Greening Airlines Through IT

A Decision Support Framework for Implementing Greening by IT in Airlines: A Case Study at KLM

Management of Technology Master Thesis

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AIRFRANCE KLM GROUP

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A Decision Support Framework for Implementing Greening by IT in Airlines: A Case Study at KLM

by

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Executive Summary

As the aviation industry faces mounting pressure to mitigate its environmental impact and with zero-emissions aircraft still likely years away, it is crucial that airlines find intermediary steps to make progress in the meantime. An opportunity with massive potential is for airlines to leverage IT technologies to reduce their footprint, otherwise known as Greening by IT. Through applications such as better flight planning algorithms which could reduce 0.5-1% of annual emissions or better data oversight to more easily identify polluting elements of the operation, the ways in which Greening by IT can help airlines is numerous. Despite its promise and several demonstrated examples in the industry, airlines still seem to lag in fully implementing Greening by IT solutions and realizing its full potential. A good example of this is within KLM Dutch Royal Airlines, where most efforts to improve sustainability within IT have been put into *Green IT*, which consists of measures to make IT itself more sustainable. While many of these efforts are admirable, one should question why so much effort is put into reducing IT's contribution to the total footprint, which makes up less than 1% of total emissions from KLM. When one looks closer, it is easy to see that implementing Greening by IT is more complicated, as coordination with stakeholders outside of IT is needed and the impacts of changes you make are less clear.

If navigating tight resource constraints, balancing many other high priority needs, and complying with aviation's many regulations wasn't enough, the research on how to best implement Greening by IT is scattered and lacks concrete answers. There is a lack of an understanding in which factors influence implementation the most, which strategies can be used, and a lack of a widely-accepted adoption model which could be used by practitioners and researchers alike. Beyond this, there is a complete absence of prior research on Greening by IT's application within airlines, nor any unique aspects which must be considered.

As a result, the purpose of this study was to explore the key factors impacting Greening by IT implementation, the strategies to guide it, and to integrate these together into a decision support framework. This framework is designed to be used primarily by IT practitioners within airlines to understand the implementation process, select the barriers which impact them the most, and choose strategies which can be used to help overcome them. In order to design a framework that is relevant in practice and to understand the complex phenomena involved with Greening by IT in practice, the study was carried out together with KLM's CIO Office. Conducting this study with KLM enabled access to important documentation and stakeholders within the company. More specifically, the use-case within KLM Information Services was defined as Data & Technology platform, which combines business and IT elements to provide IT services for several KLM-specific business streams. Three qualitative research methods were used, consisting of a literature study, desk research of KLM documents, and stakeholder interviews. The research process was broken down into five sub-questions which were used to guide the research.

First, it was necessary to develop a conceptual model to aid in understanding the Greening by IT implementation process and serve as a basis for constructing the decision support framework. For this, the *Green IT* adoption model developed Bose and Luo (2011) was adapted for Greening by IT. It uses the Technological-Organizational-Environmental (TOE) framework to group the influencing factors and features three adoption phases from Innovation Diffusion theory. Next, a literature study was conducted to fully define Greening by IT and its scope for airline sustainability. A desk research was then performed on KLM sustainability documents, analyzing the Climate Action Plan and IT-specific sustainability intranet pages. This was done to comprehend airlines' sustainability challenges and the objectives they have set to tackle them. Combining these results with the results of informal discussions around the company on Greening by IT, a list of example Greening by IT applications for airlines was constructed. These examples are then used to facilitate the stakeholder interviews. The third sub-question set out to identify the barriers and enablers which impact Greening by IT implementation. Previously conducted literature was used in order to compile a list of factors and group them according to the TOE framework. These factors were then used during the eight stakeholder interviews where the participants were asked to rank them. Based on these rankings, a semi-quantitative analysis was performed to provide an overall scoring of all the factors and then compare the answers between participants. The top five barriers and enablers can be seen below:

Most Impactful Barriers

- Lack of resources
- Unclear business value
- Not considered a priority
- Cost of solutions too high
- Lack of metrics to measure impact

Most Impactful Enablers

- Org. has sustainability strategy
- Able to measure impact
- IT strategy embedded in business strategy
- Defined Greening by IT strategy in IT
- Accessible impact data

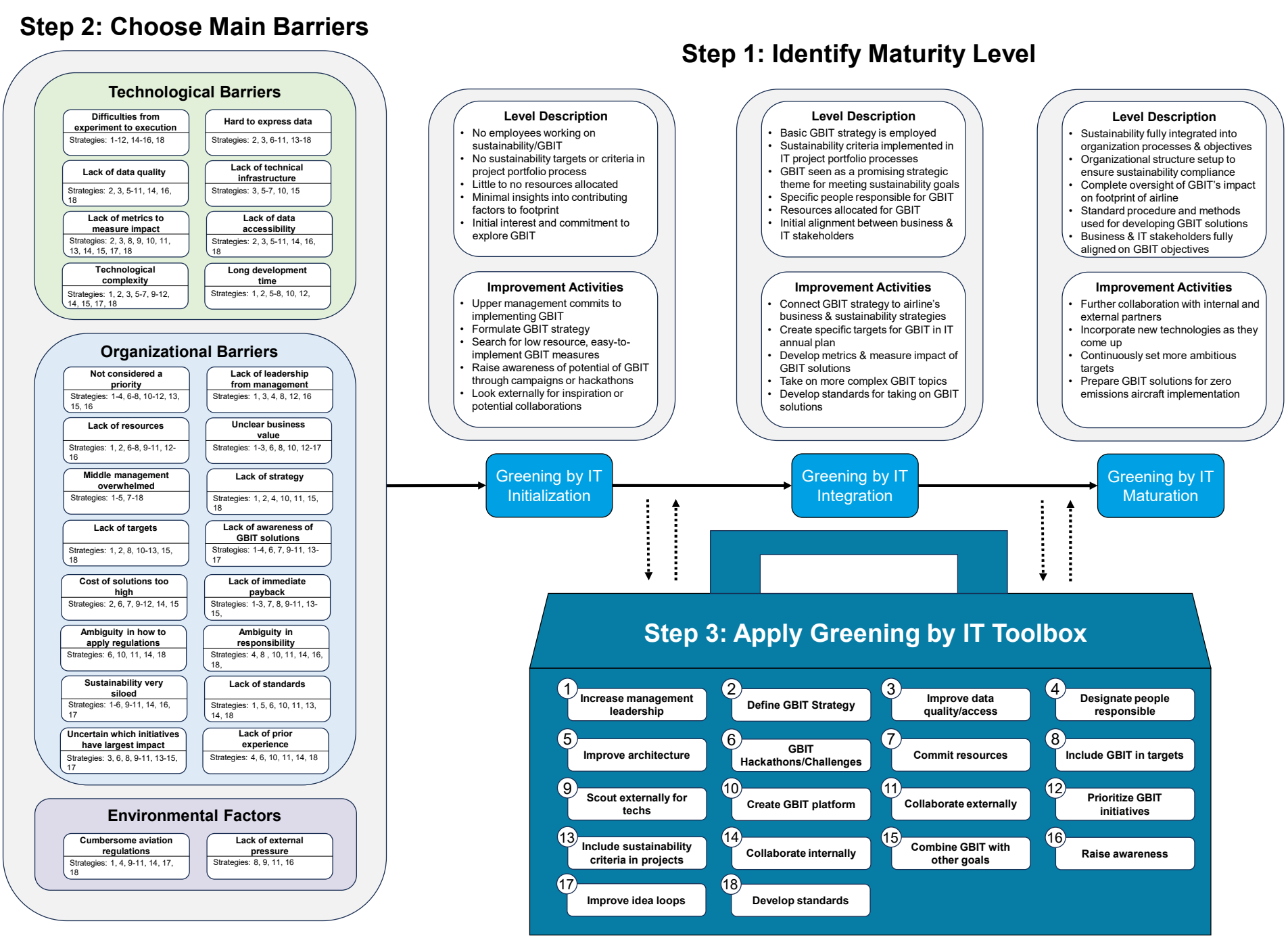
Differences were also observed in the answers between the four interview participants from the strategic management layer and the four from the operational management layer. Strategic management ranked having a specific Greening by IT strategy while operational management favored having a more global sustainability strategy within the organization. Operational management ranked the obstacles stemming from issues above them higher and strategic management did the opposite, looking below them. Next, a coding analysis was performed to analyze the factors which the participants noted were missing, which led to the addition of 11 barriers and 2 enablers. The most notable additions to the barriers were difficulties from experiment to execution, hard to express data, lack of data quality, and operational management being overwhelmed. Hard to express data refers to inconsistent variables being used to express the impact of sustainability initiatives, such as liters of fuel saved, euros, or kg of CO_2. Operational management being overwhelmed highlights how burdened the operational management layer already is with solving issues related to the operations and that they don't have time for implementing sustainability measures.

Also evaluated in the stakeholder interviews were the strategies which could be used to implement Greening by IT. Participants were asked to base these on the enablers with the purpose of lowering the barriers. A wide variety of strategies were suggested, ranging from having a dedicated Greening by IT lab to combining it with other business goals. Through the interview discussions and analysis performed afterwards, each of these strategies were mapped to all of the barriers compiled in the previous analysis. This study also looked into the strategies which could be applied in the short-term and those which could be for the long-term. The short-term strategies included setting up Greening by IT hackathons, combining Greening by IT with other goals, and scouting externally for solutions. Long-term strategies focused on improving data quality/access, modernizing architecture, and designating people or a team responsible for Greening by IT.

These strategies were then integrated with the barriers into the conceptual model devised at the start of the study to create the decision support framework for Greening by IT implementation. Using additional results from the interviews, the three implementation phases in the conceptual model were expanded to include a description of the phase and the suggested activities to mature to the next phase. Using the framework consists of three steps for practitioners, starting first with reviewing the implementation phases and identifying their maturity level. Next, they can evaluate the list of barriers to select those most impactful for them. Each barrier features a list of potential strategies which can be employed to overcome it. These 18 strategies can be found in the decision support framework in the "Greening by IT toolbox."

Overall, this study made steps in both the academic and practical understanding of Greening by IT implementation. From a societal point of view, the decision support framework can be applied by IT practitioners to identify the barriers most relevant to them and select strategies which can be used to overcome them. Illustrating all of the researched barriers and their connections to strategies makes this decision support framework useful for a wide variety of IT stakeholders, whether they be a C-level decision-maker or a project manager on the operational level. It does not recommend a single set of measures to be blindly followed, but puts the power into the hands of practitioners themselves to find the solutions most applicable to their situation. The application of this framework can be used to implement Greening by IT further within airlines and aid in driving aviation's sustainable transition even further.

In an academic sense, this framework can serve as a foundation to conduct future research into Greening by IT within the airline industry. The primary knowledge gaps observed in the literature study of this research were there being a lack of an adoption model, concrete strategies, and research in the implementation of Greening by IT in the airline context. This research directly fulfills these gaps by providing a decision support framework to understand implementation, specific strategies which can be used, and an evaluation of its applicability for airlines. Future research could investigate the use of the decision support framework in practice and evaluate the effectiveness of the recommended strategies. It is suggested to research the reproducibility of the results and application the framework within other airlines, varied by region, age, and business model. Furthermore, the framework could be applied to other industries to observe its applicability or if adjustments are needed. Although limited by the process used to compile the factors, use of literature from *Green IT*, and findings from other industries, the findings were strengthened based on the validation process with both KLM and TU Delft supervisors. Despite the massive obstacles that were noted within KLM while carrying out this thesis, it is hoped that this study can contribute to KLM's sustainable transition and integrate Greening by IT as a core means to do so. The decision support framework for Greening by IT implementation can be found on the next page and a guide with further steps is included in Chapter 8.


Step 2: Choose Main Barriers
Technological Barriers
Difficulties from experiment to execution
Strategies: 1-12, 14-16, 18
Hard to express data
Strategies: 2, 3, 6-11, 13-18
Lack of data quality
Strategies: 2, 3, 5-11, 14, 16, 18
Lack of technical infrastructure
Strategies: 3, 5-7, 10, 15
Lack of metrics to measure impact
Strategies: 2, 3, 8, 9, 10, 11, 13, 14, 15, 17, 18
Lack of data accessibility
Strategies: 2, 3, 5-11, 14, 16, 18
Technological complexity
Strategies: 1, 2, 3, 5-7, 9-12, 14, 15, 17, 18
Long development time
Strategies: 1, 2, 5-8, 10, 12,
Organizational Barriers
Not considered a priority
Strategies: 1-4, 6-8, 10-12, 13, 15, 16
Lack of leadership from management
Strategies: 1, 3, 4, 8, 12, 16
Lack of resources
Strategies: 1, 2, 6-8, 9-11, 12-16
Unclear business value
Strategies: 1-3, 6, 8, 10, 12-17
Middle management overwhelmed
Strategies: 1-5, 7-18
Lack of strategy
Strategies: 1, 2, 4, 10, 11, 15, 18
Lack of targets
Strategies: 1, 2, 8, 10-13, 15, 18
Lack of awareness of GBIT solutions
Strategies: 1-4, 6, 7, 9-11, 13-17
Cost of solutions too high
Strategies: 2, 6, 7, 9-12, 14, 15
Lack of immediate payback
Strategies: 1-3, 7, 8, 9-11, 13-15,
Ambiguity in how to apply regulations
Strategies: 6, 10, 11, 14, 18
Ambiguity in responsibility
Strategies: 4, 8 , 10, 11, 14, 16, 18,
Sustainability very siloed
Strategies: 1-6, 9-11, 14, 16, 17
Lack of standards
Strategies: 1, 5, 6, 10, 11, 13, 14, 18
Uncertain which initiatives have largest impact
Strategies: 3, 6, 8, 9-11, 13-15, 17
Lack of prior experience
Strategies: 4, 6, 10, 11, 14, 18
Environmental Factors
Cumbersome aviation regulations
Strategies: 1, 4, 9-11, 14, 17, 18
Lack of external pressure
Strategies: 8, 9, 11, 16
Step 1: Identify Maturity Level
Level Description
No employees working on sustainability/GBIT
No sustainability targets or criteria in project portfolio process
Little to no resources allocated
Minimal insights into contributing factors to footprint
Initial interest and commitment to explore GBIT
Improvement Activities
Upper management commits to implementing GBIT
Formulate GBIT strategy
Search for low resource, easy-to-implement GBIT measures
Raise awareness of potential of GBIT through campaigns or hackathons
Look externally for inspiration or potential collaborations
Level Description
Basic GBIT strategy is employed
Sustainability criteria implemented in IT project portfolio processes
GBIT seen as a promising strategic theme for meeting sustainability goals
Specific people responsible for GBIT
Resources allocated for GBIT
Initial alignment between business & IT stakeholders
Improvement Activities
Connect GBIT strategy to airline's business & sustainability strategies
Create specific targets for GBIT in IT annual plan
Develop metrics & measure impact of GBIT solutions
Take on more complex GBIT topics
Develop standards for taking on GBIT solutions
Level Description
Sustainability fully integrated into organization processes & objectives
Organizational structure setup to ensure sustainability compliance
Complete oversight of GBIT's impact on footprint of airline
Standard procedure and methods used for developing GBIT solutions
Business & IT stakeholders fully aligned on GBIT objectives
Improvement Activities
Further collaboration with internal and external partners
Incorporate new technologies as they come up
Continuously set more ambitious targets
Prepare GBIT solutions for zero emissions aircraft implementation
Greening by IT Initialization
Greening by IT Integration
Greening by IT Maturation
Step 3: Apply Greening by IT Toolbox
1 Increase management leadership
2 Define GBIT Strategy
3 Improve data quality/access
4 Designate people responsible
5 Improve architecture
6 GBIT Hackathons/Challenges
7 Commit resources
8 Include GBIT in targets
9 Scout externally for techs
10 Create GBIT platform
11 Collaborate externally
12 Prioritize GBIT initiatives
13 Include sustainability criteria in projects
14 Collaborate internally
15 Combine GBIT with other goals
16 Raise awareness
17 Improve idea loops
18 Develop standards

Nomenclature

Key Terms

Greening by IT (Green IS in literature) = ”the development and use of information systems to support or enable environmental sustainability initiatives” (Jenkin, McShane, & Webster, 2011)

Green IT = the aim to make IT itself more sustainable through improved ”energy efficiency and equipment utilization” (Watson et al., 2008)

Green Information Systems (Green IS) = treated as synonymous with Greening by IT for this study

Adoption of Greening by IT = the process behind making the commitment to use Greening by IT within an organization

Implementation of Greening by IT = the process of actually putting Greening by IT into practice

Sustainability = For this study, sustainability mostly refers to reducing the emissions of airlines

CO_2 = Carbon dioxide, the most abundant greenhouse gas contributing to climate change which is also emitted from aircraft operations

Footprint = The negative environmental impact produced by an organization, process, activity, etc...

Absolute Emissions = The actual quantity of emissions resulting from an organization, taking into account both direct and indirect contributions.

Passenger Kilometer = The total distance traveled by a flight in km divided by the total amount of passengers

Decision Support Framework = The tool produced by this study which guides decision-making for Greening by IT implementation within the airline industry

Stakeholders = People or groups directly or indirectly involved or impacted

Strategic Management = Used in this study to refer to C-level management, VPs, and directors which focus on more strategic themes

Operational Management = Used in this study to refer to the Product Owners and Project Managers which focus on more operational themes

Barriers = Obstacles which make it more difficult to implement Greening by IT

Enablers = Factors which help lower the barriers obstructing Greening by IT implementation

Drivers = Factors which pressure organizations to adopt Greening by IT (external factors in this study)

Strategies = In this study, it is an approach to lower barriers and drive Greening by IT implementation

IT = Information Technology, but often referred to in this study when referencing the overall department responsible for it

SkyTeam = The airline alliance KLM belongs to which is comprised of 19 airlines around the world

KLM IS = KLM Information Services, the IT division at KLM

KLM Business = Frequently used in this thesis when referring to the business side and its corresponding stakeholders in a certain domain within KLM (e.g. cargo or ground)

Abbreviations

Abbreviation	Definition
AFKL	Air France - KLM
CIO	Chief Information Office(r)
DOP	Director of Product
DOT	Director of Technology
E&M	Engineering & Maintenance
D&T	Data and Technology
GBIT	Greening by IT
IMO	Information Management Office
IT	Information Technology
IS	Information Systems or Information Services if referring to KLM
KLM	Koninklijke Luchtvaart Maatschappij (Royal Aviation Company)
KPI	Key Performance Indicator
OKR	Objectives & Key Results
RTK	Revenue Tonne Kilometer
TAM	Technology Acceptance Model
VP	Vice President (Referred to in this study as the executive management of a KLM business)

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1 Introduction

As the world becomes increasingly digitized and concerns on climate change remain firm, efforts to understand how to leverage IT to aid in sustainable transitions have never been greater. This aim, also known as Greening by IT, has massive potential to aid in minimizing carbon footprints through the automation of business processes, increased energy efficiency, and waste reduction (Singh & Sahu, 2020). Not to be confused with Green IT, which represents the aim to make IT itself more sustainable, Greening by IT, often referred to as Green Information Systems in literature, is defined as "the development and use of information systems to support or enable environmental sustainability initiatives (Jenkin, McShane, & Webster, 2011)." It has been demonstrated that companies who implement Greening by IT reap numerous benefits beyond becoming more sustainable including cost reductions, improved reputation, and more advanced green innovation capabilities (Loeser et al., 2017; Nanath & Pillai, 2017; Qu & Liu, 2022). Secondary benefits also arise from having better environmental data visibility as it improves corresponding decision-making processes and to share the information with suppliers or customers (Qu & Liu, 2022). With Industry 4.0 technologies such as Internet of Things, Cloud Computing, and Artificial Intelligence already being introduced, the opportunities to leverage these advancements in designing sustainable transitions are numerous, especially for industries which face tremendous obstacles in becoming more sustainable.

One of these afflicted industries where Greening by IT could make a substantial impact is the airline industry. Although sustainability is a broad term and there are various aspects which should be considered in the transition of any industry, reducing the emissions which contribute to climate change is the primary objective for airlines. With aviation currently making up 2.4% of all human-related emissions worldwide and the Dutch government's goal to reduce aviation emissions in 2030 by 55% compared to the 1990 level (Davydenko & Hilbers, 2024), it is of upmost importance for airlines to find new ways to curb these emissions.

Upcoming EU and international legislation such as the Corporate Sustainability Reporting Directive and next zero carbon goals by 2050 resulting from the International Civil Aviation Organization (Davydenko & Hilbers, 2024) only add more pressure to drive sustainable transitions in aviation. Furthermore, airlines typically have low profit margins by nature due to heavy competition, high fixed costs, and fuel prices, meaning that there are inherently less resources to invest in adopting new technologies (Heiets et al., 2022; Kıyıklık et al., 2022). This makes it even more critical that the right measures are taken to make the largest impact.

The situation becomes nearly insurmountable when factoring in the increased demand from passengers (Heiets et al., 2022). Looking purely at the Dutch aviation sector, growth projections for 2050 range between 98 and 138 million passengers annually, which is a steep increase compared to the 81 million in 2019 (Davydenko & Hilbers, 2024). Despite important advancements being made the last several decades in the efficiency of aircraft, this near 4% of annual air traffic growth has only continued to accelerate the industry's emissions (Ansell, 2023). This means that even through the renewal of their fleets with more fuel-efficient aircraft, airlines are still fighting an uphill battle to decrease their footprint. With emission-free aircraft running on alternative fuels likely still decades away, airlines need to search for more short-term options to cut emissions.

