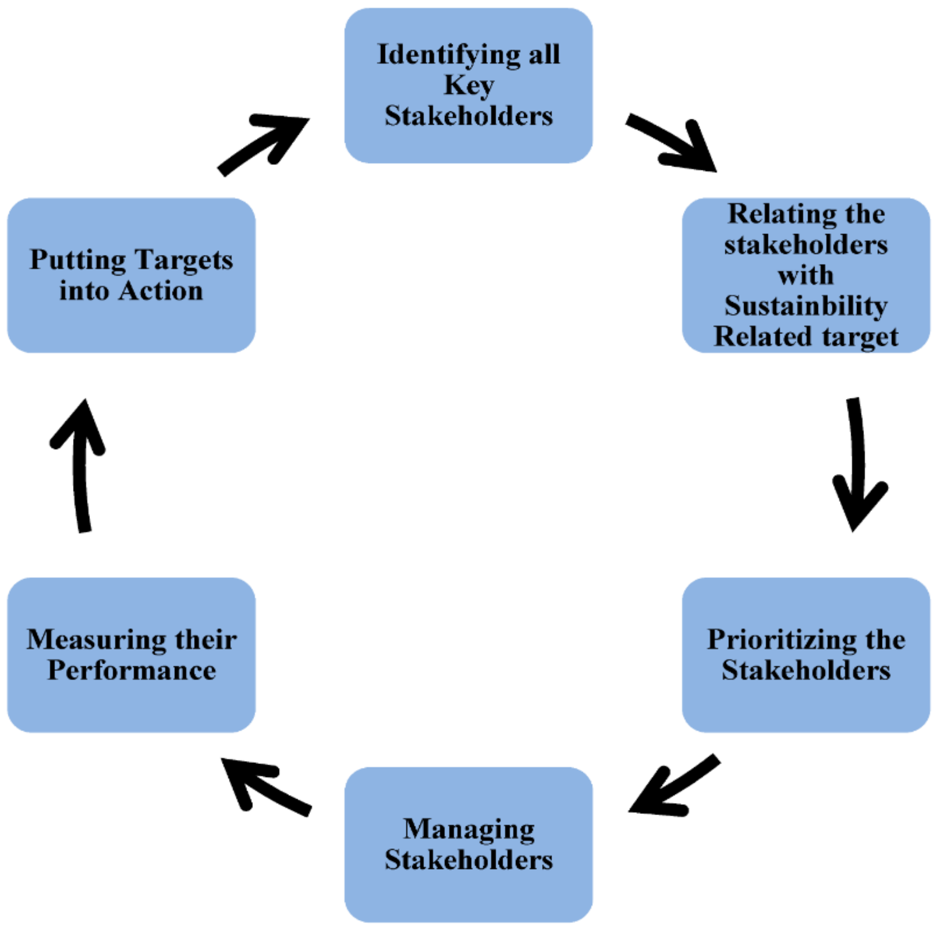

Figure 11. Stakeholder engagement process for sustainability (Bal et al. 2013: 703)

The first step is to identify the key stakeholders. A company may have numerous stakeholders in its supply chain, but only limited ones are highly relevant to sustainability (Bal et al. 2013: 704). For instance, the key suppliers who provide the largest number of materials and the regulatory agencies which enforce environmental laws, are especially important. Thus, recognizing these main stakeholders is crucial as it forms the foundation for the entire process.

The second stage is to connect the key stakeholders with different sustainability-related goals. Since different stakeholders are responsible for different work, they should be linked to corresponding sustainability indicators. Freight forwarders, for example, can be related to carbon emissions and energy consumption. Moreover, the various capabilities and expertise of stakeholders will contribute to different fields of sustainable outcomes (Bal et al. 2013: 704). Therefore, the stakeholders should have their specific roles to promote the company's sustainability situations.

The next step is to prioritize these stakeholders based on their intensity of interests, knowledge, integrity, ability, and potential impact on sustainability success (Bal et al. 2013: 704). It might be difficult to pay equal attention to all the key stakeholders, and sometimes the needs of one stakeholder need to be sacrificed to meet the needs of another, so they should be prioritized according to their sustainability-related issues and relevant characteristics (Bal et al. 2013: 704). As a result, a company can implement the stakeholder engagement strategy more effectively.

The fourth stage is to manage the stakeholders, such as offering regular training and workshops for them to optimize their actions and habits to achieve a more sustainable future (Bal et al. 2013: 705). It is particularly important for external stakeholders who are outside the company's strategy because this step can assist stakeholders like suppliers and customers to enhance sustainable awareness and improve related behaviors. During this stage, efficient and deep communication between the firm and its stakeholders, so that they can achieve common goals and work together toward them.

The fifth step is to measure the stakeholders' performance. Measurements need to be established to encourage continuous improvement of efficiency, performance quality, and potential opportunities for promoting performance (Wegelius-Lehtonen 2001: 108). Measuring each key stakeholder's performance with clear and detailed KPIs is obviously necessary to determine how well he or she achieves the sustainability objectives. In this stage, both quantitative (data analysis) and qualitative (customer surveys) methods should be used to comprehensively understand the stakeholders' situations.

The final step is to put pargets into action. After the measurement, plans should be modified and optimized to ensure the continued achievement of sustainable development-related goals (Bal et al. 2013: 705). In the opinion of Ayuso et al., systematic planning of stakeholder engagement is an effective mechanism to focus on the innovation orientation of enterprises in the context of sustainable development (2011: 1400). Thus, all the well-adjusted plans need to be put into action to bring meaningful and valuable results. The new results should be measured for the next circle process so that the company can continue improving the stakeholder engagement strategy for the common sustainability objectives.