Greening by IT is a promising option for reducing airlines' footprint in the short-term. For example, implementing better flight planning software on all KLM flights has the potential to reduce 0.5-1% of absolute CO_2 (KLM Sustainability Office, 2023). Applications such as these, together with optimized air traffic control measures, have the potential to save around 10% of CO_2 from European aviation (Eurocontrol, 2021). Also important to note is that over the last couple decades, airlines have become increasingly digital in efforts to optimize operations and improve customer satisfaction. This is reflected in the overwhelming use of IT systems in nearly every step of airline operations, ranging from ticket price prediction to algorithms predicting the allocation of meals on a flight, and in the development of new business strategies (Heiets et al., 2022). The potential added value by further digital transformation within airlines is huge, potentially resulting in an additional $5-10 per passenger annually (Kıyıklık et al., 2022). This demonstrates that further digital improvements to airline services offer increased business value, in addition to potential sustainability benefits. Through these several decades of expansion of IT within airline operations, a wide development space exists to leverage Greening by IT as a way to aid in driving sustainable transitions (Heiets et al., 2022).

1.1. Problem Statement & Objective

Despite a large amount of literature on the potential for Greening by IT and its numerous benefits, there is still little literature on the adoption process itself (Singh & Sahu, 2020), let alone when being applied in the airline industry. The airline industry itself is extremely complex, dealing with extensive legislative requirements, a wide variety of stakeholders, high competition, and high operating costs. These factors and especially the tight resource constraints make it even more essential that the decisions made in implementing Greening by

IT are sensible and well-reasoned. Investigating the barriers, enablers, and corresponding strategies relevant to the airline industry which impact the success of Greening by IT would be fundamental. There is currently an ample amount of research on the influencing factors of Greening by IT in a wide variety of industries in different countries, but, to the best of our knowledge, there is a complete lack of research into its application in airlines. Applying previous research to the airline context and integrating the findings into a decision support framework to guide airline practitioners in implementing Greening by IT can contribute to filling this knowledge gap. Everything considered, there is an excellent prospect for conducting additional research to apply of relatively under-tested Greening by IT findings to a specific use case and also assist the airline industry in becoming more sustainable.

In conclusion, despite the surge of research on Greening by IT in the last couple decades, there is a profound gap of knowledge on the application of Greening by IT in airlines, the key factors which impact its effectiveness, and the strategies that can be used to enable implementation. Given the inherent complexity of airline operations and the massive potential for Greening by IT to aid in cutting emissions, it is crucial to understand how airlines can make use of Greening by IT and foster its use. Therefore, the *objective of this research is to explore the key factors impacting Greening by IT implementation in airlines, the strategies to guide its implementation, and to integrate these into a decision support framework to guide practitioners in implementing Greening by IT.* The users of this framework are the operational and strategic-level management layers within airlines, such as C-level decision-makers or project managers. This is decided given that they have the most influence to implement Greening by IT, whether it be at an organizational level or local to a certain area. The following are the research questions which are used to fulfill this objective:

What is the decision support framework which can support airlines in implementing Greening by IT initiatives?

- **SQ1:** What is the conceptual model that can be used to help understand Greening by IT implementation in this study?
- **SQ2:** How can Greening by IT contribute to airline sustainability?
- **SQ3:** What are the barriers and enablers of Greening by IT implementation within airlines?
- **SQ4:** Which strategies can be used to overcome the identified barriers and drive Greening by IT implementation in airlines?
- **SQ5:** What is the corresponding decision support framework which integrates the identified key factors and strategies?

1.2. Approach Overview: KLM IS Case Study

This thesis is being carried out via a Graduation Internship at KLM Royal Dutch Airlines, within the CIO Office of Information Services. Being the world's oldest airline under the same name, KLM has a rich history in aviation and currently operates 173 aircraft to 92 European cities and 70 international destinations ("Holland Herald", 2024; KLM Sustainability Office, 2023). KLM's direct CO_2 emissions in 2022 were 9.07 Mt with 99% of it resulting from the combustion of fuel in their operations (KLM Sustainability Office, 2023). With this in mind, KLM also has a relatively long history of trying to make aviation more sustainable, as it started its environmental reporting already back in the 1990s (KLM Sustainability Office, 2023). Despite these early efforts, KLM has found itself under pressure recently after a Dutch court ruled that KLM had run misleading advertising on the sustainability of their flights and had therefore broken the law (Sterling & Plucinska, 2024). This adds extra pressure to come up with tangible, verifiable steps to combat sustainability challenges.

KLM currently has an initiative within Information Services called IT Matters which consists of Green IT, which looks at making IT itself more sustainable, and Greening by IT, which explores how to leverage IT in helping other parts of the airline become more sustainable. Despite the massive potential of Greening by IT and IT's contribution to KLM's absolute emissions being but a fraction of a percent, nearly all of IT Matters' efforts have been put into Green IT. Compared to the 73% of absolute emissions coming from fuel consumption, it is hardly an overstatement that Greening by IT is a critically underdeveloped solution for airline sustainability challenges. As suggested by KLM's Climate Action Plan, implementing better flight planning algorithms already has the potential to reduce 1% of fuel consumption across all flights (KLM Sustainability Office, 2023). After initial discussions with KLM employees within the CIO Office and reviewing some brief documentation, the following can be concluded about KLM and potentially extended to the rest of the airline industry:

- **Early Efforts Need Guidance:** There are efforts to implement Greening by IT initiatives, at least within KLM IS and likely at other airlines, but many are still at an early stage, being driven by employees volunteering alongside their normal tasks. Guidance is needed on where to focus efforts to make the largest impact, what strategy to follow in implementation in the long run, and how to measure the results.
- **Resource Constraints:** A massive hurdle for any sustainability innovation or initiative within airlines is working with the deeply embedded values of safety and profits. Safety is always the number one priority by nature in aviation, and profits is a close number two given the low profit margins and high fixed costs in the business. As a result, there is often little resources to dedicate to sustainability issues and there are strict requirements to be met when implementing any new solutions, which makes the steps chosen even more critical.
- **Massive sustainability challenges:** As discussed in the intro, the airline industry faces enormous hurdles in becoming more sustainable in the coming decades to curb its current footprint. With new-age, non-emitting aircraft likely still several decades away, it is crucial to see what can be done now to lower emissions in the short term, which would serve society as a whole greatly in fighting climate change.

As can be seen, there is a critical need for more research to aid in solving these problems for airlines and guiding their efforts. Using KLM as a case study enables this research to develop a comprehensive understanding of the factors involved in Greening by IT in an actual airline and provide an opportunity to validate the findings as the research is carried out. Working together with KLM allows access to multiple stakeholders within the company, KLM documentation, and meetings to observe the day-to-day inner workings of KLM IS and its IT Matters initiative. Given the merging of Air France and KLM and the resulting complexities, it is proposed to only perform the case study using KLM-specific resources. Despite the large amount of overlap and cooperation between certain branches, the focus is purely on KLM to maximize the validity of the findings. For example, there might be sustainability initiatives in Air France, KLM, and the Air France-KLM (AFKL) Group overall. In this case, only the KLM initiatives would be referred to.

To summarize, this study begins with a comprehensive literature study of Greening by IT looking into the contributing theories, key factors, and strategies. Desk research is conducted using KLM resources to get in-depth insight into Greening by IT applications and their potential impacts. Stakeholder interviews are conducted to test these findings and explore any gaps. Then, a decision support framework is constructed to guide Greening by IT implementation, which integrates the key factors and strategies together. An overview of the literature study can be found in Chapter 2. Following this is a detailed overview of the research approach in Chapter 3. A conceptual model for understanding Greening by IT implementation is developed in Chapter 4. In Chapter 5, Greening by IT is defined, airline sustainability challenges are explained, and potential Greening by IT applications within airlines are described. Next, the influencing factors and strategies for implementation are explored in Chapter 6 and Chapter 7. The decision support framework to guide implementation is constructed and detailed in Chapter 8. The conclusion, limitations, and recommendations for future research are highlighted in Chapter 9.

2 Literature Study

This chapter aims to describe the process followed for locating the literature used in this study, understand the Greening by IT literature landscape, and establish the knowledge gaps which require additional research. This is a preliminary first step needed to motivate the chosen research direction. The findings of this review are not discussed in detail as they are included in the subsequent chapters. In Section 2.1, the literature study protocol which was used for compiling the articles chosen for the subsequent chapters for each sub-question is explained. This chapter is concluded with Section 2.3 which describes the research gaps which were observed when performing the literature study.

2.1. Literature Study Protocol

In this section, the process used to perform the literature study is described. To begin, an overview of the search topics and their relation to the research questions is explained in Subsection 2.1.1. Then, the search process, which is based on the circular model for literature searching developed by Boell and Cecez-Kecmanovic (2014), is outlined in Subsection 2.1.2. Finally, the results from performing each step of the search process method are described in Subsection 2.1.3.

2.1.1. Literature Study Search Topics

In this subsection, a description of the process followed to search for literature and the characteristics used to select relevant articles is discussed. The first four sub-questions were all partially or fully completed through the use of the literature study. Therefore, it was instrumental that a thorough procedure was followed. The search topics for each of these research questions can be reviewed in Table 2.1.

Table 2.1: Literature Study Topics per Sub-question

SQ	Literature Study Topics
1	Conceptual models on Greening by IT implementation
2	Greening by IT definition and scope for airlines
3	Barriers and enablers for Greening by IT implementation
4	Strategies for Greening by IT implementation

As further expanded on in Subsection 2.1.3, there exists a lack of literature on Greening by IT within the airline context. Due to this and the exploratory nature of the study, it was chosen to not limit the articles used to work published from certain industries, countries, or unit of analyses when performing the literature study. Any potential impacts of this are mentioned with the rest of the study's limitations in Section 9.4.

2.1.2. Search Process

The literature study process follows the method for searching suggested by Boell and Cecez-Kecmanovic (2014). This model best represents the iterative process that is necessary to conduct a high quality literature study. The seven stages in the circular framework for searching and acquiring literature are described as follows (Boell & Cecez-Kecmanovic, 2014):

1. **Searching:** In this phase, literature is searched for using the chosen search operators and other criteria. It is also recommended to first focus on secondary literature such as literature reviews which summarize the given topic's landscape. The circular framework also suggests to focus on smaller batches of highly relevant articles rather than long lists where it is unclear.
2. **Sorting:** During sorting, the articles located via the search phase are critiqued based on criteria such as relevance, the number of citations, and the date that the article was published.
3. **Selecting:** Selecting consists of choosing specific papers from the sorting list to read. This is done by reviewing the titles and abstracts of the articles.
4. **Acquiring:** In this phase, each article is reviewed to check they can be acquired via accessible databases.
5. **Reading:** This is where the researcher reads the selected articles to learn more about the research topic, identify key themes, and concepts which can be used in another iteration of this process.
6. **Identifying:** Using the articles that were read in the previous stage, additional relevant articles are identified by citation tracking. The most relevant journals, authors, and conferences from those papers can also be used to locate additional literature.

7. **Refining:** The conclusions from completing one round of the process can be used to improve the next iteration. For example, a citation pearl growing strategy could be used to search for articles based on the keywords seen in previous articles or search for articles in a different database.

2.1.3. Application of Search Process

To begin, a first iteration of the process was conducted to investigate the existing literature landscape and get familiar with it. Various search term combinations were experimented with in order to find the literature most relevant for the research questions. It was found that there are some unfortunate disadvantages to searching with ”Green IT” and ”Green IS,” as they can be mistaken for sentences containing ”...green, it...” or ”Green is...” As a result, it was chosen to use ”Greening by IT” and the term it’s often referred to in literature, ”Green Information Systems,” as the primary governing terms for searches. In later iterations, additional search terms were added to locate literature more specific to the various research questions. The main search phrase used for a majority of the papers found can be seen below:

Main search phrase: *(”Green* by IT” OR ”Green Information System*”) AND ((”key factor*” OR ”inhibitor*” OR ”Barrier*” OR ”Enabler*”) OR (”adoption strateg*” OR ”Green IT/S Strateg*” OR ”Green IS strateg*”))*

This main search phrase was passed into Scopus where 33 papers were located. Moreover, one iteration of the search included terms related to aviation to evaluate if any prior research has been done in the domain relating to the airline industry. Only two papers, which were deemed somewhat relevant, were found after successive searches, demonstrating the lack of prior research done specific to the airline industry. This was reinforced by Jongsaguan and Ghoneim (2017) who state that literature focused towards the aviation context is lacking due the fact that Greening by IT is still emerging and in its early stages. A summary of the key words and search terms used in the various exploratory searches can be seen in Table 2.2.

Table 2.2: Keywords & Search Terms

Keywords	**Search Terms**
Greening by IT	*Greening by IT, Green Information Systems*
Airline	*Airline*, Aviation, Air transport, Airline industry*
Key factors	*Factor*, Barrier*, Inhibitor*, Enabler**
Strategies	*Adoption Strateg*, Green IT/S Strateg*, Green IS Strateg**
Framework	*Framework*, Decision Support, Model*

After some exploratory iterations of the search process, 33 papers were found and were evaluated more in-depth based purely on their relevance to the research subject. Following the screening, 15 of the 33 were selected. These papers were then fed into Research Rabbit, a literature mapping tool. Research Rabbit maps the citations, references, and connections between uploaded papers. It also generates a list of similar works based on the papers you enter, which was found to recommend several useful papers which weren’t located using the traditional methods. This tool was used to perform the *backward* reviewing, looking at the references the paper uses, and *forward* reviewing, looking forward at papers that have cited it since publishing, as suggested by Webster and Watson (2002). Briefly reflecting on Boell and Cecez-Kecmanovic’s literature study process, using a tool such as Research Rabbit makes the stages for Identifying, Refining, and then Searching again much more streamlined and less cumbersome. From Research Rabbit’s recommendations, 45 papers were selected based on their titles and reading the abstracts which Research Rabbit had access to. These, together with the original 15, were combined to form a list of 60 articles.

After generating this list, a more detailed Selecting and Reading phase was performed to generate the list of articles which would end up being used for the literature study. First off, in order to ensure the quality of the papers found via Research Rabbit, they were searched for on traditional scientific databases to ensure their legitimacy. If found, they were included and if not, they were discarded. Certain papers originated from databases which could not be accessed via TU Delft library resources, so these were also discarded. Next, each paper was skimmed to ascertain its usefulness in relation to the research questions and removed if not deemed satisfactory. Preference was also put towards including literature reviews on the Greening by IT domain as these should ideally summarize previous research on Greening by IT and deliver recommendations for future research which could be used for devising this study. This resulted in a final list of 49 papers to be used in the literature study which can be found in Appendix A. The complete process can be seen in Figure 2.1.

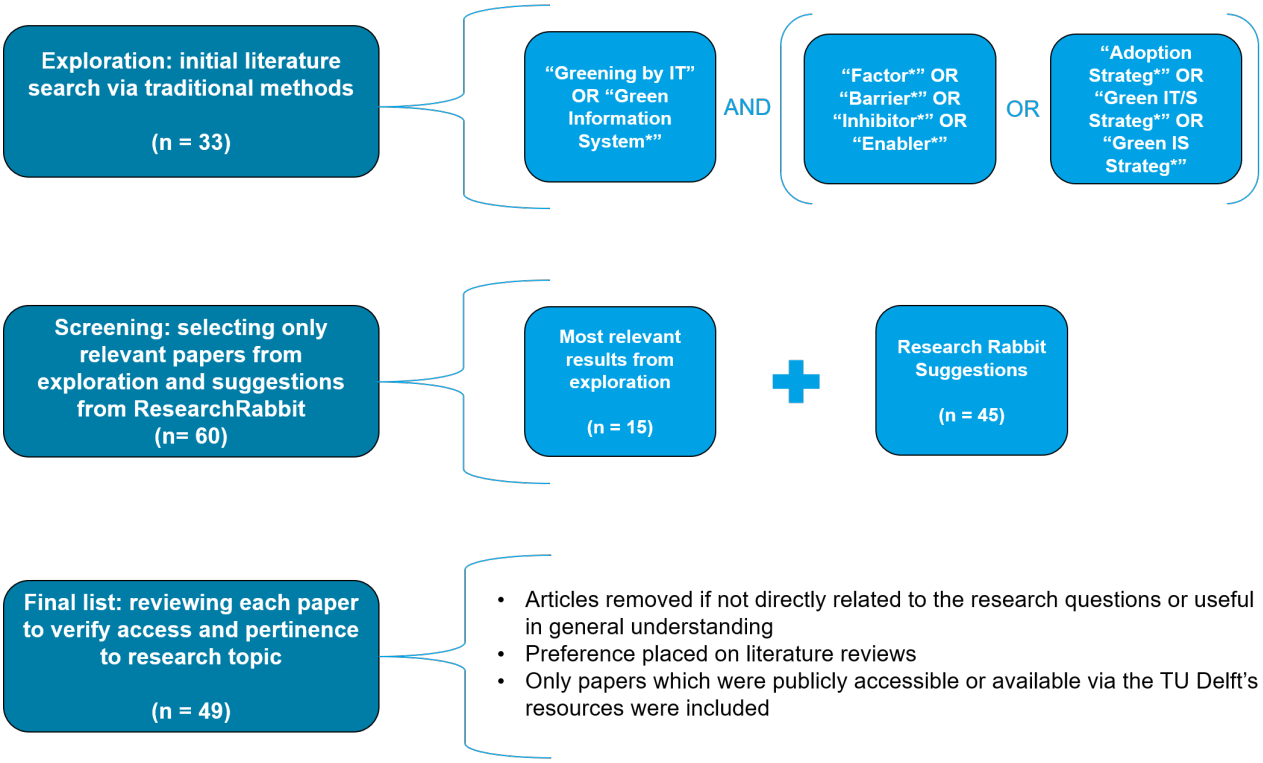


Figure 2.1: Literature Search Process

2.2. Greening by IT Literature Landscape

As mentioned by Boell and Cecez-Kecmanovic (2014), one of the key ways to map literature for a literature study is by illustrating the historical development of the landscape. After this initial review of Greening by IT, it can be seen that a lot of the foundational research on the topic was carried out in the late 2000's to the early 2010's when the idea of Green IT and Greening by IT were taking shape. There are literature reviews which look specifically into the development of the topic and corresponding articles specifically such as "*Towards adoption of Green IS: A literature review using classification methodology*" (Singh & Sahu, 2020). The review by Singh and Sahu demonstrates that even after the better part of two decades, there is still a lack of a consensus on certain aspects, such as the definition of Greening by IT and its adoption phase. The ten literature review articles chosen for this study are also relatively evenly distributed between 2010-2023, with there being a new review nearly each year in that period. These ten literature reviews are seen in bold in the list of articles used in the literature study found in Appendix A.

Using these articles and the list of literature compiled in Section 2.1, some basic conclusions can be made. Much of the foundational literature from the late 2000's revolves around demonstrating the benefits of Greening by IT, developing the concept, and researching peoples' perceptions on the topic. In the 2010's, the research investigates more specific scopes such as the drivers, key success factors, and strategies involved in actually implementing Greening by IT. However, this result is limited by the fact that these research topics were also the most sought after for this study in particular, even though there is an abundance of literature on those topics between 2010-2020. For example, 18 of the 22 articles used to research the key factors for this study were published between 2010 and 2019 and nearly always consist of qualitative research using surveys to gain insights from IT practitioners. The most recent literature tends to try to bring together much of the work done in the previous decade to try to make firmer actionable conclusions. For example, Kirchner-Krath et al. (2024) highlight the importance of employee's attitude towards Greening by IT in contrast to the abundance of research on organizational-level factors. Additionally, Kirchner-Krath et al. mention that early literature focused on the potential benefits for IT to directly contribute to reducing footprints, but that increased efforts have been made to research operational Greening by IT, which looks at educating employees about sustainable choices through better awareness and feedback loops. The papers used in this literature study were ordered by date and assembled into a table which can be seen in Figure 2.2.

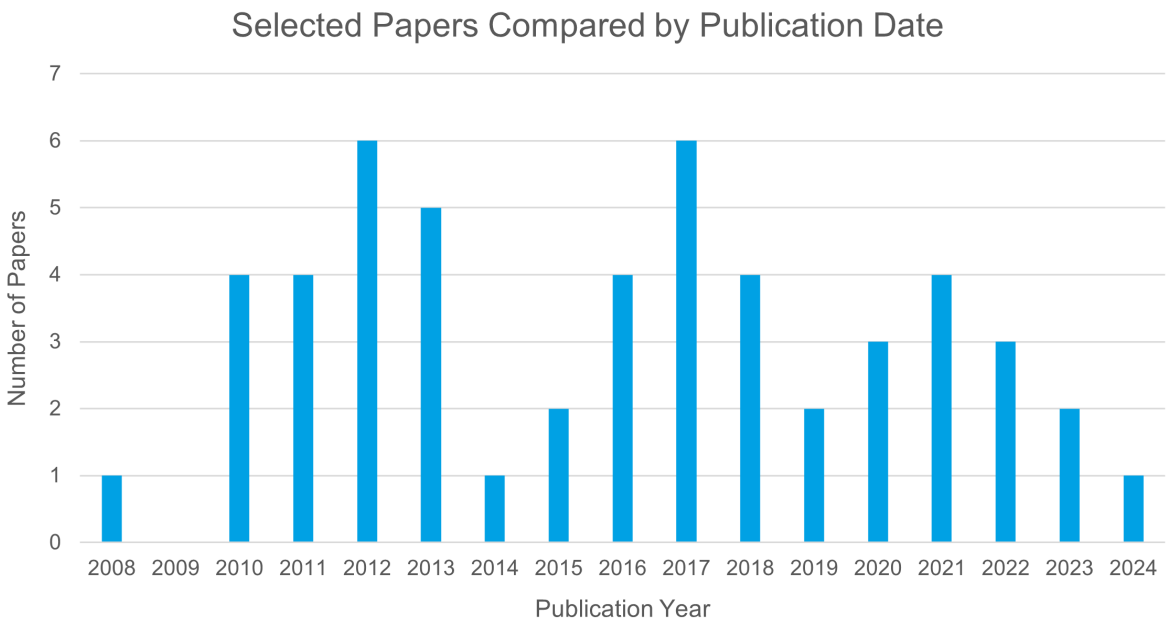


Figure 2.2: Selected Papers Sorted by Publication Date

Most noticeable in Figure 2.2 is that there is only a single article pre-2010. After 2010, several peaks can be observed, occurring in 2012, 2017, and 2021. Much of the early, foundational literature used in this study was published between 2010 and 2013. After reviewing the articles, several knowledge gaps were identified and are presented in Section 2.3.

2.3. Knowledge Gaps

After conducting this brief look into the existing literature on Greening by IT and the associated factors, several knowledge gaps can be formulated from an academic point of view:

1. **Lack of Accepted Definition:** There exists a lack of a universally accepted definition and understanding of Greening by IT (Singh & Sahu, 2020).
2. **Under-researched Adoption Phase:** Historically, there exists more focus on the pre-adoption phase of Greening by IT in previous research, just as any new technology or application would experience, but a lack of research evaluating the adoption phase. Additionally, there is no widely-accepted adoption model for Greening by IT (Jongsaguan & Ghoneim, 2017) and many of the theoretical developments are purely conceptual and require additional analysis (Khor et al., 2015).
3. **Lack of Research on Barriers and Strategies:** After reviewing several areas of literature, it can be preliminary concluded that there are many studies looking into the key factors influencing the implementation of Greening by IT and frameworks to organize them, but less studies looking into implementation strategies (Singh & Sahu, 2020). Additionally, there is a lack of understanding of which strategies are the most relevant for specific barriers. Most studies on strategies, such as Khor et al.'s 2015 study "*Bridging the Gap of Green IT/IS and Sustainable Consumption*," list various organizational theories and comment on their applicability to Greening by IT, but do not develop them further.
4. **Absence of Research on Airline Application:** More specifically, there is a complete absence of research looking into Greening by IT within airlines, similarly stated by Jongsaguan and Ghoneim (2017). There is no knowledge on which applications, key factors, and potential strategies would be effective or if there are unique elements which would be more relevant.
5. **Insufficient Comprehension of Industry 4.0:** Additionally, given the pace and new developments in the IT landscape, there is less research including new Industry 4.0 technologies and how they relate to Greening by IT (Laranja Ribeiro et al., 2021).

Given the time frame and amount of resources to conduct this study, it is not reasonable to research all of these gaps in extreme depth. It is decided to not consider the first gap in there not being a widely-accepted

Greening by IT definition, but to instead assume a definition to be used for carrying out the study. Also, the fifth gap regarding a lack of understanding of how to apply Industry 4.0 technologies for Greening by IT is also not touched upon in this study, but remains attractive for future research. The remaining gaps are deemed sufficiently related to be targeted together for this study. A crucial first step is to treat the second gap and construct a conceptual model for the implementation of Greening by IT. This is represented in the first sub-question which creates this conceptual model which is to serve as the foundation for the decision support framework developed in the final step.

Before addressing the other gaps, it is first critical to highlight the potential for Greening by IT and apply it to the airline context. It is decided to formulate the second sub-question around this and explore how Greening by IT can contribute to airline sustainability. Next, given the abundance of literature on key factors and drivers of Greening by IT, it is chosen to compile these findings, apply them to the airline context, and map them to strategies. This would effectively cover gaps 2, 3, and part of 5. These gaps are represented in the third and fourth sub-questions which identify the relevant barriers in the airline context and connect them to strategies.

Finally, in order to weave all of these findings together, the fifth sub-question is dedicated towards creating a decision support framework to aid practitioners in implementing Greening by IT in airlines and serve as a basis for further research. This helps fill in the second knowledge gap as well as it was found that there is a lack of a widely-accepted adoption model for Greening by IT. As later mentioned when discussing prior research on strategies in Chapter 7, besides loose concepts and frameworks to organize Greening by IT strategies, there is no framework which incorporates influencing factors, strategies, and implementation phases all together. This would add value from an academic point of view as it would combine several areas of Greening by IT research, but would also create a tool useful for practitioners. This decision support framework is also used in formulating the main research question, which asks what decision support framework can support airlines in stimulating Greening by IT initiatives. These research questions can be found at the start of Chapter 3.

3 Research Approach

In this chapter, the research approach for this study is outlined, beginning with an overview of the approach in Section 3.1. Next, in Section 3.2, an overview for each research question is provided, explaining the reasoning behind the question, the methods used, and the anticipated result. The validity & reliability and ethical considerations are shown in Section 3.3 and Section 3.4. To conclude, the research flow diagram is displayed in Section 3.5.

The protocols which are followed for the literature study, desk research, and interviews are explained when they are first used throughout the study. As a result, the literature study protocol can be found in Section 2.1, the protocol of the desk research in Section 5.2, and the protocol of the interviews in Section 6.4. Given that the they are so heavily referenced in this chapter, the research questions, which stem from the gaps identified in the literature study and the corresponding objective statement in Chapter 1, are shown again for reference:

What is the decision support framework which can support airlines in stimulating Greening by IT initiatives?

- **SQ1:** What is the conceptual model that can be used to help understand Greening by IT implementation in this study?
- **SQ2:** How can Greening by IT contribute to airline sustainability?
- **SQ3:** What are the barriers and enablers of Greening by IT implementation within airlines?
- **SQ4:** Which strategies can be used to overcome the identified barriers and drive Greening by IT implementation in airlines?
- **SQ5:** What is the corresponding decision support framework which integrates the identified key factors and strategies?

This decision support framework can be used by both practitioners in implementing Greening by IT and researchers in understanding it. The employees within the operational management and strategic management layers within airline IT departments make up the practitioners. This framework can guide them in understanding the stages of Greening by IT implementation, identifying the most relevant obstacles specific to their case, and selecting some potential strategies to drive it further. This is explained in more detail in Chapter 8.

3.1. Research Approach Overview

For this study, a qualitative approach is chosen due to the exploratory nature of the main question, the need to develop a deep contextual understanding of the case to answer the question, and the inherent complexity of airline IT. This is evaluated through the use of various qualitative methods including a literature study, desk research of KLM documents, and interviews with expert stakeholders. Findings from literature are explored and tested through this case study at KLM. This corresponds with the research objective as it enables a comprehensive understanding of the intricacies of applying Greening by IT to a specific case and provides a platform for developing an effective decision support framework for its use. An outline of the various methods used per research question and the deliverables can be seen in Table 3.1.

Table 3.1: Methods and Deliverables Per Sub-question

RQ	Methods	Deliverable	Connection to Next Question
1	Literature Study	Conceptual model to be used for understanding Greening by IT implementation	Serves as the basis for following research questions and for creating the decision support framework
2	Literature Study Desk Research	List of Greening by IT applications for airlines	Example applications are used to guide interview questions on factors & connect them to strategies
3	Literature Study Desk Research Interviews	Most relevant barriers & enablers within the airline context	The identified strategies in the next question should treat the barriers & be based on the enablers
4	Interviews	Map connecting the identified strategies to the barriers	The strategies appear as options for overcoming the barriers shown in the decision support framework
5	Interviews	Decision support framework to guide airlines in implementing Greening by IT	Creates deliverable for main question

This multi-pronged approach enables this study to establish a broad foundation of knowledge on Greening by IT, evaluate its potential use within airlines, and create to a tool to foster its implementation. The decision support framework that is developed using these insights also has the opportunity to be validated and iterated upon through discussions with KLM employees. Ultimately, this type of approach enables the comprehensive insight which is required to understand the complex phenomena of airline IT and how to best enact Greening by IT.

3.2. Research Question Descriptions

This section describes the main research question and each of the sub-questions by explaining at the reasoning behind the question, the methods that are used to answer it, and the anticipated result. The overview for the main research question can be found first in Subsection 3.2.1 followed by each of the five sub-questions in Subsection 3.2.2, Subsection 3.2.3, Subsection 3.2.4, Subsection 3.2.5, and Subsection 3.2.6.

3.2.1. Main Research Question

What is the decision support framework which can support airlines in stimulating Greening by IT initiatives?

Reasoning

The main question is designed to deliver a decision support framework for airlines to follow for incorporating Greening by IT into their business and IT practices. It directly serves the problem identified in that there is a lack of prior research on the Greening by IT adoption phase, an absence of research on its application in airlines, and the current, practical need of the airline industry to understand how to implement it. It also fulfills a societal need to aid in developing measures to mitigate the footprint of the airline industry which contributes climate change.

Methods

As described in the previous section, this main research question is answered through the use of several sub-questions which break down the question into actionable components. The methods include a literature study, desk research, stakeholder interviews, and corresponding analysis whose findings are used in the creation of the decision support framework

Result

The result is a detailed decision support framework which guides airline IT practitioners in understanding the implementation of Greening by IT, identifying the most relevant barriers, and selecting some corresponding strategies. This framework can also be used by researchers who wish to evaluate its application within other airlines or adapt it for use in other industries. This is explained in more detail in Subsection 3.2.6.

3.2.2. Sub-Question 1

What is the conceptual model that can be used to help understand Greening by IT implementation in this study?

Reasoning

A necessary first step before carrying out the investigation is to first understand the concepts surrounding Greening by IT and its implementation. It must aid in framing the connections between the influencing factors and strategies in understanding Greening by IT implementation. Compiling these into a conceptual model doesn't only assist in comprehending the topic, but also serves as a useful basis to create the decision support framework.

Methods

The primary method used in answering this sub-question is a literature study which aims to review the theories surrounding Greening by IT implementation. Various conceptual models are evaluated to select one which can be adapted for this research. The selected conceptual model is then explained and applied to this study's scope.

Result
The outcome is the selection of a conceptual model from prior research. Any necessary adaptations are made and a version specific to this study is presented. The conceptual model is then used when exploring the key factors, strategies, and decision support framework.

3.2.3. Sub-Question 2
How can Greening by IT contribute to airline sustainability?

Reasoning
To begin answering the main research question, a broad foundation on Greening by IT and airline sustainability challenges is required. This serves as a prime basis to build upon when its implementation within airlines is explored in more detail, as it should first be evident how Greening by IT can contribute to their sustainability goals. The three main elements to include in this sub-question would be the definition of Greening by IT, as provided by literature, the main sustainability challenges faced by airlines, and potential Greening by IT applications specific to airlines. Once each of these aspects has been researched, they can be woven together to justify Greening by IT's potential for improving the sustainability of airlines.

Methods
For this sub-question, a literature study and desk research are used. The literature study aims to develop the required background knowledge on Greening by IT. The desk research sets out to use KLM resources to understand the sustainability challenges at KLM, the corresponding strategy and objectives, and any potential applications of Greening by IT. A desk research protocol is developed to answer this sub-question in an efficient and valid way.

Result
The result of this sub-question comprises of a detailed synopsis of Greening by IT from the literature study. Using KLM resources, an overview of the challenges regarding sustainability and progress at KLM is delivered. Additionally, a list of historical/potential Greening by IT applications grouped by the various KLM businesses is shown. Several examples from this list are chosen to guide the rest of the research when exploring barriers, enablers, and strategies through the stakeholder interviews.

3.2.4. Sub-Question 3
What are the barriers and enablers of Greening by IT implementation within airlines?

Reasoning
Progressing with the broad foundation and example applications provided by the first two sub-questions, the factors which could impede or enable the successful implementation of Greening by IT initiatives within airlines are explored. This is useful to begin translating the general Greening by IT literature to the airline context and explore any unique aspects which arise. This is instrumental in the eventual creation of a decision support framework as any proposed strategies should base themselves in the enablers and overcome the barriers.

Methods
First, a literature study is used to produce an overview of the barriers and enablers identified in prior Greening by IT research. But, a necessary next step before conducing interviews to apply these factors is to define the case study scope within KLM. The organizational structure of IT is reviewed through a desk research of KLM documentation. Once the use-case has been defined, a stakeholder analysis is performed and validated with employees to identify participants for the interviews. Then, the factors from the literature study are applied to the airline context by conducting stakeholder interviews. These interviews cover the questions relevant to this sub-question along with those for the fourth and fifth sub-questions. These interviews use the example applications from the second sub-question as a way to explore the topic and help participants visualize the barriers which arise. They are asked to describe the factors they see from their perspective, rank them, and point out any missing factors. The results from this ranking are analyzed using a semi-quantitative analysis to provide an overall score for all the factors and compare answers between stakeholders.

Result
The answer to this sub-question is an overview of the factors most pertinent to Greening by IT within airlines. This is comprised of an overall ranking of the literature study factors based on their relevance, supporting quotes from the participants, and a list of any previously unrecognized factors. These factors are used to shape the strategies which are developed in Subsection 3.2.5 and the influencing components of the decision support framework in Subsection 3.2.6.

3.2.5. Sub-Question 4
Which strategies can be used to overcome the identified barriers and drive Greening by IT implementation in airlines?

Reasoning
After developing an understanding of the influencing factors related to Greening by IT implementation, strategies can then be developed to assist practitioners in overcoming obstacles. These strategies are based on the identified enablers and are designed with participants to treat the barriers. These strategies are then used in the following sub-question to develop the decision support framework.

Methods
Comparable to the previous sub-question, the findings from the initial literature study on potential strategies is expanded upon through the stakeholder interviews. After exploring the key factors in the beginning of the interview, the participants are asked to suggest strategies based on the enablers to handle the top barriers they identified.

Result
The result of this question is a synopsis of strategies which can be used to overcome the most relevant barriers. This is comprised of a list of strategies suggested by the various participants and the corresponding reasoning. This result is then directly used in Subsection 3.2.6 in creating the decision support framework.

3.2.6. Sub-Question 5
What is the corresponding decision support framework which integrates the identified key factors and strategies?

Reasoning
As a way to illustrate the findings from the previous sub-questions in a concise way for airlines, it is necessary to construct a decision support framework based upon the conceptual framework proposed in Subsection 3.2.2. This is instrumental from an academic perspective as it puts prior research Greening by IT implementation to use in a specific context. The framework would be equally relevant from a practical standpoint for airlines to use as a tool for implementing Greening by IT. The decision support framework includes implementation phases based on the conceptual framework, the influencing factors, and strategies to overcome the obstacles.

Methods
Several interview questions are used to understand the implementation phases of Greening by IT in the eyes of the participants. Using the results from the previous sub-questions, a preliminary version of the decision support framework is made and validated through discussions with various KLM employees to identify any necessary improvements. These employees consist of personnel within the CIO Office, the participants in the interviews from D&T, and other members of D&T's strategic management. Improvements which are easily done can be implemented into the framework and the others can be compiled in a list of recommendations.

Result
This sub-question delivers a decision support framework for Greening by IT implementation which integrates the conceptual model's maturity phases, the identified factors, and strategies. This framework is used directly in answering the main research question and forms the final result of this study.

3.3. Validity of the Results

Given the inherent complexity of this case study and relatively unexplored research topic, it is critical to ensure the validity of the conclusions. Triangulation between the results of each method and reviews with KLM employees is used to help guarantee validity. The results at each phase are presented to various employees to gather feedback, with some being strategic stakeholders within the CIO Office and others being at the operational level within D&T. This allows for adjustments to be made continuously throughout the study, which enable it to stay true to its primary objectives. The results of these validation discussions held with KLM employees are shown at the end of each chapter of each sub-question. The results of the research are limited to the context of KLM as a result, as there is insufficient time to carry out detailed external validations. Limitations resulting from this are discussed in Chapter 9.

Internal validity is crucial in this case study, as the complexity of the subject being researched makes it tough to guide the research efforts in a direction which consistently represents the proposed research questions. To mitigate this, a comprehensive protocol is developed for each method such as the literature study, desk research, and interviews. This reliability is manifested through measures such as the application of an established search method in the literature study, the use of firm search criteria for the desk research, and a well-defined use-case and stakeholder analysis for conducting the interviews.

Given the specificity of this study to airlines, the external validity is a crucial aspect given the uniqueness of the airline industry and the differences between airlines. For example, there are unique aspects which arise from Air France - KLM's complex organizational structure. The differences with other airlines could be based on geographical location, working-culture, IT structure, and age of the airline. The external validity of the results is treated during the stakeholder interviews by collecting the participants' opinions on the generalizability of the results to the rest of KLM and other airlines. The external validity to other industries is reflected upon in Chapter 9.

3.4. Ethical Considerations

Ethical considerations were kept at the upmost priority throughout the various phases of this study. Certain aspects such as collection of personal data, conducting interviews on potential conflicts within the organization, and preventing the re-identification of participants were considered. Given the nature of the case study being conducted within KLM, extensive planning was conducted to incorporate their requirements for which documents may be used, identify confidential information, and correctly store the data. For interviews or personal communication with KLM employees, they were informed of the research well in advance, prompted for their consent, and made aware of what data is being collected. All of the risks and mitigation measures were outlined in the Data Management Plan and Human Research Ethics Form which were approved by the TU Delft.

3.5. Research Flow Diagram

Using the methodology presented above, a research flow diagram can be constructed to illustrate the steps taken and how they answer the posed research questions. It can be seen in Figure 3.1.

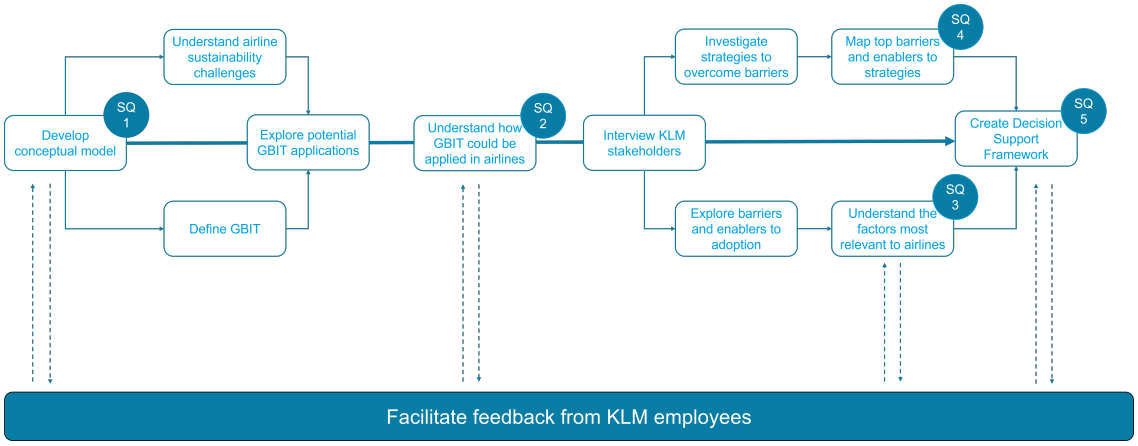


Figure 3.1: Research Flow Diagram

4 A Conceptual Model for Greening by IT Implementation

This chapter answers the first sub-question which asks: ”What is the conceptual model that can be used to help understand Greening by IT implementation in this study?” Therefore, the objective is to explore conceptual models used by previous research and construct one specific to this study. To answer this sub-question, a literature study which follows the process described in Chapter 2 is used to explore existing conceptual models and the contributing theories. This is shown in Section 4.1 and is followed by Section 4.2 which explains the contributing theories. The chapter is concluded in Section 4.3 which presents the conceptual model.

4.1. Review of Existing Greening by IT Implementation Models

This section clarifies the need for a conceptual model in Subsection 4.1.1, reviews conceptual models from previous research in Subsection 4.1.2, and makes a selection of a conceptual model to be adapted for this study in Subsection 4.1.3.

4.1.1. Purpose of Conceptual Model

Given the lack of a widely-accepted conceptual model for Greening by IT adoption (Jongsaguan & Ghoneim, 2017), several papers which propose models and conceptual frameworks for Green IT and Greening by IT implementation were reviewed. It is desired to locate a conceptual model which was used in previous research to serve as the foundation for understanding Greening by IT implementation in this study and adapt it if necessary. The model should incorporate the contributing factors impacting Greening by IT implementation such as the barriers and enablers. It should also provide a foundation to organize the corresponding strategies and measures. Overall, it should serve as a basis to understand and connect the findings from the following four sub-questions.

4.1.2. Existing Models

Previous research has explored Greening by IT implementation through various theoretical lenses including Innovation Diffusion Theory, the Technology Acceptance Model (TAM), the Technology-Organization-Environment (TOE) Theory, and the Belief-action-outcome Framework. It seems that the most recent studies attempt to expand upon foundational Greening by IT models from the last 20 years by integrating more recent theories or looking into a more narrow aspect of one of the foundational theories. Most of the reviewed conceptual models focus on evaluating the influence of specific factors on the implementation of Greening by IT (or Green IT). There is a front-end focus, looking at the factors which lead to the intent to adopt and how these factors are related. For example, Asadi et al. (2021) evaluate the intention to adopt green information technology based on five influencing factors, being managerial interpretation, awareness of consequence, ascription of responsibility, personal norm, and subjective norm. Bryan and Zuva (2021) researched the integration of the TAM and TOE frameworks for use in IT adoption and relate influencing factors to the perceived usefulness of IT. Papers even from more recent years are generally still setting out to formulate a theoretical framework for Greening by IT implementation, as proposed by Carvalho et al. (2022) who set out to create a maturity model for Green Information Technology.