6 Conclusion

This thesis has explored the important role of supply chain analytics in improving sustainability. Through understanding the procedure of supply chain analytics and a practical application case of Unilever, the study demonstrates how data-driven insights can address various sustainability challenges and promote sustainability development. The results highlight the wide possibility of analytics in optimizing overall environmental and social impacts. Furthermore, the technical and organizational challenges of adopting supply chain analytics for sustainability reveal various obstacles. By identifying the challenges, this thesis provides a foundation for developing strategies to overcome them. In addition, the study has outlined the importance of several widely recognized sustainability standards and KPIs, which offer specific metrics for analytics and reporting. Hence, this thesis builds a practical framework for companies to modify and optimize their sustainability efforts. These metrics are critical for setting benchmarks and making informed decisions in line with the sustainability objectives. Moreover, the study has introduced and explained the difficulties and opportunities of balancing profitability and sustainability through their nonlinear relationship, which offers companies a guide to adopt appropriate strategies in different stages of sustainability. This thesis also provides a six-step method to engage stakeholders in achieving profitability and sustainability goals collectively.

For further research, the study of supply chain analytics can be connected to more advanced technologies, such as big data analysis, the Internet of Things, and cloud services, so that supply chain analytics can achieve more powerful functions and contribute more to sustainable operations. Besides, the tactics for overcoming the challenges and barriers of supply chain analytics can be deeply studied, which will enhance the analytics ability, and significantly promote a company’s sustainability performance.

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Appendices

Scope 1 and 2 GHG emissions of Unilever operations in 2018-2022 (a)

CLIMATE ACTION	**2022**	**2021**
Scope 1 and 2: Unilever operations [a] **Includes: Unilever's own manufacturing facilities, offices, warehouses and labs**		
GHG emissions: Unilever operations		
Scope 1 GHG emissions (tonnes CO_2)[a]	**503 909**	**565 988**
Renewable energy	0	0
Non-renewable energy	482 599	542 620
Refrigerants	21 310	23 368
Scope 2 GHG emissions (tonnes CO_2)[a]	**117 773**	**144 752**
Purchased renewable electricity	0	0
Purchased non-renewable electricity	25 699	57 033
Purchased renewable thermal energy	0	0
Purchased non-renewable thermal energy	91 807	87 719
Total Scope 1 and 2 GHG emissions (tonnes CO_2)	**621 682**	**710 740**
Reduction in Scope 1 and 2 GHG emissions from energy and refrigerant use in our operations since 2015 (%)	-68%	-64 %
GHG emissions: Unilever manufacturing only		
Manufacturing Scope 1 and 2 CO_2 emissions from energy use (market-based, tonnes CO_2)	557 826	651 491
Manufacturing Scope 1 and 2 CO_2 emissions from energy use (market-based, kg CO_2/tonne of production)	30,35	34,06
Manufacturing Scope 1 and 2 CO_2 emissions from energy use (location-based, tonnes CO_2)	1,562,623[b]	1 620 007

Scope 1 and 2 GHG emissions of Unilever operations in 2018-2022 (b)

CLIMATE ACTION	2020	2019	2018
Scope 1 and 2: Unilever operations [a] Includes: Unilever's own manufacturing facilities, offices, warehouses and labs			
GHG emissions: Unilever operations			
Scope 1 GHG emissions (tonnes CO_2)[a]	**606 771**	**659 028**	**758 232**
Renewable energy	0	0	-
Non-renewable energy	592 342	632 560	-
Refrigerants	14 429	26 468	-
Scope 2 GHG emissions (tonnes CO_2)[a]	**216 740**	**469 063**	**893 825**
Purchased renewable electricity	0	0	-
Purchased non-renewable electricity	128 442	382 057	-
Purchased renewable thermal energy	0	0	-
Purchased non-renewable thermal energy	88 298	87 006	-
Total Scope 1 and 2 GHG emissions (tonnes CO_2)	**823 511**	**1 128 091**	**1 652 057**
Reduction in Scope 1 and 2 GHG emissions from energy and refrigerant use in our operations since 2015 (%)	-58 %	-42 %	-
GHG emissions: Unilever manufacturing only			
Manufacturing Scope 1 and 2 CO_2 emissions from energy use (market-based, tonnes CO_2)	756,085[a]	1 154 104	1 438 042
Manufacturing Scope 1 and 2 CO_2 emissions from energy use (market-based, kg CO_2/tonne of production)	38.93[a]	60,42	70,46
Manufacturing Scope 1 and 2 CO_2 emissions from energy use (location-based, tonnes CO_2)	1,658,444[a]	1 725 282	1 964 505

Unilever full value chain GHG emissions 2020-2022

Scope 1, 2 and 3: Full value chain GHG emissions[g]	2022	2021	2020
Extrapolated Scope 3 GHG emissions (million tonnes CO_2e) [h]	**33,69**	**33,03**	**34,85**
Raw materials and ingredients	20,16	19,35	19,32
Packaging materials	4,54	4,60	4,53
Downstream transport and distribution	1,00	1,02	2,78
Retail ice cream freezers	3,55	3,75	4,01
Direct consumer use (HFC propellants)	0,82	0,71	0,77
Product end of life	3,62	3,60	3,44
Scope 1 and 2 GHG emissions: Unilever operations (million tonnes CO_2e)	**0,62**	**0,71**	**0,82**
Scope 1, 2 and 3 emissions in scope of net zero target (million t	**34,31**	**33,74**	**35,67**
Scope 3 - Indirect consumer use emissions	57,54	64,87	65,76
Total Scope 1, 2 and 3 GHG emissions (million tonnes CO_2e)	**91,85**	**98,61**	**101,43**