4.1.3. Selected Conceptual Model: Bose and Luo (2011)

The most important criteria used when evaluating the various conceptual models were their applicability to Greening by IT, their inclusion of influencing factors, and their potential to serve as a foundation to build the decision support framework. The inclusion of the influencing factors in some way is crucial given their importance in this study. It would also be helpful for it to be a potential foundation for the decision support framework as this would streamline the research process from developing the initial understanding of Greening by IT implementation to delivering the final result of the study.

After careful review, **the conceptual framework developed by Bose and Luo (2011) is selected as the foundational conceptual model.** In Bose and Luo’s model for *Green IT* adoption, the influencing factors are grouped according to the Technology-Organization-Environment (TOE) framework and flow into the first three stages of Rodger’s Innovation Diffusion theory (Rodgers, 1995). These contributing theories are expanded upon in more detail in Section 4.2. Despite Green IT not being the focus of this study, the its objective and the challenges it faces are extremely similar to that of Greening by IT. This comparison is elaborated on in more

depth in Subsection 5.1.2. Reviewing the selection criteria, this is deemed sufficiently applicable to Greening by IT to be used as the conceptual model for this study.

The model also includes the influencing factors, fulfilling another important criterion. However, the factors used by Bose and Luo within the TOE categories are not relevant for the purpose of this study. The influencing factors for Greening by IT implementation which are identified through the literature study and expanded upon in interviews are used in these categories instead. The implementation process could follow the same three stages, as the implementation of Green IT and Greening by IT would likely follow similar steps. The decision support framework is then based around the three implementation phases used by Bose and Luo. Overall, this model is directly applicable to Greening by IT, provides a great basis to organize the key factors, and proposes stages to help structure the decision support framework. A visual of their conceptual model can be seen in Figure 4.1.

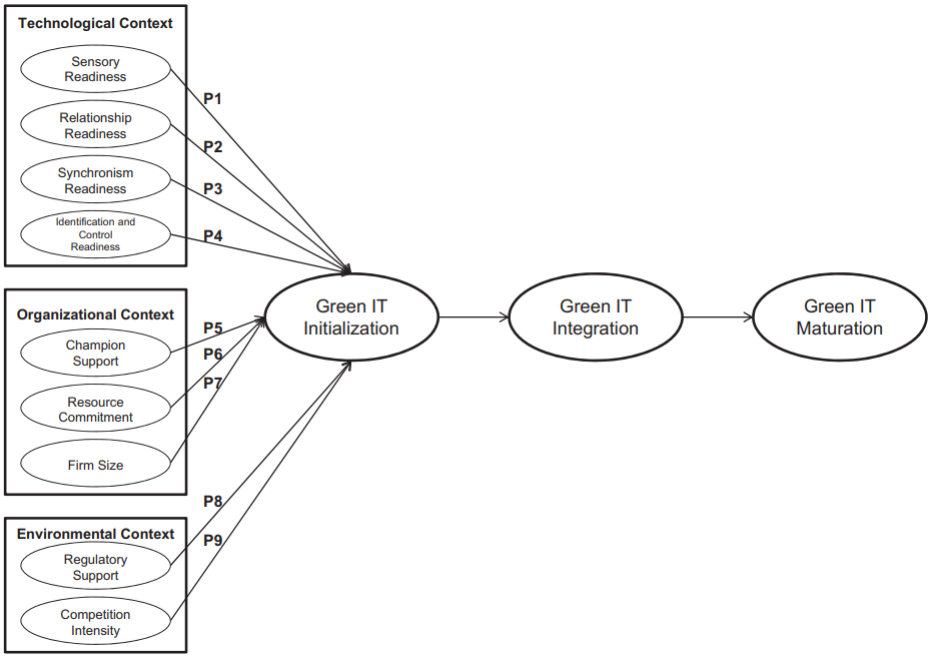


Figure 4.1: Conceptual Model for Green IT Adoption (Bose & Luo, 2011)

Several more recent studies cite Bose and Luo's model due to its integration of the TOE framework and Innovation Diffusion theory (Almeida et al., 2022; Carvalho et al., 2022). There are several more recent studies which utilize aspects of Bose and Luo's model in the development of their own (Ayala et al., 2019; Bryan & Zuva, 2021; Zheng, 2014), but most are researching narrower scopes which make Bose and Luo's model still the most attractive for this study. More recent studies, such as Almeida et al.'s (2022) paper developing a framework for deciding when to adopt industry 4.0 technologies, reference Bose and Luo's work as being particularly relevant to decisions on the adoption of green information technologies based on its use of Innovation Diffusion Theory. Additionally, Almeida et al. state that other recent studies such as Ayala et al.'s 2019 paper have similarly used the first three stages of Innovation Diffusion Theory for information systems adoption. Carvalho et al. (2022) mentions the paper by Bose and Luo specifically due to its inclusion of Innovation Diffusion Theory. As can be seen, the three stages proposed by Innovation Diffusion Theory remain relevant to the current theoretical landscape.

There is also demonstrated use of the Technological-Organizational-Environmental framework to group influencing factors. Almeida et al. also use the TOE categories to group relevant factors, alike to Bose and Luo's conceptual model. The TOE framework was also used for grouping factors in Zheng's (2014) study which proposed an adoption model for Green IT/IS and in Bryan and Zuva's study on the TAM-TOE integration which was previously mentioned. The TOE is also demonstrated to still be a leading method to structure influencing factors for Greening by IT adoption research.

4.2. Contributing Theories

In this section, each of the main contributing theories to Bose and Luo's model are explained. The Technology-Organization-Environment theory is explained in Section 4.2 and Innovation Diffusion theory in Section 4.2.

Technology-Organization-Environment (TOE) Theory

Bose and Luo use the TOE framework to group the influencing factors on Green IT and add the perspective of the wider environment that it takes place in. The TOE framework revolves around how the context of a firm impacts the implementation of a technology (Baker, 2011). Originally introduced by Depietro et al. in 1990, the organizational context is broken down into three elements consisting of the technological, organizational, and environmental context. Descriptions of each as described by Baker (2011) and Bose and Luo (2011) are as follows:

- **Technological context:** this is made up of all of the characteristics of the technologies the organization could potentially adopt and the technologies already used by the firm. This context can be illustrated by tangible elements such as technical equipment and intangible elements like processes.
- **Organizational context:** this context consists of the firm's characteristics and resources such as its structure, size, innovation-enabling processes, top management strategic behavior and leftover resources.
- **Environment context:** this context represents the regulatory elements, make-up of the industry, and external support for certain technologies.

Innovation Diffusion Theory

Based on the introduction of Innovation Diffusion theory by Rodgers, Bose and Luo introduced three main categories to structure the conceptual framework which are initialization, integration, and maturation. These are an alternative interpretation to Rodgers's five phases being knowledge, persuasion, decision, implementation, and confirmation (Rodgers, 1995). Bose and Luo define initialization as when the firm decides to "go Green" and starts implementing simple, low-cost measures to achieve moderate sustainable goals. Then, as the firm becomes more experienced, learns from the initialization phase, and begins to experience the benefits from the innovation, it enters the integration phase (Bose & Luo, 2011). Here, it starts to formulate more specific strategies and develop existing infrastructure to include green criteria. The primary focus is still reducing footprint and achieving the corresponding cost reductions, but it begins to consider other aspects such as its image, marketing, and its position in relation to competitors related to sustainability. Finally, the maturation phase is achieved once it has successfully integrated Green IT, in the case of Bose and Luo's study, across its activities across the entire value chain. Many of these aspects are similarly relevant for Greening by IT, but would be more geared to improving non-IT specific operations.

4.3. Conclusion of Sub-Question 1

This chapter was dedicated to answering the first sub-question, which considers the need for a conceptual model to be used in understanding Greening by IT implementation. From the various conceptual models which were reviewed, the model from Bose and Luo (2011) was selected based on its applicability to Greening by IT and ideal basis to structure this study's research. The TOE categories used in the conceptual model are kept, but the influencing factors within them are discarded. More relevant factors to this study are used instead and are omitted from the model at this stage as they are only explored later on. The conceptual model which guides this study in understanding Greening by IT implementation is shown in Figure 4.2.

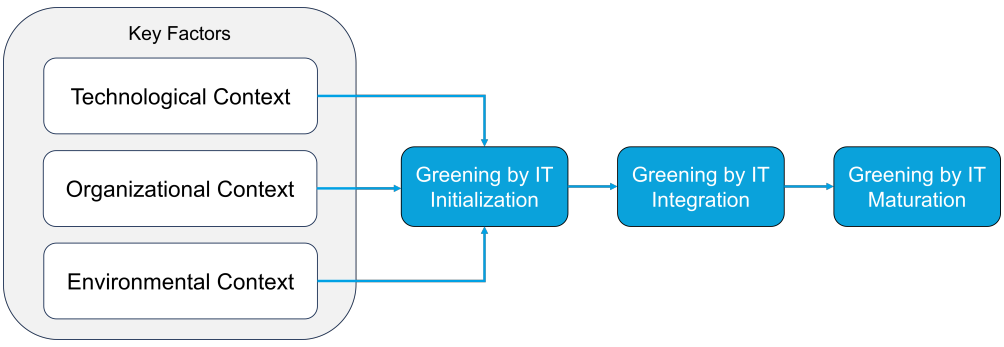


Figure 4.2: Conceptual Model for Greening by IT Implementation

5 Greening by IT Contribution to Airline Sustainability

This chapter answers the second sub-question which asks: ”How can Greening by IT contribute to airline sustainability?” A literature study, using the process described in Chapter 2, is used to define Greening by IT and understand its scope for airlines whereas desk research is used for understanding airlines’ sustainability challenges and potential Greening by IT applications. To begin, an overview of Greening by IT is provided in Section 5.1. Next, the desk research protocol used for reviewing KLM documentation is explained in Section 5.2. Then, an analysis of KLM’s sustainability documentation is outlined in Section 5.3. Following that, potential Greening by IT applications for airlines and practical takeaways from the desk research are shown in Section 5.4. The conclusion of the second sub-question is provided in Section 5.6.

5.1. Synopsis of Greening by IT

In this section, a description of Greening by IT and its potential benefits is shared. The findings presented here are derived from the literature study conducted for this research using the process described in Chapter 2. First off, a comparison between Information Technology and Information Systems is made in Subsection 5.1.1. Next, a description of its definition and contrast to Green IT is discussed in Subsection 5.1.2.

5.1.1. IT vs. IS

After several decades of prior research, the rising importance of sustainability, and the ever-increasing use of IT, numerous studies have emerged in the past couple years attempting to comprehend and structure the knowledge on Greening by IT thus far. The term most often used in literature, although not consistently defined, is ”Green Information Systems”, also known as Green IS. Breaking down this terminology, it is useful to first describe the difference between Information Technology (IT) and Information Systems (IS), which are often used interchangeably, yet have a crucial difference. According to Brooks et al. (2012), IT refers to ”the technology involving the development, maintenance, and use of computer systems, software, and networks for the processing and distribution of data” (p.19). On the other hand, IS is described as ”an integrated and cooperating set of people, processes, software, and information technologies to support individual, organizational, or societal goals” (Brooks et al., 2012, p. 19). The difference lies in the fact that IT describes the technology specifically whereas IS refers to the combination of technology with the corresponding human and process components to further a specific goal.

5.1.2. Defining Greening by IT

When applying the ”greening” or sustainability-related term to these definitions, similar comparisons can be made. Some of the most-cited literature from the mid-to-late 2000’s, written by Watson et al. (2008), describe Green IS as ”the design and implementation of information systems that contribute to sustainable business processes” (p.2) and Green IT as ”mainly focused on energy efficiency and equipment utilization” (p.2). Watson et al. also explain that the potential of Green IS is much more than that of Green IT as it can take on a much larger challenge in making entire systems more sustainable compared to just improving IT itself. Similarly, Jenkin, McShane, and Webster (2011) describe Green IS as ”the development and use of information systems to support or enable environmental sustainability initiatives” (p.18) and Green IT as the initiative which ”addresses energy consumption and waste associated with the use of hardware and software” (p.18). Examples of Green IS range from direct applications such as ”dynamic routing of vehicles to avoid traffic congestion and minimize energy consumption” (Watson et al., 2008, p. 18) to more strategic uses such as developing Executive Support Systems (ESS) for sustainable decision making (Sarkis et al., 2013). Specific measures for the airline industry are expanded upon in Section 5.4.

More recent literature, such as Singh and Sahu’s (2020) literature review of Green IS adoption, highlights the discrepancies in terminology which arise from contradictory use of additional terms such as ”Greening of IT,” Greening by IT,” and ”Green IT/S.” Singh and Sahu then define Green IS as ”the effective and efficient IT/S expertise and set of practices focused on plummeting GHGs emission, carbon footprints and ensuing environment sustainability in the society” (p.3). It is clear that there exists a lack of a concise definition which is extendable to a majority of the research being performed on this topic. Given the confusion that can arise from the difference of Green IT and Green IS and that the focus of this study is on the application of IT for the purpose of ”greening” airline practices, **the author has decided to use the term ”Greening by IT” for this study.** This aids in the research remaining unambiguous in its purpose and consistent in the terminology

used. When referencing literature, this term is treated as synonymous with the use of ”Green IS” in most literature, only when it aligns with the specified intent of this study. Findings for Green IT and Green IS have also been consolidated in literature in the past given their similarities in improving sustainability, yet different focus (Asadi et al., 2017). It is elected to use Jenkin, McShane, and Webster’s (2011) definition of Green IS to represent Greening by IT in this research as ”the development and use of information systems to support or enable environmental sustainability initiatives” (p.18).

Greening by IT, broad in both the definition used and the applications that fall under it, needs to be clarified further. Given that this study is evaluating the implementation of Greening by IT within airlines, it would be most beneficial to only consider aspects relating to the practices which are most beneficial to airlines and those aspects which concern its implementation the most. For example, it is not useful at this stage to consider greatly the resource allocation, impact on external parties, or what standards should be used. This subsection will clarify what type of initiatives will be considered within this study and which will not.

A useful visual, shown in Figure 5.1, illustrates the differences between Greening by IT and Green IT. This uses simplified examples based on Loeser’s (2013) paper on *”Green IT and Green IS: Definition of Constructs and Overview of Current Practices”*. What is most important in this diagram is the discrepancy between Green IT practices and Greening by IT practices. Green IT focuses on the sourcing, optimization, and usage of IT hardware and software whereas Greening by IT looks at the application of IT on business processes and its impact decision-making.

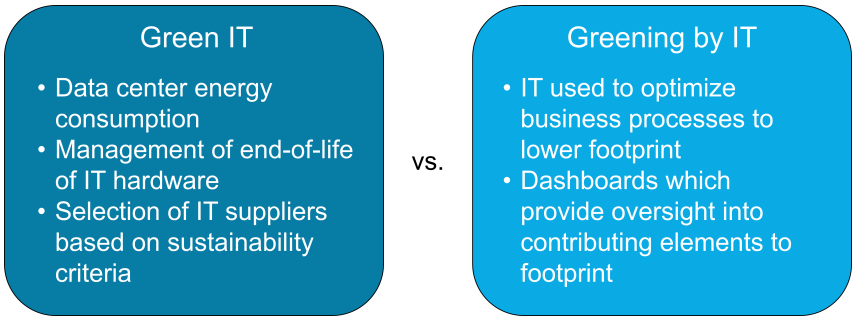


Figure 5.1: Green IT vs. Greening by IT

As made clear in the figure, it is not of interest for this study to consider Green IT practices nor the aspects of Greening by IT related to the external market. This is not considered to be particularly interesting for initial implementation within airlines and its assumed that the most impactful measures would lie in the optimization of business processes with IT, in the Organizational category identified by Loeser. The strategy for Greening by IT and alignment needed between IT and business from the IT Department category is also considered to be useful for this study. This is included given that the strategies for Greening by IT are central to this study and naturally have an impact on its implementation.

One final discrepancy which must be distinguished is the difference between Greening by IT adoption and implementation. **Most literature uses the term adoption, which generally refers to the organizational process involved in deciding to commit to Greening by IT, but the focus of this study is largely on its implementation, the actual process of putting Greening by IT into practice.** The two terms naturally have some overlap, so when discussing literature and its findings, the word adoption is used. But since the objective of the thesis is on putting it into practice, the word implementation is used more frequently.

5.2. Desk Research Protocol

An overview of the objectives and the types of data sources can be found in Table 5.1. The KLM resources sought out are a make up of IT-specific and KLM corporate documentation. The IT-specific documents are used to elaborate on the measures already being taken within IT and what the main strategies are. KLM corporate sustainability documents were reviewed to identify the main challenges the airline faces and identify their strategies.

Table 5.1: Desk Research Objectives & Corresponding Data Sources

Objective	Data Source
Generate list of potential Greening by IT applications	1. Informal discussions with KLM employees 2. Documentation of past Greening by IT initiatives
Comprehend primary sustainability challenges & corresponding objectives of KLM	1. KLM Sustainability "Flight Plan" 2. IT Matters Intranet site & documentation

5.2.1. Search Strategy

The search strategy is comprised of a snowballing method in conjunction with suggestions made by KLM employees. As it was not previously known by the researcher what sustainability strategy or Greening by IT documentation exists, KLM employees within the CIO Office were asked for advice when searching for useful resources. These documents could be in the form of yearly reports, presentations, or project evaluation documentation. A necessary first step was first checking together with this study's supervisor at KLM if any contents of the documents were confidential. As stated in the Data Management Plan submitted for this study, confidential information was not sought out on purpose, but it may be stumbled upon inadvertently. As a final step, the thesis report and findings are reviewed with KLM employees within the CIO Office and D&T to check for any confidential information. When searching without assistance from KLM employees, KLM's intranet search function was used to look for additional resources and snowball further based on the suggestions made by employees.

5.2.2. Search Criteria

The main criteria used when selecting sources were based on two things: the relevance to the research topic and the publication date. The first point was used to avoid expanding the scope unnecessarily and only put effort into reviewing documents which were pertinent. The latter is important to keep the findings relevant to the current situation, as there might be strategic overviews or presentations from several years ago which no longer reflect the current situation. It is decided to set a limit for this desk research to not include any sources from before 2013, in order to include any 10 year plans which were implemented that year whose results can now be evaluated.

5.2.3. Data Collection & Accessibility

Documents that are used from KLM were kept on the KLM computer given to the researcher and documents which exist on the KLM intranet were kept there and not downloaded. If KLM employees sent documents as suggestions, they were first asked if the documents are okay to be used for the purpose of the study and if any confidential information is present within them. Given that all documentation was kept on the KLM laptop and if applicable, not downloaded from the intranet, there were no extensive measures needed to properly store the documents. Caution was still maintained when reviewing the documents when working off of the KLM campus as to not inadvertently leak information that way.

5.3. KLM Sustainability

This section will explore the key challenges, objectives, and strategies used by KLM regarding sustainability. **Any information in this section can be assumed to come from KLM in their 2023 "Climate Action Plan" (KLM Sustainability Office, 2023).** If another source is used, it will be referred to specifically. As stated in the introduction, when referring to sustainability, it mainly refers to the climate impact due to the emissions from KLM flights. The plan also considers waste generated by the flights and other operations, but will not be expanded upon as much in this section. The challenges, objectives, and strategies will be described separately in Subsection 5.3.1, Subsection 5.3.2, and Subsection 5.3.3.

5.3.1. KLM Sustainability Challenges

In 2022, KLM's direct CO_2 emissions amounted to 9.07 Mt, 99% of which was a result of the consumption of jet fuel in operations. This is clearly the largest impact that KLM makes on the environment and should be the focus of a majority of the mitigation measures that are taken. Non-CO_2 effects, such as the effects from contrails, are not included in calculations due to the lingering scientific disagreements on their impact. Before looking at each of KLM's emission scopes, it is first important to explain the three scopes used in emissions quantification.

- Scope 1: The direct emissions resulting from the operations of the company (Teske, 2019).
- Scope 2: The indirect emissions produced by the energy the company purchases (Teske, 2019).
- Scope 3: The sector-specific, indirect emissions as a result of the organization's activities, but which are not directly controlled by the organization (Teske, 2019).

Looking at KLM specifically, 73% of its total emissions come from scope 1, 0.2% comes from scope 2, and 27% comes from scope 3. This is best explained by the Figure 5.2 which was created by KLM as a part of the Climate Action Plan document.

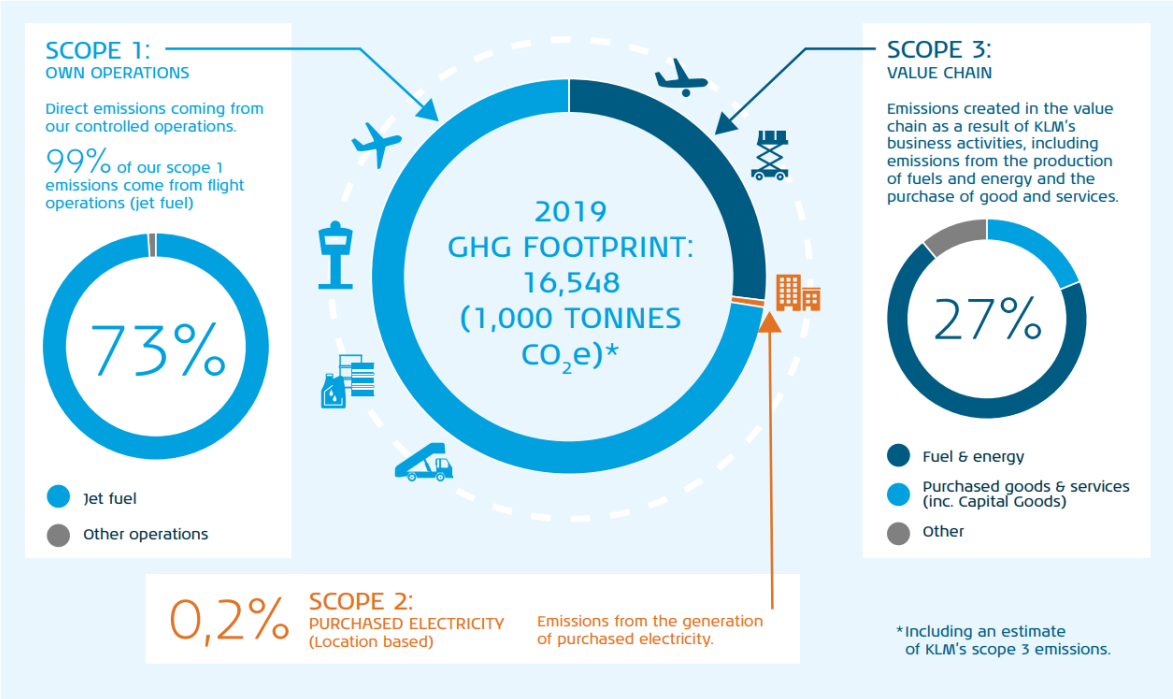


Figure 5.2: Breakdown of KLM total emissions by emission scope (KLM Sustainability Office, 2023)

As can be seen, nearly all of the scope 1 emissions are a result of jet fuel coming from KLM's operations. Scope 2 makes up a fraction of a percent of KLM's total emissions, resulting from the purchased electricity for powering KLM's buildings. Scope 3 can be broken down by the emissions produced earlier in the life cycle by fuel and energy, the purchased goods and services, and other contributions which are not specified.

The Climate Action Plan mentions other sustainability challenges such as noise pollution, particulate matter emissions at Schiphol, nitrogen emissions, and waste. It does not explain these in much detail, which reinforces the point that they are of lesser importance compared to the emissions resulting from flight operations.

5.3.2. KLM Sustainability Objectives

KLM has set several ambitious targets for overcoming these challenges for the coming decades. The objectives can be largely broken down into those for 2030 and the goal for 2050, which is to have net-zero emissions. The 2030 goals can be summarized as the following:

- Zero ground emissions
- -12% absolute CO_2 emissions compared to 2019
- -50% non-residual and non-hazardous waste
- 10% Sustainable Aviation Fuel (SAF) usage worldwide

Zero ground emissions means that KLM aims to have zero ground emissions resulting from ground operations at the airport by 2030. This means that as soon as the aircraft touches down, the rest of the segment including taxiing, turnaround at the gate, and departure will not generate any emissions. This is incredibly

ambitious considering the large amount of vehicles which will need to be converted to electric versions and the necessary infrastructure needed to support them. Avoiding emissions from aircraft while taxiing is also a tremendous challenge and will likely require new types of non-emitting vehicles which can tow the aircraft as required.

When describing the second objective, to reduce absolute, or total, CO_2 emissions, it is best to refer to Figure 5.3, which illustrates KLM's predicted absolute CO_2 emissions and the impacts of various initiatives.

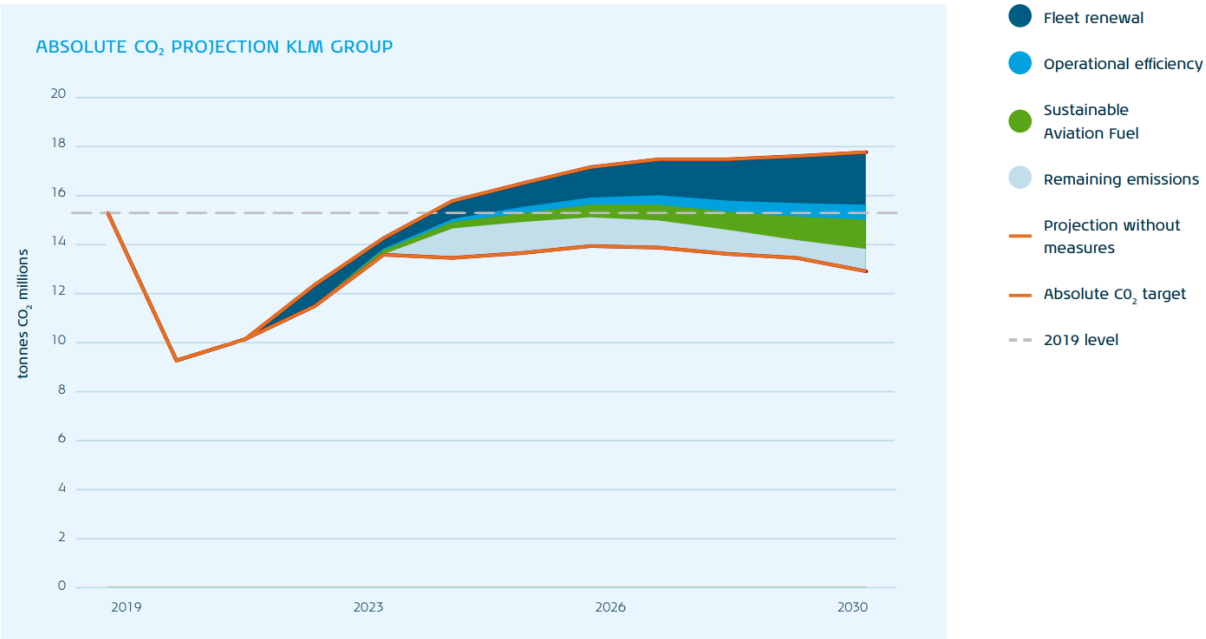


Figure 5.3: KLM Future Absolute CO_2 Emissions (KLM Sustainability Office, 2023)

Following the bottom orange line, which represents the absolute CO_2 target, one can see that in 2030, it should be at a level which is 12% of the start of the line in 2019. KLM also specifies a waste reduction goal of -50%, which is not expanded upon greatly in the report. The waste from KLM's operations consists of catering waste (65%), on-board cleaning waste (10%), and from E&M and Cargo processes (25%). The objective regarding sustainable aviation fuel usage is described in Subsection 5.3.3.

5.3.3. KLM Sustainability Strategies

The Climate Action Plan breaks down three strategic pillars for accomplishing their goal in becoming a front-runner in sustainable aviation. The first pillar is to transform to a net-positive company, which creates more value for the world than it consumes. The second pillar is to create technological advancement which focuses on creating the technology needed to make aviation sustainable. The third pillar is to run a great airline for their customers and employees, which cements the need to include this in decision-making related to sustainability. It breaks these down into four categories of measures being fleet renewal and radical innovation, flight operational efficiency, sustainable aviation fuels, and other measures.

Fleet renewal and radical innovation

This strategy comprises of investing in new aircraft which are more fuel-efficient and therefore result in fewer emissions from flying. Examples of this include replacing the Boeing B737-800 which the A321neo which emits 20% less CO_2 per passenger kilometer and replacing the Boeing 747-400 with the Airbus A350F freighter which consumers 40% less fuel. KLM expects that these renewal efforts will result in a 12% contribution to its 2030 CO_2.

Flight operational efficiency

This strategy can be broken down into measures that KLM can take itself to optimize its flights and those it can take together with regulatory partners, accounting for a 4% reduction in CO_2. For the measures KLM can take itself, this consists of route optimization, weight reduction, and more fuel efficient procedures. For

example, using advanced route planning algorithms, AI tools, and optimizing taxiing operations are all listed as potential measures. For weight reduction, KLM plans to reduce the weight of catering equipment, carry less water on its flights, and improve the required fuel modeling to carry less and as a result, burn less. The measure which KLM can take on with regulatory partners is to redesign EU and Dutch airspace to make them more efficient, which could result in 2% lower emissions.

Sustainable Aviation Fuels

Sustainable Aviation Fuels (SAFs) are fuels which are produced from plant or animal resources, instead of oil like conventional aviation kerosene. The main attractive point with these fuels is that they lower the absolute emissions produced in the life cycle from extracting and producing the fuel, potentially up to 65% of absolute emissions from aviation (*Net-Zero Carbon Emissions by 2050*, 2021). KLM requires the SAFs that it uses to have at least a 75% lower life cycle than traditional kerosene, have a minimal impact on biodiversity, and have no impact on food or animal feed production. Soy and palm oil cannot be used as feed stocks for the fuel. The goal to include 10% SAF on all flights in 2030 will contribute 8% of the 2030 target.

Other measures

KLM states that additional measures are needed to makeup the remaining gap to its goal or consider purchasing additional SAF, which is typically quite expensive. These are not extensively discussed further in the Climate Action Plan.

5.3.4. Conclusions for Greening by IT based on KLM Sustainability Desk Research

Looking at the sustainability challenges that KLM faces and the objectives it has set, there is no doubt that massive advancements will need to be made in the coming years, to at least meet its 2030 goals. Greening by IT could aid in these advancements in several ways, particularly for the strategy to optimize flight operations, which make up nearly all of the scope 1 emissions. The other strategies using SAFs and fleet renewal are not strategies where Greening by IT would be directly applied, but could benefit from the enhanced data quality and oversight that it could provide. Looking purely at the potential 2% reduction mentioned for achieving greater flight operation efficiency, Greening by IT applications could make up a large portion of that. In order to further explore these potential applications, Section 5.4 looks at various examples per KLM business which were gathered from informal discussions around the company.

5.4. Greening by IT Applications

As a final step in answering the first sub-question on how Greening by IT can contribute to airline sustainability, it was decided to create a Greening by IT applications table. This table is categorized by several example KLM business domains and comprises of example applications of Greening by IT and the sustainable contribution they make. This table is created through suggestions compiled from KLM employees within the CIO Office, informal discussions had with various KLM Sustainability Leads throughout the company, and members of the corporate KLM Sustainability Office. Every KLM business has a single Sustainability Lead which is responsible for developing sustainability within the business and works in conjunction with the corporate-level Sustainability Office. Various Greening by IT initiatives which were already implemented are included along with several that are currently being evaluated for the future.

Inspiration is taken from Loeser's (2013) table of potential initiatives with categories based on IT Governance, the Organization, the External Market, and so on. It is decided to categorize this applications table based on the various KLM businesses such as Cargo, Engineering & Maintenance, Flight Operations, Ground, and In-Flight Services. Similar to Loeser, a category for IT Governance will also be included as there will likely be crucial steps to be taken within IT which do not involve the KLM businesses directly. The table can be found in Figure 5.4.

Category	Greening by IT Application	Sustainability Impact
IT Governance	Developing better models to measure Scope 3 footprint (cost vs. use based)	Improves data on footprint for developing future measures
	Integration of sustainability responsibilities into organizational functions	Improved organizational structure to facilitate GBIT initiatives
	Creation and monitoring of Greening-by-IT-related KPIs	Improved governance on progress with GBIT
	Sustainability criteria implemented into project evaluation process	Potentially results in additional GBIT solutions being taken on
	Formation of IT-specific Greening by IT strategy	Increased organizational focus & tangible results
Cargo	Optimized load sheets for cargo to decrease drag during flight	Decreased flight emissions
	Improved data quality for residual packing waste	Decreased fuel emissions & less material waste
	Improved data quality for building energy use	Decreased energy usage from cargo buildings
Engineering & Maintenance	Predictive models for scheduling maintenance	Decrease material loss from failed parts
	Model analyzing footprint impact for replacing certain components	Decreased flight emissions
	Improved waste data quality to aid in strategic decision-making	Decrease material loss from failed parts
	Software to quantify scope 3 emissions from suppliers	Decreased scope 3 emissions
Flight Operations	Machine learning tool to optimize climb/descent flight patterns	Decreased flight emissions
	Improving data quality of aircraft parameters (engine settings, fuel flow, etc…)	Improves data quality for fuel-optimization software
	Arrival management software to coordinate cross-continent arrivals	Decrease fuel emissions from delaying incoming traffic
	Devices to store cockpit manuals electronically	Decreasing waste from paper versions
	Flight planning software to avoid contrail creation	Decreased non-CO2 effects from flight
Ground Services	Application to enable self-service for passengers baggage handling	Less baggage terminals needed & lower electricity usage
	Predictive models for passenger connections & corresponding flight planning	Decrease excess fuel & consumables usage
	Improved data quality for ground ops and pilot coordination	Decreased emissions from APU use & delayed engine start
	"Smart gating" algorithm to assign incoming aircraft nearest available gate	Decreased emissions from taxiing
In-flight Services	Meals on Board - algorithm for better meal planning	Reduced fuel use & less food waste
	Incorporate passenger meal confirmation into check-in process	Reduced fuel use & less food waste
	Expand meal planning algorithm to include drinks package per flight	Reduced fuel use & less food waste
	Application to manage flight operational information for cabin crew	Decreasing waste from paper versions

Figure 5.4: Greening by IT Applications at Airlines

A disclaimer must be included in that while some of these applications have already been put into practice, others have not been tested yet. Going forward, these applications are used in the stakeholder interviews with several KLM stakeholders conducted in Chapter 5 to investigate the barriers and enablers. These application examples can help the participants recall any potential obstacles that they run into or what helped overcome them.

5.4.1. Practical Takeaways & Strategic Implications from Desk Research

As has been demonstrated, KLM's Climate Action Plan provides several strategies to carry out the sustainable transition of the company, but the execution of the strategy faces numerous challenges in practice. In every one of the discussions with sustainability leads around the company, several questions were posed. The leads were asked to describe the primary sustainability challenges in their area of the company. Then, they were asked how IT could be used to help solve their sustainability challenges. Several of them were unsure and did not have ideas on how IT could help. This signals a shortcoming in the awareness of the potential of Greening by IT and demonstrates that there is also an opportunity to drive things further. This contrasts with the Climate Action Plan where achieving greater efficiency through IT applications is specifically mentioned as a core strategy. Most of the sustainability leads were also not aware of how IT was structured within their area of the business and how it is interfaced with KLM IS. One also made it clear that although IT is an enabler for business goals, that IT should not hide behind this. They encouraged KLM IS to take the lead with this and put more effort into making business stakeholders aware of the potential IT solutions can offer.

Also asked in these discussions was whether sustainability criteria were applied in project portfolio management within their area. The overwhelming answer was no, there are currently no criteria applied when evaluating different projects and the decision-making on which to take up. Overall, they also made clear that they need a stronger vision and firmer commitment from KLM upper management. They mentioned that this

would help with the roll-out of Greening by IT as the added pressure from upper management would help align business stakeholders. It was heard in multiple discussions that these motivated, sustainability leads often get dismissed when raising concerns around the company from stakeholders who are more focused on operational concerns. Having more pressure from KLM's leadership would help overcome this.

Within KLM IS itself, there is an initiative called IT Matters which comprises of Air-France and KLM employees who dedicate a small portion of their time to working on sustainability within IT. There is an intranet page which explains the initiative and distinguishes their efforts between Green IT and Greening by IT. Yet, after a review of all of the available site pages, there is nearly no content on Greening by IT. Almost all of the content is focused on Green IT. There was one sub-page found called Greening by IT which describes its goal as decreasing the environmental footprint of in-house applications, which actually falls within the definition of *Green IT*. One of the main features of the site is an IT CO_2 Reduction Dashboard which shows the following:

- Green score of scan-able applications
- Sustainability Code of Conduct signatures with IT suppliers
- Electricity consumption of IT buildings and data centers
- Number of employees who attended a climate awareness workshop

It can be concluded that all of these factors are related to Green IT and there are no metrics included which measure Greening by IT, or IT's contribution to CO_2 reduction in the rest of the airline. Also displayed on the dashboard is a conversion of the absolute emissions of AFKL IT in the first quarter of 2024, which is also shown in equivalent emissions for 29 round-trip flights between Amsterdam and Rio de Janeiro, Brazil. Given that this is a flight that happens multiple times a week for KLM, one must beg to question why so much effort is put into Green IT and reducing the footprint of KLM IS, when it contributes so little to lowering the total emissions of KLM.

Using the total emissions of AFKL IT for the first half of 2024, 32400 tons of CO_2, and doubling it, one can estimate a total emission of 64800 tons of CO_2. As mentioned in the KLM Climate Action Plan, the total emissions of KLM were 9.07Mt of CO_2 in 2022 (KLM Sustainability Office, 2023). Assuming the same amount for 2024, KLM's IT contribution amounts to 0.7% of total CO_2 emissions. Even if Green IT measures could reduce this from 0.7% to 0.5% for example, the impact is still much less than if a flight optimizer or climb & descent optimizer was applied for all KLM aircraft. The contrast is striking and demonstrates the untapped potential of Greening by IT to contribute to reducing KLM's total emissions.

5.5. Validation of Results

First off, the results from the desk research of KLM sustainability documents was discussed with several employees within the CIO office, consisting of upper IT management. Several of these employees reinforced the point that despite most of the total emissions of KLM coming from fuel consumption on flights, most of the effort done within IT is on Green IT initiatives. These initiatives consist of things like a dashboard to measure the energy consumption of the IT office, campaigns for people to delete emails, or to remove intranet sites which are not longer in use. They reiterated that although these measures do help make people feel like they contribute and that they do make a small impact, it pales in comparison to any reductions in fuel consumption which could be made. Additionally, they agreed that there is still no road map for how IT plans on achieving the sustainability goals set by the corporate level.

The list of Greening by IT applications was also presented in several update meetings around the company. Several of the applications were based on initiatives which either have been or are currently being implemented, such as algorithms for optimizing meal planning or aircraft climb/descent. As a result, many of the applications were recognized and the ones not implemented yet were reinforced as potential options in the coming years. They did, however, confirm some of the complexities which arise when considering some of these options. For example, in a discussion with a pilot, they confirmed that they are working on implementing the optimization tool for climb and descent, but that there is a lot of engine data which they need which is not currently recorded. All in all, many of the findings from this chapter were confirmed and validated through discussions with Sustainability Leads within the various businesses, employees within the CIO Office, stakeholders within D&T.

5.6. Conclusion of Sub-Question 2

This chapter answered the question posted by the second sub-question, asking how Greening by IT can contribute to airline sustainability challenges. Through the reviewing of KLM sustainability documentation and

discussions with sustainability leads around the company, it was demonstrated that there are numerous possible applications for Greening by IT to contribute to overcoming the challenges outlined in the KLM Climate Action Plan, some of which are already included within the proposed strategies. Greening by IT was concluded to be able to potentially save at least 2% of the airline's fuel consumption and play a crucial role in understanding the contributing elements to the other sustainability challenges. Yet, when investigating the sustainability intranet pages within IT, a majority of the efforts thus far have been put into Green IT, which would only help reduce a small fraction of KLM's absolute footprint in comparison given that 99% of KLM's scope one emissions come from jet fuel combustion.

Despite the acknowledgment of IT's potential to contribute to KLM's sustainable transition, it was made evident during several discussions with Sustainability Leads around the company that there is a lack of understanding of how to leverage IT in practice. To answer the sub-question and improve this understanding, a list of Greening by IT applications relevant to several KLM business streams was created. The examples from this applications list are used to facilitate the discussions in the stakeholder interviews. For the rest of the study, these findings provide a basis for exploring the influencing factors and strategies for implementing Greening by IT.

6 Barriers and Enablers of Greening by IT Implementation

The objective of this chapter is answer the third sub-question, which prompts: ”What are the barriers and enablers of Greening by IT implementation within airlines?” A literature study is used to evaluate factors identified in prior research, which can be found in Section 6.1. Next, the use-case within KLM is described in Section 6.2 and is followed by Section 6.5 which analyzes stakeholders to for selecting interview participants. Then, the protocol used for conducting the stakeholder interviews is explained in detail in Section 6.4. The coding analysis of these interviews and the semi-quantitative analysis of the factor rankings follows in Section 6.5. The validation steps taken following this chapter is explained in Section 6.6. The chapter is concluded with Section 6.7 which answers the third sub-question.

6.1. Literature Study Results: Greening by IT Implementation Factors

Before conducting interviews and researching the key factors within the setting of KLM, it is first crucial to explore prior literature to understand what factors have already been identified previously. To begin, 21 papers were selected for use in answering this sub-question based on their relevance to the topic and can be found listed in Appendix B. Most of these papers explore the barriers and enablers to Greening by IT Implementation through the use of case studies, surveys, or literature reviews. Given that many of the case studies and surveys were performed in various industries and countries, a brief description of the method was noted when reviewing each paper. Any barriers and enablers identified in the papers were summarized shortly and added to the list. A similar method to Jongsaguan and Ghoneim (2017) was used to select which factors would be included by scrutinizing each of them based on their significance to the topic and repetition within the papers that were read. For the purpose of this review, it is assumed that Green IT and Greening by IT would encounter similar barriers and enablers. This is decided as even though their purposes are not the same, they are both sustainable initiatives which are likely to conflict with the status quo and both revolve around the use of IT. Therefore, for the purpose of this review, they are not separated to help illustrate the knowledge landscape.

6.1.1. Method & Factors Table

Once the initial review of the 21 papers was complete, several rounds of categorization were performed within the Technology-Organizational-Environment Framework to organize the findings, in line with the conceptual model designed in Chapter 4. The TOE framework offers an effective blend of the internal organizational factors which could impact implementation, along with the elements related to Greening by IT technology itself and the external factors from the Environmental category. Not all of the factors identified in each paper were included in the final list shown in Figure 6.1. Factors were selected based on whether they were mentioned by multiple studies or were considered interesting to evaluate further in the airline context. When similar-sounding or closely-related factors were found, they were either grouped together or a factor title which better matched the description was devised. A full overview of the factors found in each paper from the literature study can be found in Appendix B.

It is also necessary to define what is meant as a barrier, enabler, and what other terms are often used in literature. For this purpose, the following definitions are used, drawing inspiration from (Luken et al., 2019):

- **Barriers:** factors which make it difficult to implement Greening by IT when organizations do decide to use it
- **Enablers:** factors which lower the barriers for Greening by IT implementation
- **Drivers:** factors which pressure organizations to implement Greening by IT

All of the identified factors can be seen in Figure 6.1. The barriers and enablers are categorized in the Technological and Organizational categories, whereas the drivers are grouped together in the Environmental category.

	Barriers	Sources	Enablers	Sources
Technological	Long development time	Savita et al. (2014)	Able to measure impacts	Seidel et al. (2010)
	Lack of technical infrastructure	Volkoff et al. (2011); Kirchner-Krath et al. (2024)	Accessibility of data	Seidel et al. (2010)
	Lack of metrics to measure impact	Schmidt et al. (2010); A. J. Chen et al. (2011); Savita et al. (2014)	Technical Compatibility	Deng & Ji (2015)
	Technological complexity	Deng & Ji (2015); Bokolo (2016)		
Organizational	Lack of prior experience	Schmidt et al. (2010); A. J. Chen et al. (2011); Bose & Luo (2011); Bokolo (2016)	Positive organizational attitude towards sustainability	Jenkin, Webster, & McShane (2011); Gholami et al. (2013); Baggia et al. (2019); Kirchner-Krath et al. (2024)
	Lack of standards	Schmidt et al. (2010); A. J. Chen et al. (2011)	High motivation of employees	Schmidt et al. (2010); Seidel et al. (2010); Molla & Abareshi (2012); Brooks et al. (2012); Kirchner-Krath et al. (2024)
	Ambiguity on how to apply regulations	Volkoff et al. (2011)	Prior experience	Schmidt et al. (2010); Hu et al. (2017)
	Ambiguity in responsibility	Kirchner-Krath et al. (2024)	IT department size	Carberry et al. (2017)
	Uncertain which initiatives have largest impact	Molla & Abareshi (2013)	Senior management leadership	Schmidt et al. (2010); Molla & Abareshi (2012); Deng & Ji (2015); Bokolo (2016); Hu et al. (2017); Carberry et al. (2017); Singh & Sahu (2020)
	Lack of immediate payback	A. J. Chen et al. (2011); Savita et al. (2014)	IT strategy embedded in overall business strategy	Seidel et al. (2010)
	Lack of resources	Bose & Luo (2011); Molla & Abareshi (2013); Buchalcevova & Gala (2013); Bokolo (2016); Schmermbeck et al. (2020); Kirchner-Krath et al. (2024)	Sufficient resource allocation	Molla & Abareshi (2012)
	Cost of solutions too high	Savita et al. (2014); Kirchner-Krath et al. (2024)	Good economic environment	Brooks et al. (2012)
	Unclear business value	Bose & Luo (2011); Buchalcevova & Gala (2013); Savita et al. (2014); Bokolo (2016); Schmermbeck et al. (2020)	Perceived value of technology	Deng & Ji (2015)
	Not considered a priority	Bokolo (2016); Schmermbeck et al. (2020)	Defined Greening by IT strategy in IT	Seidel et al. (2010); Deng & Ji (2015); Bokolo (2016); Yang et. al. (2017)
	Lack of leadership from management	Bose & Luo (2011); Bokolo (2016)	Org. has sustainability-oriented strategy	Schmidt et al. (2010); Baggia et al. (2019)
	Drivers		**Sources**	
Environmental	Coercive pressure (gov't regulations, suppliers, customers, shareholders)		A. J. Chen et al. (2011); Brooks et al. (2012); Gholami et al. (2013); Buchalcevova & Gala (2013); Deng & Ji (2015); Bokolo (2016); Carberry et al. (2017); Hu et al. (2017); Baggia et al. (2019); Singh & Sahu (2020); Singh & Sahu (2021); Chen & Roberts (2023); Kirchner-Krath et al. (2024)	
	Mimetic pressure (competitors' practices, strategies, and structures)		A. J. Chen et al. (2011); Buchalcevova & Gala (2013); Deng & Ji (2015); Bokolo (2016); Hu et al. (2017); Baggia et al. (2019); Singh & Sahu (2020); Singh & Sahu (2021); Chen & Roberts (2023)	
	Normative pressure (media, public opinion, industry standards)		Deng & Ji (2015); Loeser et. al. (2016); Bokolo (2016); Carberry et al. (2017); Hu et al. (2017); Singh & Sahu (2020); Singh & Sahu (2021); Chen & Roberts (2023)	

Figure 6.1: Barriers, Enablers, & Drivers of Greening by IT Implementation

6.1.2. Barrier Identification

In this subsection, the barriers identified in the literature study are described. The explanations are broken down between the Technological barriers and the Organizational barriers.

Technological Barriers

Lack of technical infrastructure

The lack of technical infrastructure is best described by Volkoff et al. (2011) in that infrequent use or a lack of universal access to the system leads to issues. For example, it was observed that a lack of digital access

led to specialists spending most of their time doing data entry instead of performing analyses (Volkoff et al., 2011). Extending it to Greening by IT, any proposed applications would see additional obstacles if it is not well-integrated within current infrastructure or cumbersome to use.

Long development time: Long development times could hinder the decision to implement Greening by IT as it would mean that any resulting payoff from its use would be only felt long after the decision was made. This might make justifying and motivating the decision to invest in Greening by IT more difficult. This impacts the choice to implement as other projects might seem more appealing (Savita et al., 2014).

Technological Complexity: Additionally, technological complexity has been described as a barrier as it could impact the understanding of the potential of Greening by IT and what would need to be done to implement it. Deng and Ji (2015) refer to the fact that complexity will negatively impact the perception of ”ease of use” which would act as a natural impediment to the decision to utilize Greening by IT.

Lack of metrics to measure the impact: Furthermore, several studies concluded that a lack of metrics to measure the performance of Greening by IT initiatives was a key obstacle to its use (A. J. Chen et al., 2011; Savita et al., 2014; Schmidt et al., 2010). This is inherently difficult as the organization should already posses quality data measuring its emissions, electricity usage, material usage, etc... to determine the impacts after implementation. The impacted processes might be extremely complex which could make it difficult to determine whether any changes were due to the Greening by IT initiative or other factors. Lacking well-defined indicators and the associated data to measure them would be an obstacle in implementing Greening by IT.

Organizational Barriers

Lack of prior experience

A lack of prior experience was found to be a barrier in several papers as it raises the learning curve needed to implement Greening by IT and makes various aspects related to it more uncertain (D. Q. Chen et al., 2010; Schmidt et al., 2010). Having prior experience also makes organizations more aware of the benefits and best practices for Greening by IT (Schmidt et al., 2010).

Lack of standards

A lack of standards was similarly found to be an obstacle as these standards would guide the use of Greening by IT and not having them makes the implementation process more uncertain (Schmidt et al., 2010). One could reason that not having standards also raises the amount of effort needed to implement an initiative as there is no defined method or system in place to set it up. Singh and Sahu (2021) found that high effort expectancy also obstructs implementation as a steep learning curve for adopting a new system decreases its attractiveness. Similar to the previous factors, unfamiliarity with the proposed system was also found to be an obstacle as it again diminishes its appeal(Volkoff et al., 2011).

Ambiguity in responsibility & Ambiguity in how to apply regulations

Volkoff et al. (2011) identified both an ambiguity in responsibility and in how to apply existing regulations as barriers as it makes it less clear who should be responsible for implementing Greening by IT and how any regulations which drive its implementation can be translated into actionable tasks. These factors are obstacles as it requires more alignment and coordination between stakeholders, raising the bar with regards to the amount of effort needed to implement Greening by IT solutions.

Uncertain which initiatives would have largest impact

Molla (2013) concluded that uncertainty regarding which Greening by IT initiative would lead to the greatest impact obstructed any action being taken in the end, likely resulting from limited resources. This uncertainty refers to the outcome or success of a Greening by IT initiative being unclear and becomes an obstacle to it being taken up (Schmidt et al., 2010). This barrier is crucial as businesses likely have numerous aspects in which they must improve and knowing which area to focus efforts to make the largest sustainable impact is inherently complex.

Unclear business value

Several studies found that if the benefits or added value to business was unclear, Greening by IT implemen-

tation was also hindered (Bokolo, 2016; Buchalcevova & Gala, 2012; Savita et al., 2014; Schmermbeck et al., 2020). This is easily understandable through the lens that if an initiative only has sustainability benefits and does not add any business value or even detracts from it, it will be much harder to justify.

Not considered a priority
Greening by IT not being a priority or other priorities being more important was also identified as a barrier to Greening by IT implementation (Bokolo, 2016; Schmermbeck et al., 2020). This is relatively straightforward in that if Greening by IT is not seen as a priority in the first place, it will be way more cumbersome to implement.

Lack of leadership from management
It was also found that a lack of leadership from senior management stunted the implementation of Greening by IT (Bokolo, 2016; Bose & Luo, 2011). This is relatively straightforward, as management is often the decision-maker which sets objectives and allocates resources.

Lack of immediate payback
Regarding the lack of an immediate payback, A. J. Chen et al. (2011) saw that this prevented organizations from readily accepting Greening by IT, especially organizations which were very focused on profit. This falls in line with the previous barriers as it makes it harder to justify investing in Greening by IT solutions where the value is uncertain.

Lack of resources
Numerous studies identified a lack of resources or small IT budget as being critical, as implementing a new Greening by IT initiative is likely to require additional resources (Bokolo, 2016; Kirchner-Krath et al., 2024; Molla, 2013; Schmermbeck et al., 2020). Jongsaguan and Ghoneim (2017) state that while organizations often use traditional evaluation techniques such as the net present value or internal rate of return, they do not always incorporate intangible impacts or non-financial factors. This is further amplified when coupled with the previous factor, a lack of an immediate payback, as it makes justifying the investment even harder.

Cost of solutions too high
Lastly, high upfront costs were also seen to obstruct Greening by IT in several studies. Similar to the previous barrier, organizations might be very interested in Greening by IT, but lack the capital to cover the upfront costs needed to implement it (Bokolo, 2016; Buchalcevova & Gala, 2012; Kirchner-Krath et al., 2024; Savita et al., 2014). This is further complicated by it being naturally hard to quantify the indirect costs associated with investing in Greening by IT initiatives (Jongsaguan & Ghoneim, 2017). Greening by IT can result in extended costs due to organizational restructuring, disposal of existing hardware, and re-training that might need to occur (Jongsaguan & Ghoneim, 2017), which further reduces the attractiveness to implement it.

6.1.3. Enabler Identification
Next to be covered are the enablers, or the factors which can lower the identified barriers. Similar to the previous section, the enablers are broken down into Technological and Organizational enablers.

Technological Enablers
Able to measure impacts
Being able to measure the impacts of any implemented Greening by IT initiative would be instrumental in diminishing uncertainty on its effectiveness and monitoring its performance. The main measurements would revolve around the sustainability variables that the initiative would have aimed to improve such as carbon emission reduction (Seidel et al., 2010).

Accessibility of data
As discussed further by Seidel et al. (2010), the transparency of the collected data is also key to highlighting where environmental performance is poor and where it is good. Providing this information makes it possible to benchmark the resulting impact of any new initiative and makes it possible to manage it further (Seidel et al., 2010).

Technical compatibility
Regarding technical compatibility, Deng and Ji (2015) concluded that it would be a key enabler for implementing Greening by IT as it would make it easier to interface with existing infrastructure within the organization. Given that Greening by IT could upend the status quo for certain processes, it being compatible from both a software and hardware standpoint would go a long way to overcoming resistance to implementation (Deng & Ji, 2015). Bokolo (2016) identified maturity of existing Greening by IT systems as an enabler, which is grouped together with technical compatibility. If the organization has already implemented a system in the past and is actively using it, this could be an effective facilitator for further initiatives as it is likely to be more technically compatible.

Organizational Enablers

Positive organizational attitude towards sustainability
The attitude towards sustainability represents the attitude of management, the employees, and the organization overall to sustainability and the Greening by IT initiatives. The attitude of employees towards Greening by IT and their attitude towards environmental issues is crucial (Molla & Abareshi, 2011). This is further demonstrated by the fact that forcing these initiatives on employees has been observed to make them indifferent to the subject (Kirchner-Krath et al., 2024). Several studies also concluded that the management's attitude was a key predictor of Greening by IT implementation (Baggia et al., 2019; Brooks et al., 2012; Gholami et al., 2013). The attitude of the manager was found to play an important role in including sustainability in the strategy in the company (Baggia et al., 2019). Additionally, Baggia et al. (2019) exemplified the fact that organizational attitudes translate into the organizational strategy and resulting decisions on Greening by IT implementation, which also makes it very important.

Motivation of employees
Seidel et al. (2010) further explained that the intrinsic motivation of employees, or how attached they are to the Greening by IT solution, and the extrinsic motivation, such as the sustainability objectives that the organization has committed to, are crucial enablers. Bottom-up support also makes it easier to locate people within the organization who are motivated to take up Greening by IT projects and implement solutions in the existing day-to-day processes (Seidel et al., 2010).

Senior management leadership
Complementary to this is the vision and leadership of senior management which can act as an facilitator for spurring the implementation of Greening by IT (Bokolo, 2016). It was also concluded to be an enabler by Jenkin, Webster, and McShane (2011) as it would play an important role in formulating the sustainability strategy of the organization and driving Greening by IT as a means to carry out. Seidel et al. 2010 mention top management support for Greening by IT, particularly that from the CEO and COO, as an enabler as it ensures "both strategic commitment and support for making changes in the day-to-day operations" (p.6).

Prior Experience
Similar to the barrier that was identified regarding experience, having prior experience in implementing Greening by IT was also identified as an enabler (Schmidt et al., 2010). It can be reasoned that this would help lower the barriers regarding the uncertainty about its success and any ambiguity on how to apply it.

IT Department Size
The size of the IT department will naturally facilitate the implementation of any Greening by IT initiative as limited manpower would otherwise be a constraining factor in being able to it on (Hu et al., 2016).

Sufficient Resource Allocation As described during the description of the barriers, having enough resources to allocate for Greening by IT initiatives will directly impact the decision to implement (Molla & Abareshi, 2011).

Good economic environment
Additionally, the economic environment relates to this as it likely determines the amount of resources available within an organization and impacts the attitude of key stakeholders. If there is an economic recession, there might have to be cuts made to IT budgets which would further hamper sustainability initiatives (Brooks et al., 2012). Although this can be perceived as an environmental factor, it is decided to look at the impact of it from

an internal, organizational perspective.

Perceived value of technology
First of all, the perceived value of the Greening by IT initiative, based on the relative advantage mentioned by Deng and Ji (2015), considers the benefits in cost reduction, functionality, or image that the initiative adds adds. These benefits will be evaluated and play a role in determining the added benefit of employing Greening by IT.

Defined Greening by IT strategy in IT & Org. has sustainability-oriented strategy
Next, the initial strategy to enable implementation is having a strategy specifically for Greening by IT within IT itself (Yang et al., 2017). In parallel to this is the need for the organization to have a sustainability-oriented strategy as this would further encourage the Greening by IT strategy used by the IT department. Furthermore, it was concluded by Jenkin, Webster, and McShane ((Jenkin, Webster, & McShane, 2011)) that the higher level the strategy is, the more widespread the Greening by IT initiatives will be. This also corresponds with the level of motivating forces that the organization faces, meaning that a lot of pressure will also result in strategies being employed at the highest levels as well.

IT strategy embedded in overall business strategy
Finally, Seidel et al. (2010) found that one of the most effective enablers was having the Greening by IT strategy specifically embedded within the overall business strategy itself.

6.1.4. Environmental Factors

The Environmental factors of the TOE framework represent the external factors contributing to the implementation of Greening by IT. Despite the focus of this study being on the internal factors which impact implementation, these Environmental factors are still integral to getting a complete understanding. They do not, however, play a decisive role in this study. Many of the studies which were used in the writing of this research review also included many external, environmental factors. In line with the definitions provided in Subsection 6.1.1, these factors all represent external drivers which push organizations to implement Greening by IT. Even though the focus of the study is largely on the internal factors in an organization which impact implementation, it is still considered worthwhile to mention the external factors to provide a complete the picture for practitioners. An overview of the papers and which environmental factors they identified can be seen in Appendix B.

As seen in Figure 6.1, there are three main categories of factors which are grouped together into coercive pressure, mimetic pressure, and normative pressure. They are left in the general groups and not specified further in line with their described pertinence for this study.

Coercive Pressure
This represents the driving effect from regulatory bodies, suppliers, customers, and shareholders and was identified as having a positive impact on Greening by IT implementation by multiple articles (Baggia et al., 2019; A. Chen & Roberts, 2023; A. J. Chen et al., 2011; Deng & Ji, 2015; Gholami et al., 2013; Jenkin, Webster, & McShane, 2011; Jongsaguan & Ghoneim, 2017). As mentioned by Jongsaguan and Ghoneim (2017), this is especially pertinent for the aviation industry given its high level of regulation from organizations such as the Federal Aviation Administration (FAA) in the U.S. and the European Aviation Safety Agency (EASA). These regulations include taxes which aim to reduce the amount of noise pollution and emissions coming from aircraft. The International Civil Aviation Organization has also made commitments for aviation being net zero by 2050. Other non-aviation related regulations such as the Corporate Sustainability Reporting Directive (CSRD) which require organizations to report on various aspects of their footprint and measures also have an impact as they only add to long list of regulations the industry must comply with.

Mimetic Pressure
Gholami et al. describe mimetic pressure as the pressure which occurs from firms who follow other firms which implement certain practices, technologies, or organizational structures and desire the similar positive impact which they observed. Firms tend to opt for mimicking their competitors as a response to uncertainty which is especially prevalent with the complexity of environmental issues (A. J. Chen et al., 2011; Deng & Ji, 2015; Jongsaguan & Ghoneim, 2017). Given the low turnover and fierce competition in the airline industry, this is likely to be a very relevant factor for airlines when taking on new sustainability measures and definitely requires additional research.

Normative Pressure
This type of external pressure comes from industry standards, cultural expectations, public opinion, and the media. Deng and Ji (2015) describe normative pressure as being associated with professionalization through the development and use of industry standards and tools. There has also been an impact from activists in that concern for climate change has also become a widespread staple for firms and results in initiatives like Greening by IT becoming something that they are expected to take on (Carberry et al., 2019). The effect of general public opinion and reporting in the media has a similar effect and was also identified as a contributing success factor (Singh & Sahu, 2020).

6.2. Research Use-case Within KLM: Data & Technology Division

After completing this review into the influencing factors, the next step is defining the use case within KLM and applying the factors within the stakeholder interviews in order to answer the third sub-question. Over the past several decades, IT has become a crucial element within the entire value chain for airlines, from the purchasing of a ticket all the way to the route planning chosen for a flight. The structure of IT at KLM is inherently complex due to the nature of the various IT disciplines needed in effectively running an airline and the added component of the merger with Air France. KLM is broken down into various sub-businesses for the various aspects of the airline such as Cargo, In-flight Services, Flight Ops, etc... Due to the merger with Air France, several of these businesses are merged and some remain KLM-specific. For the businesses which are merged, such as Cargo and Engineering & Maintenance, a more classical organizational structure is used where the business department and IT development departments are separate. New innovation is facilitated by the Information Management Office (IMO) which acts as a bridge between business and IT. This organizational structure can be seen in Figure 6.2.

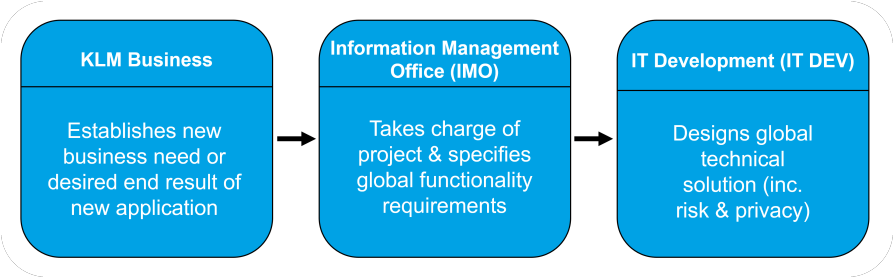


Figure 6.2: Classical KLM Business-IT Structure

The businesses that remain un-merged fall under the KLM-only Data & Technology (D&T) platform, where the business and IT components are combined. Using the IMO as a facilitator is abandoned for a more streamlined structure where IT specialists and business analysts fall under the same team. This was done in an effort to modernize the tech landscape, develop better in-house engineering capabilities, and transition to having centralized responsibility within the platforms which fall under D&T. Each platform is governed by both a Director of Product and Directory of Technology. The Director of Product focuses on solutions for the business side and answers to the relevant KLM business executive. The Director of Technology focuses on how to achieve the desired solution from a technological point of view and answers to the VP of Technology of KLM. The platform is further broken down into Product Teams which consist of business analysts, product owners, data scientists, and software engineers with a focus on a specific business value streams. For example, D&T supports the Ground Services business through six value streams being Planning & Assignment, Customer Management, Baggage, Disruption & Service Recovery, Aircraft Turnaround, and Front-line Staff Support. Drawing inspiration from internal KLM documents describing D&T, a visual was created to help illustrate the structure and can be seen in Figure 6.3.

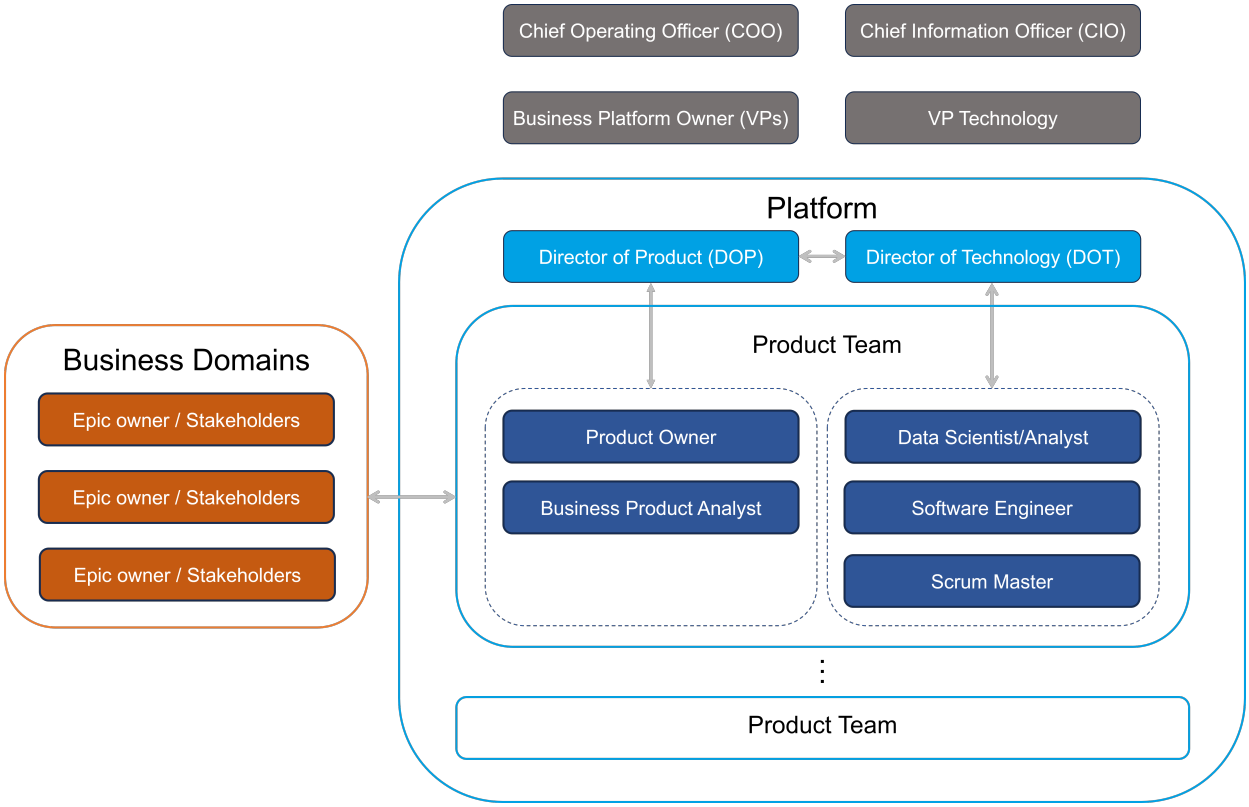


Figure 6.3: D&T Organizational Structure

Given the fact that D&T is specific to KLM and that both the business and IT elements co-exist within the division, **it is decided to use D&T as the primary use-case for conducting the case study of this study.** After initial discussions with several experts within KLM, it was reasoned that the interaction between the business and IT domains would yield the greatest insight into the influencing factors which impact the implementation of Greening by IT initiatives and would be the best intervention point for potential Greening by IT implementation strategies.

6.3. D&T Stakeholder Analysis

A stakeholder analysis was conducted to evaluate the involvement of various players in the implementation of Greening by IT and to select participants for the interviews. This should expand on which stakeholders are relevant in the process, where their power lies, and what kind of decisions they can make. In Subsection 6.3.1, the stakeholders identified within D&T are described and an interest grid is developed in Subsection 6.3.2.

6.3.1. Stakeholder Identification

In this subsection, the direct stakeholders internally involved in the process of generating, approving, and implementing Greening by IT initiatives within the D&T division are evaluated. Therefore, certain indirect stakeholders involved in the process such as the customers or government are excluded as this analysis is internally-focused and is merely used to select the interviewees. Given that this division is unique to KLM, it could be that the structure and specific roles that are mentioned are different from other airlines in the industry. That being said, the following direct stakeholders were identified through a review of KLM documentation and review with experts within the company.

- **Chief Information Officer (CIO):** Is responsible for overseeing the development and implementation of KLM's IT strategy at the highest level. Manages the CIO office which works on IT's portfolio management, strategy development, commercialization, and governance.
- **Chief Operating Officer (COO):** Is responsible for overseeing the day-to-day operations of KLM and the efficiency of its various business processes. Develops and implements business strategies, manage

resources, and improve operational processes to deliver the most value to KLM passengers. Manages the corresponding VPs to each KLM business.

- **Business Platform Owners (VPs):** Reports to the COO for the KLM business they are responsible for (e.g. Cargo). Similar to the COO, they are in charge of implementing business strategies, managing resources, and improving the operational processes of their respective business. With respect to D&T, they are the platform owner which the Director of Product reports to.
- **VP Technology:** Oversees the DOTs from each of the five business platforms that are included within D&T. Reports to the CIO of KLM.
- **Director of Product:** Leads a D&T business platform in developing quality products which maximize business value. Supports the KLM businesses in improving business processes with corresponding digital solutions. Co-manages the platform with the Director of Technology.
- **Director of Technology:** Similar to the Director of Product, they lead a D&T business platform, but from a technology and architecture point of view, such as the effectiveness of the chosen architectural design choices. Shares responsibility with the Director of Product for overseeing the performance of their shared platform.
- **Portfolio Manager:** Responsible for ensuring the quality of all proposed projects and oversees the process itself. Reports to the VP responsible for Operations Decision Support.
- **Product Owner:** Tasked with improving the performance of a business process. Defines the product's vision and aligning the various business stakeholders. Manages the business analysts associated with a product and reports to the Director of Product for the given area.
- **Data/Engineering Lead:** Although very different in practice, these roles are treated equally for the purpose of this stakeholder analysis. Whereas the Data Science Leader manages the data scientists and analysts working on machine learning and AI solutions, the Engineering Lead works with a group of software engineers on the architecture for any proposed solutions. Both functions report to the Director of Technology for their respective area.
- **Business Product Analyst:** Tasked with analyzing the product's impact with the goals of driving user adoption and enabling business process change. Aids the product team in envisioning business process changes, ensuring that the product matches its requirements, and supports users in the adoption of any changes.

6.3.2. Stakeholder Interest Grid

Together with review of KLM documents and several discussions with employees within D&T, a stakeholder interest grid breaking down the stakeholders upon the level of power they have and the interest they posses was created. This interest grid was performed with respect to the stakeholders which can influence the implementation of Greening by IT initiatives within KLM's D&T division specifically. The completed grid can be found in Figure 6.4.

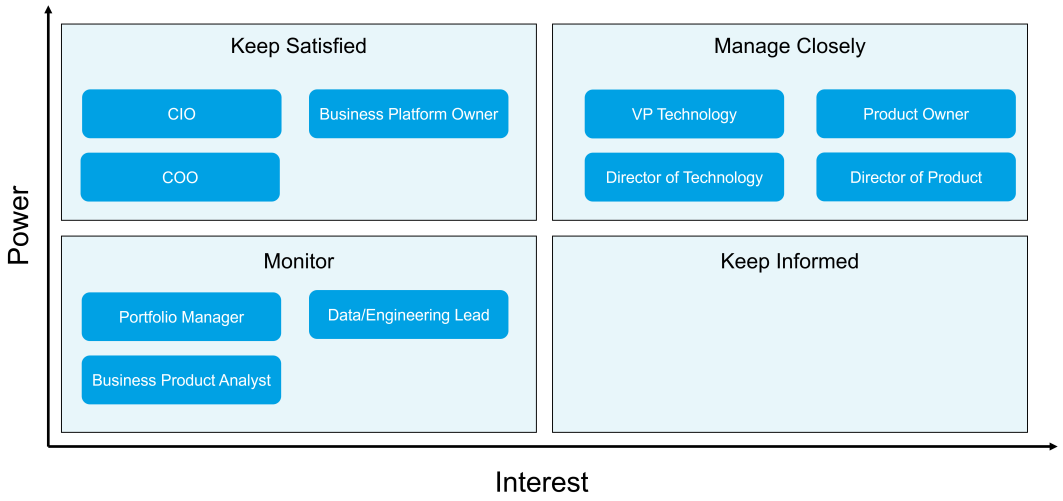


Figure 6.4: Stakeholder Interest Grid

As can be seen, the primary stakeholders which have both high influence and high interest in the implementation of Greening by IT are the Directors of Product, the Directors of Technology, the Product Owners, and the VP of Technology. Several of these stakeholders should certainly be interviewed within the case study for this research. The more executive functions such as the CIO, COO, and business platform owners (VPs) all fell within the ”Keep Satisfied” category, which represents stakeholders with high power but low interest. This was chosen for these stakeholders given that they do indeed posses high power, but with respect to implementing Greening by IT within D&T specifically, it is too detailed to be within their interest. The rest of the stakeholders, being D&T’s portfolio manager, data/engineering leads, and business product analysts all fell within the ”Monitor” category, which represents stakeholders with both low power and interest. Nevertheless, it could still be interesting to interview several of them as they are lower in the hierarchy compared to the rest of the stakeholders that were evaluated and could offer some good insights. To conclude, it is recommended to interview several directors, product owners, and VPs involved with Greening by IT within D&T.

6.4. Interview Protocol

After developing an understanding of the key factors influencing Greening by IT implementation, it is now necessary to apply these findings to a real airline context. This is crucial to qualitatively evaluate the findings from the literature and explore them in more depth. Conducting interviews with pertinent stakeholders was chosen as the qualitative method due to the complex nature of the topic at hand and lack of prior dedicated research to the airline domain.

6.4.1. Interview Sampling

Based on the stakeholders identified in Section 6.3, the following criteria were applied when selecting the participants:

- **Involvement in D&T Project Process:** This is chosen as the main criterion for selecting interviewees as those that are heavily involved in the process of selecting projects or dictating the strategy for D&T will have the best knowledge of the key factors influencing Greening by IT implementation. Participants who are very involved in the process are also be a helpful source for generating the most impactful strategies and intervention points to overcome the identified barriers.
- **Experience within the company:** The level of experience within the company, which is expressed in the amount of time the participant has worked there, is also chosen as a criterion. This represents how familiar the participant is with the process and various years of experience helps in determining the main obstacles for Greening by IT. The cut-off for this criterion is defined as less than 6 months of experience within KLM.
- **Department has sustainability challenges:** For the participants chosen for stakeholders within the business platforms, it is decided to opt for business platforms which deal with great hurdles in becoming more sustainable. Within D&T, examples include Flight Operations and Ground Services. This is decided as such as they are likely to have experienced the approval process for sustainable projects in the past and would have insights into the influencing factors. Interviewing an expert from a different domain, such as Crisis Management, would still be useful in understanding the project approval process, but not as beneficial as interviewing someone who works in an area with significant hurdles in becoming more sustainable.

Furthermore, it is not critical that the participants be involved in sustainability efforts themselves or be sustainability ”champions” within the company, but they must play a pertinent role in the process of strategy formation or the selection of projects. Only interviewing pro-sustainability experts within the company could otherwise lead to a bias in the results and not a complete understanding of the current situation.

The participants were identified using the personal network through my internship within the company and through referrals from employees within the CIO office and D&T. All participants work within the D&T division at KLM or are involved in managing it. Each participant was contacted initially via email to explain the research topic and schedule an introduction meeting. During this meeting, basic background information was given on the research topic and the interview process. An overview of the selected participants can be seen in Table 6.1.

Table 6.1: Participant Descriptions

Participant #	Anonymized Title in Research [1]	Time in KLM	Management level
1	Executive Manager KLM IS	6.5 years	Strategic Management
2	Upper management D&T (Tech Side)	18 years	Strategic Management
3	Upper management D&T (Tech Side)	6 months	Strategic Management
4	Upper management D&T (Business Side)	23 years	Strategic Management
5	Senior Product Owner	5 years	Operational Management
6	Product Management Improvement Lead	10 months	Operational Management
7	Portfolio Manger	26 years	Operational Management
8	Sustainability Program Manager	5 years	Operational Management

As can be seen, the main stakeholders within the platform who are involved in strategy formation and project process are represented. The exact titles of the strategic and executive management are not included to prevent the re-identification of the participants. Beyond the stakeholders identified during the stakeholder analysis, two additional functions are included based on recommendation of D&T's management: a Product Management Improvement Lead and a Sustainability Program Manager. The Product Management Improvement Lead is involved in the process for creating a shared strategic overview for business and IT, which could be crucial in incorporating sustainability objectives. The Sustainability Program Manager oversees various sustainability initiatives within the digital transformation within D&T and could provide in-depth insights into the key influencing factors for Greening by IT.

6.4.2. Data Collection

The data source consists of semi-structured interviews with the identified experts. A survey is not used as it would lack the detailed understanding which is desired of the case and would prevent the opportunity for the researcher to engage further with the interviewees on their answers. As a result, it is decided to conduct semi-structured interviews given the complexity of the topic in practice and the desire to still pose several structured questions for specific themes such as the barriers and enablers. Leaving the interviews semi-structured also leaves the freedom to explore certain relevant topics which come up during the interviews to which the researcher was previously unaware.

Before conducting the interviews themselves, the participants were sent a consent form, a one pager with background information on the topic, and the list of questions. The data consent form outlined how their personally identifiable data will be protected, what steps will be taken to ensure their anonymity in the thesis report, and how the interview data will be analyzed and stored. An example consent form can be found in Appendix C. The one pager included background information on the goals of the research, useful definitions, and any relevant themes. It did not include detailed findings from the literature study in order to avoid pre-biasing the participants to include certain answers in their interview.

For conducting the interviews themselves, the participants were informed again about the information from the consent form and it was confirmed that the participant was aware and in agreement. It was elected to use Microsoft Teams to conduct the interviews as it can both record and provide a transcript at the end of the meeting. The recordings, transcript, and any additional notes that are taken were stored on the laptop provided by KLM to the researcher and the TU Delft OneDrive. The interviews were scheduled to take one hour, but some were condensed to be shorter based on the schedule of the participant. The questions posed to the participants can be found in Appendix CA copy of the transcript was sent to the participant after the interview for their feedback and they were given a chance to correct anything.

6.4.3. Data Analysis

Following each interview, a transcript was made by reviewing the one made by Microsoft Teams and making edits as necessary. When all the transcripts were approved by the participants, they were uploaded to Atlas.ti to prepare for the coding analysis. The analysis followed the coding analysis framework approach as outlined by Crowe et al. (2011). The coding was performed in order to analyze the participants' opinions on the factors from the literature study, distinguish any unique factors which were mentioned, and evaluate their opinion on the generalizability of the results. It was also performed to record the various strategies that were suggested

[1] For the purpose of protecting the participants identities, the names are omitted from this table. However, the members of the thesis committee have access to them along with the interview transcripts.

by the participants and discussed.

The coding began first with a familiarization stage where the researcher became familiar with the content. Next, the main themes and patterns present in the data from the interviews were identified. These elements were coded and organized based on this first round of analysis. For example, all codes representing barriers to Greening by IT implementation were grouped under the same category. These were later broken down into more specific groups according to the TOE framework. Once all the second level codes were identified, example quotes from the interviews which best explain the codes were compiled into a table to give an overview of the analysis.

The analysis also featured a semi-quantitative analysis based on the questions which ask the participants to rank the barriers and enablers which were found in the literature study. Through these questions, each interview yielded rankings for these factors. The following analyses were carried out:

- The results of all the rankings were tallied in order to produce a list of the most relevant and least relevant barriers and enablers. For example, with 15 barriers, the factor which is ranked as most important in an interview can get 14 points and the least relevant one gets none. These were then totaled up across all the interviews. This demonstrates if one barrier or enabler is consistently ranked higher and how it compares to the other top factors.
- Using the results from the previous analysis, the scores between the stakeholders from strategic and operational management were also separated and compared. This is particularly interesting for practitioners involved in implementing Greening by IT to consider.
- The results of the factor ranking were next analyzed based on their categories from the TOE framework to observe any trends between the categories. For example, if the technological barriers were consistently ranked lower, this would indicate that the D&T stakeholders do not see barriers from that category as the main obstacles for implementing Greening by IT initiatives.

Also important was to analyze if there were any additional factors that participants identified that were missing from the list compiled from the literature study. These would be useful for future research to investigate and for airline IT practitioners to be aware of.

6.4.4. Interview Validity

In order to ensure the validity of the interviews, several steps were taken. The main measure taken to ensure validity throughout the interview process was following a clear interview methodology consistently with each of the interviews. More specifically, a relevant concern could be regarding the internal and construct validity in that the interview questions might not accurately reflect the research topic or capture answers relevant for the sub-questions. This was mitigated by going over the the questions in advance with the supervisors from the TU Delft and KLM. The external validity of the interviews is also a relevant aspect given the uniqueness of D&T and some of the functions held by the participants, which may make the results less generalizable to other airlines. This is achieved by asking the participants whether they believe that factors are relevant only for D&T or are extendable to the whole industry.

For carrying out the actual interviews, there is a possibility for some anchoring bias in the rankings that were performed. The order of the factors was random to hopefully encourage the most accurate answers by the participants, but there is the possibility that there is some anchoring bias due to them reading the factors at the top first and then going down the list. This was mitigated by talking through things with the participant as they performed the ranking and discussing their results at the end. It was found that they would adjust the answers sometimes when asked why they ranked things a certain way. Additionally, due to time constraints, some participants only had time to rank the most impactful and least impactful enablers as that ranking was performed after completing the barriers. If this was the case, the unused enablers were left blank and were not included in the final scoring.

Finally, one must raise a point on the creation of the barrier and enabler lists themselves. The researcher reviewed many articles in the creation of these lists and would merge terms if they were similar or would create a new term which could encompass several if it was possible. While this might simplify the ranking section of the interview for the participant, it does create the possibility that certain information was lost when translating the results from previous studies into the factors to be used for this study. In case the reader is curious, they may review the factors which were described in previous studies in Appendix B.

6.5. Interview Results: Barriers & Enablers

In this section, the results from the part of the interviews dedicated to the barriers and enablers are discussed. The results from the rest of the interviews are treated in Chapter 7 and Chapter 8. First, the analysis of the factor rankings performed in the interviews is displayed in Subsection 6.5.1 which features several sections on the overall scoring, comparisons by TOE grouping, and comparisons between the strategic management and operational management stakeholders. Next, the coding results from the interview questions on the barriers and enablers is shown in Subsection 6.5.2. Afterwards, the participants opinions on the generalizability of their answers is outlined in Subsection 6.5.3. The questions posed in the interviews, the summaries of the answers per participant, and their rankings per factor can be found in Appendix C.

6.5.1. Ranking Analysis

In this subsection, the results from the factor rankings performed by the interviewees is presented. They are analyzed according to the methods outlined in Section 6.4. First, the overall scoring is shown along with the analysis between TOE categories. Then, the analysis between the rankings from participants from strategic management and those from operational management is presented.

Overall Scoring

The overall scoring was performed by assigning points based on the ranking by each participant and summing up all the points for each factor. Given that there are 15 barriers included in the ranking, being ranked as the most important barrier would net 14 points (13 for the enablers). The barrier that a participant would rank as the least relevant would get no points. After adding up the points across each of the interviews, the overall scoring of the barriers is shown in Figure 6.5 and that of the enablers in Figure 6.6. In these figures, colors are used to distinguish factors from the Technological and Organizational categories.

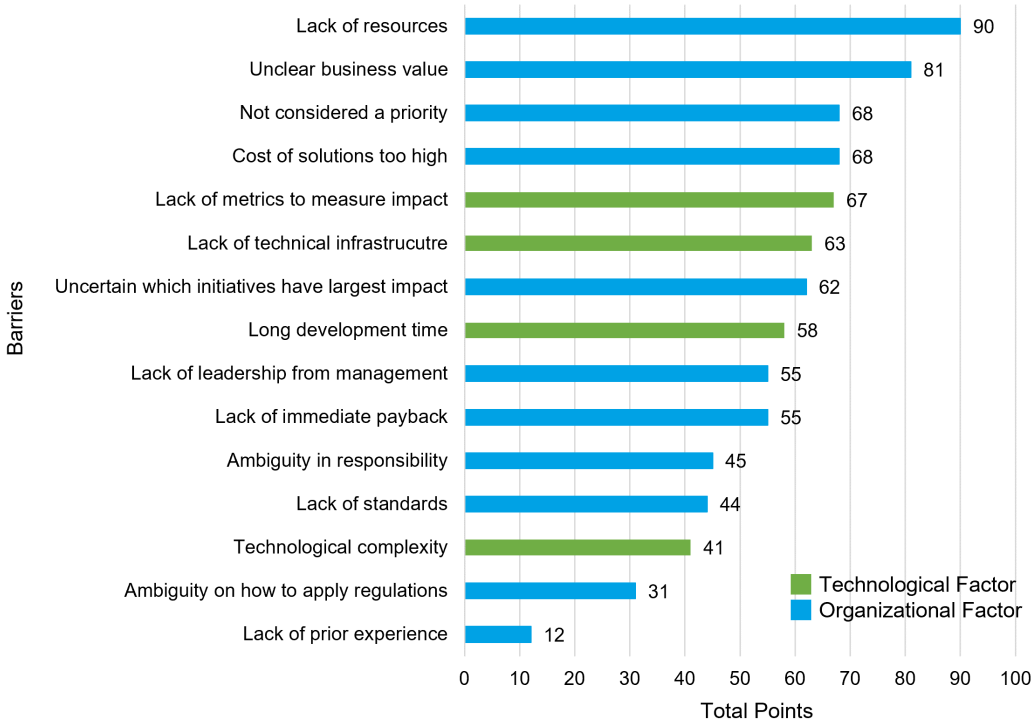


Figure 6.5: Barrier Ranking Total Points

Looking first at the barrier table, a lot can be derived from what participants ranked as the most relevant and least relevant factors. The top four factors are all organizational factors which revolve around prioritization and resource allocation: lack of resources, unclear business value, not being considered a priority, and the cost of solutions being too high. This indicates that the participants saw resource constraints and focus being elsewhere as the primary obstacles for Greening by IT implementation. Resource allocation and unclear

business value scored very high compared to even the third and fourth place barriers, demonstrating their importance. The technological factors surrounding the lack of metrics to measure performance and technical infrastructure were ranked lower, but are separated by only a couple points from the top barriers.

Shifting focus to the lowest scored barriers next, one can see that most participants did not see a lack of prior experience as a major obstacle, with it only getting 12 points across the 8 interviews. This is confirmed when looking at the coding analysis, where Participant 6 stated that prior experience is easily overcome as one can just hire for it. They said that if the precursor is fulfilled with having a strategy in place, one should see what experience is needed and can hire accordingly.

The participants similarly state that ambiguity in how to apply regulations is also not an obstacle. Participant 7 clarified that since most areas have some sort of target on sustainability so they don't think there is an ambiguity, but just a challenge in seeing how one can contribute. The most crucial conclusion from these bottom factors this is that technological complexity is not seen as an important barrier for Greening by IT implementation. The fact that the participants do not see the complexity involved in implementing Greening by IT solutions as a major barrier makes the conclusion even more stark as they believe that the complexity can be overcome, but there is unclear value, a lack of prioritization, and a lack of allocated resources as a result.

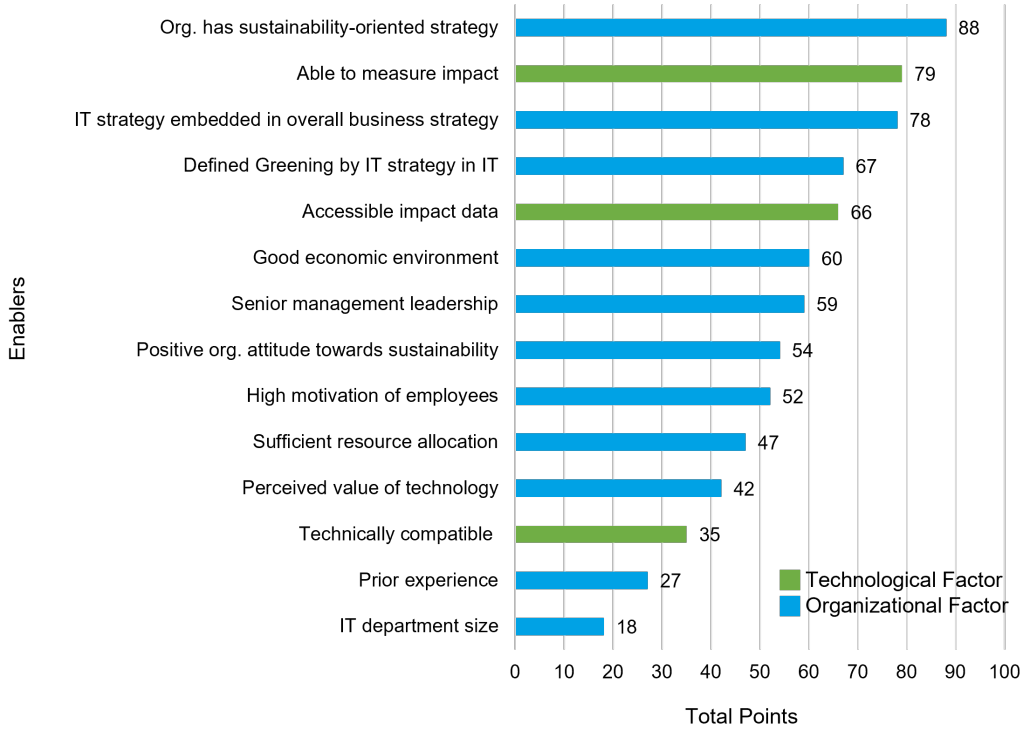


Figure 6.6: Enabler Ranking Total Points

Looking next at the figure of enablers, all three of the enablers related to strategy fell in the top five. The organization having a sustainability strategy was the highest ranked enabler, with 88 points, followed by having the IT strategy incorporated in the business strategy and having a defined Greening by IT strategy in third and fourth place. Participant 5 described the organization's sustainability strategy as being the first major step.

Two of the technological enablers performed very well, appearing in second and fifth place. Participants saw being able to measure the impact of Greening by IT solutions as a key enabler for several reasons. On the one hand, being able to measure the impact would help focus efforts on the Greening by IT solutions which would make the greatest sustainability impact. On the other hand, Participant 8 said that being able to illustrate the cost for not taking a decision would be instrumental in convincing the business stakeholders to see the value in Greening by IT. Being able to measure the impact was also seen as important to be able to observe changes after implementation and make adjustments as necessary. Related to this was having this data be accessible. It was clarified that although the data exists sometimes, it might not be easily accessible in the given format or that the data owner is from a different part of the company, complicating accessing it.

Having this data easily accessible would only amplify the effects of being able to measure the impact.

The participants did not see having a larger IT department as very helpful, except for Participant 4, a business stakeholder, who clarified that having a larger IT department would help by having more resources to develop these solutions. This was contrasted by several of the more tech-oriented interviewees who stated that the IT department size would not help, but having better architecture would.

The most surprising takeaway from the enabler rankings is that sufficient resource allocation performed so poorly. While a lack of it was seen as the highest barrier, it was not seen as a very helpful enabler. It can be concluded that this is not seen as the end-all option to drive Greening by IT, but that the other enablers would do more. Participant 3 explained that it's not so much having more money or people that would help, but having a separate budget for Greening by IT which does not have to be split with other goals. This would preserve its importance and prevent it from being deprioritized. Similarly viewed to this was having a positive organizational attitude to sustainability or highly motivated employees. Participant 7 that regardless employee positivity, if not a strategic theme, then nothing will happen. They said that it would be more important for it to be a strategic theme because even then, if people were not positive about it, something would still be done.

Comparison by TOE Categories

Given that the research objective of this chapter is to identify the barriers and enablers of Greening by IT implementation, it is also of interest to assess them based on the TOE categories used to get the best understanding of their relevance. It is difficult to make direct comparisons between the technological factors and organizational factors performance because of there being only four technological barriers and three enablers, compared to the 11 organizational barriers and 11 enablers. First looking at the barriers, three out of four of the technological barriers were ranked as fifth, sixth, and eight, indicating relatively high importance. The technological factors saw better performance in the enabler rankings where being able to measure the impact and having accessible impact data both fell within the top five. Participants saw these as effective enablers to help overcome the top organizational barriers, such as being able to demonstrate the impact and justify allocating more resources for Greening by IT. For future research, it might be helpful to ask participants directly which group of factors they found most important and include more specific groupings within the TOE framework.

Comparisons between Strategic & Operational Management

Of the eight stakeholders who were interviewed, Participants 1-4 belonged to strategic management and 5-8 could be grouped within operational management. Referring to Section 6.3, strategic management stakeholders are defined as those at a C-level (e.g. CEO), VP, or Director level position. They are responsible at a higher level for the strategy, prioritizing larger themes, and reviewing quarterly performance. Operational management is defined as those stakeholders who work at a more functional level in the process such as Product Owners, Portfolio Managers, or Program Managers. They are responsible for the actual implementation of initiatives and for executing the strategic priorities. Having this even split allows for an analysis to be performed comparing the two. In Figure 6.7 and Figure 6.8, the two rankings from both management groups are compared side-by-side. In Figure 6.9 and Figure 6.10, the same can be seen but for the enablers.

Figure 6.7: Operational Management Barrier Rankings

Figure 6.8: Strategic Management Barrier Rankings

Generally, operational management ranked the barriers not considered a priority and lack of immediate feedback several places higher than strategic management did. Strategic management ranked the cost of solutions being too high and there being a lack of metrics to measure the impact higher instead. Looking at the rest of the barriers, most were either in the same rank or were only slightly different. Lack of resources received the most points and lack of prior experience received the least for both management groups.

Figure 6.9: Operational management Enabler Rankings

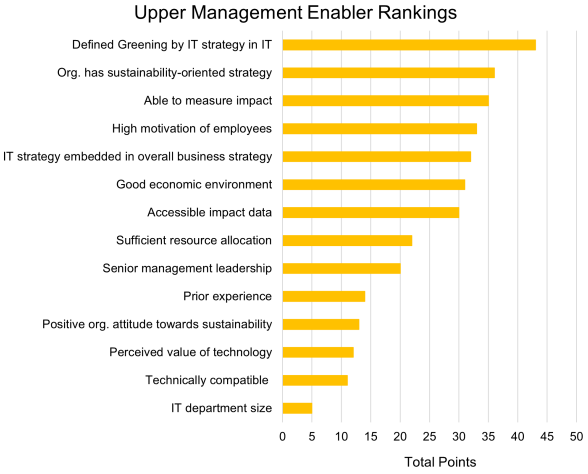


Figure 6.10: Strategic management Enabler Rankings

Looking next at the enablers, clearer differences can be observed. Strategic management saw having a defined Greening by IT strategy as much more important than operational management did, which favored the organization having a sustainability strategy instead. One could interpret this as a sort of dichotomy where strategic management looks down and sees that the Greening by IT strategy would help, whereas operational management looks up and finds the organizational sustainability strategy more important. Alike to this is the comparison for the organization's attitude towards sustainability. Operational management saw this as quite useful in overcoming the barriers while strategic management scored this much lower. In contrast, strategic management ranked having highly motivated employees as more useful, which operational management ranked low. Further demonstrating this difference is the perceived value of technology ranking, which Operational management ranked much higher. One could infer that since operational management is busy implementing solutions, they see the perceived value as more helpful given that they implement the technology in practice. Last to point out is having a good economic environment which strategic management saw as more important than operational management did. This comes across as reasonable as strategic management is more likely to be dealing with the organization's business performance and will consider changes in the economy. These differences and similarities are best seen through Figure 6.11 and Figure 6.12.

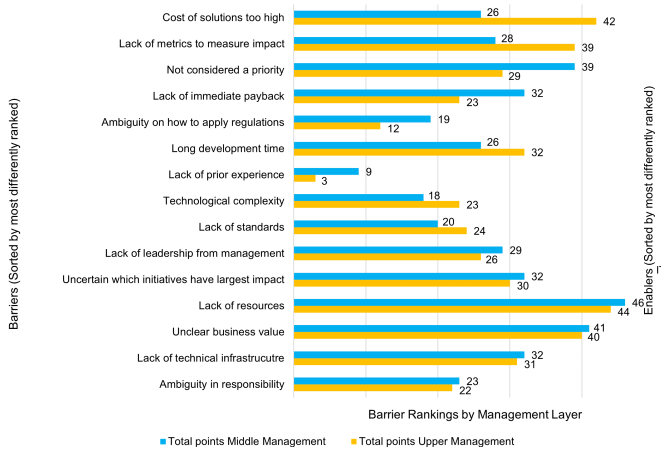


Figure 6.11: Comparison of Barrier Rankings between Strategic & Operational management

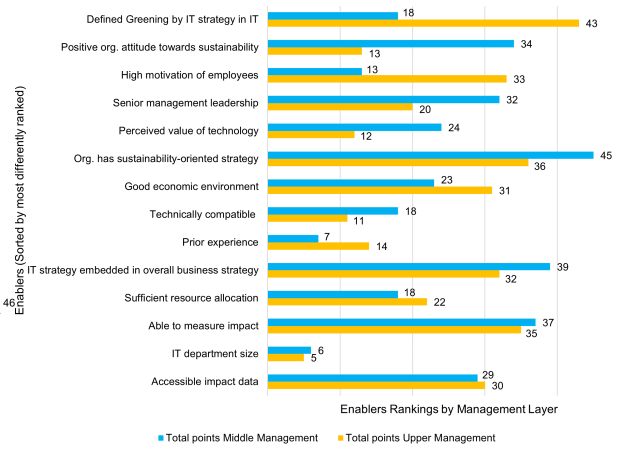


Figure 6.12: Comparison of Enabler Rankings between Strategic & Operational management

These figures show the total scoring from strategic management and operational management for each factor side-by-side. The factors are sorted by those with the greatest difference in scores at the top and with those most similarly scored at the bottom. While confirming the differences described in the text above, one can also observe that there are many factors which both sides scored nearly the same.

6.5.2. Coding Results of Barriers & Enablers

During the coding analysis of all of the interview transcripts, many codes were found which matched the factors identified in the literature study, but several were found which did not fit in previously identified factors sufficiently. All of these codes were first checked if they fit within the TOE groupings, the previously identified factors, and if not, then a new factor was created. In the end, all factors did fit within the TOE groupings, but several new factors which did not fit into the factors from the literature study were distinguished.

In this subsection, tables for the barriers and enablers for each category of the TOE framework are shown, sorted by those most often discussed by participants at the top to those least mentioned at the bottom. Factors which were found in the literature study and used in the rankings, but were not discussed by the participants are still included in the tables. This allows impressions to be made if participants put certain factors high up in the rankings, but then do not go on to talk about them in the interview discussions. Each factor includes its title, frequency in the transcripts, a short description, and a quote from one of the participants which best explains it. **The factors whose rows appear in blue are new factors which the participants brought up and were not identified in the literature study.** As a result, these factors were not included in the previously discussed rankings. Several appear trivial as for example, some enablers are the opposite of certain barriers that were previously identified, but were not mentioned specifically as *enablers* in prior research.

Coding Results: Technological Barriers

First, the coding results for the Technological factors is shown through Figure 6.13 for the barriers and Figure 6.14 for the enablers. As can be seen in both figures, several new factors were identified in the analysis, resulting in five new barriers and one new enabler. The new barriers are each explained below:

- **Difficulties from experiment to execution:** This barrier came up frequently in the interviews and refers to the difficulties from taking a Greening by IT solution from an experimental stage to being fully integrated into the operation. A part of this is also reflected in the factor about having a long development time, but it was clear in the interviews that it is more than that. Making these solutions compliant with existing systems, existing regulations, and making them fully supported for the 24/7 operations is very complex. Participants explained that IT is a mere enabler of goals set by the business and that continued support from the business is required to take on new initiatives. Past initiatives saw enthusiasm and support from the business after successful experiments on several flights, but saw support dwindle in the months afterwards as the experiments were scaled up and developed for full integration into the entire operation. This caused certain initiatives to lose budget or be canceled purely because it took too long or was too complex to be scaled up, even after initial enthusiasm and successful experiments.
- **Hard to express data:** Also raised in the interviews was that it is not only difficult to get the right data and be able to access it, but also deciding which way to express it. This was especially pertinent for Greening by IT as several departments use different variables to express how sustainable certain initiatives are, which makes it difficult to compare and understand its value. For example, some departments within the flight domain might use liters of fuel as the main variable to evaluate solutions, but others in the business might use euros or kilograms of CO_2 as the metrics. In contrast to the other barrier regarding not having metrics at all, this barrier refers to having difficulties in effectively expressing metrics related to Greening by IT.
- **Lack of data quality:** This factor refers to not having the data needed to measure the impact of Greening by IT solutions, which leads to them having an unclear value and not being picked up. This is different than data accessibility, which refers to being able to attain the data, and lacking the metrics to measure the impact, which refers to there being no targets which reflect the impact of Greening by IT solutions. Participants mentioned that due to the complex nature of the organization and legacy applications, the required data might not even be collected by existing applications. An example of this was that the required engine data needed to implement an application optimizing take off and landing for aircraft was simply not being collected by existing applications.
- **Lack of data accessibility:** Contrary to the previous barrier, this factor focuses on the data existing, but being hard to access. Participants referred to data owners sometimes being in a different part of the

organization or coming from applications which made it hard to isolate the required data, even though it does exist. This was seen as different enough compared to create a new barrier when compared to lack of technical infrastructure and the other barriers.

	Barrier	Freq.	Description	Quote
Technological	**Difficulties from experiment to execution**	16	Difficulties in transforming GBIT experiments to full-scale adoption	"So I don't exactly know why it hasn't been implemented so far, but I think these are good initiatives where we experiment, but I haven't seen them in the full scale anyway"(Participant 4).
	Hard to express data	13	Difficult to express metrics related to GBIT impacts	"you could also translate better from different things, because with the euro, it's easier to translate sustainability targets towards euros perhaps, although it costs a lot of time and a lot of alignment. (...) noise reduction, how are you going to translate it in euros?"(Participant 8).
	Lack of data quality	13	Data needed to measure GBIT impacts is missing	"But with all the projects I'm working on now, it is a precondition that we have the right data, but the right data is not there"(Participant 6).
	Lack of technical infrastructure	12	Missing or outdated infrastructure needed to implement GBIT solutions	"It's an old architecture so it really relies on the individual interfaces. It's all the software. It's old programming languages, it's people don't have the knowledge anymore. It's complex, so people don't dare to touch it, because if we touch it, it might stop working or do strange things"(Participant 7).
	Lack of metrics to measure impact	10	There are no metrics to reflect the impact of GBIT solutions	"And I think in regards to, if I talk about our platform, we don't have specific targets or business measurements where we as a IT can now directly make contribution"(Participant 5).
	Lack of data accessibility	7	Data does exist but is not easily accessible	"Yeah, we are not making it accessible. No…sometimes we do have data in our teams, but it's not that we are owner of it"(Participant 8).
	Technological complexity	5	GBIT solutions are complex to understand and implement	"I think we are really hampered in the speed of innovation within our D&T platform and that's mainly also caused by a lot of complexity, (...). And I would say that is our primary concern to really progress on the situation"(Participant 4).
	Long development time	3	GBIT solutions take a long time to develop	"So they are enthusiastic in the experiment. But (…) from experiment to real operational implementation, if that takes too long, they say 'Why does it take so long? What is so difficult?"(Participant 2).

*Cells in blue represent newly identified barriers

Figure 6.13: Coding Results of Technological Barriers

Referring to the original four technological barriers selected in the literature study, many participants also commented on their relevance and provided examples. There being a lack of technical infrastructure was often brought up as a major obstacle, mostly due to legacy applications, some of which are 20-40 years old. These applications may be incredibly reliable, but are written using outdated programming languages which relatively few within the airline still comprehend. They are not easily connectable to other applications and it can be difficult to get useful data out of them. This constrains the innovative capacity of the D&T platform and obstructs Greening by IT solutions which might need to interface with these legacy applications. Participant 8 specifically mentioned that sometimes phasing out these legacy applications can take so long that by the time it is fully phased out, the replacement applications for certain parts of the original are already considered legacy by the end of it. This was strongly reinforced as a barrier to Greening by IT solutions and is also evident by the rankings in Subsection 6.5.1.

Regarding there being a lack of metrics to measure the impact of Greening by IT solutions, participants mentioned that there are no targets or measurements which would reflect any benefits related to sustainability right now. Participant 7 discussed that there are many contributing factors to potential metrics such as emissions or fuel consumption, which makes it hard to observe and attribute any changes to a Greening by IT solution. Participant 3 said that there are metrics in place, but that the impacts aren't really being measured.

The participants brought up technological complexity several times as well, mainly mentioning the complexity stemming from handling a combination of barriers. Participant 4 stated that there is inherent complexity from infrastructure being scattered and old, along with the data itself also not being very well organized. Participant 8 took things further in saying that things become even more complex because one cannot simply shut things down and implement a new system easily because of the airline being a 24/7 operation. This requires many compliance checks and stakeholder alignment, making things more complicated.

Participant 2 saw the long development time as a key obstacle to overcome. They complained about the length of time needed to scale up these solutions and the frequent need to restart because of changes in the people responsible or attention on the business side. The pace of innovation is quite low and cumbersome, leading to certain initiatives not being taken up because of how long it would take to scale them up and integrate them fully.

Coding Results: Technological Enablers

Regarding the technological enablers shown in Figure 6.14, no new factors were identified. The most mentioned factor in discussions was being able to measure the impacts of Greening by IT solutions. Multiple participants mentioned this as being a key pre-condition to implementing Greening by IT. One reason is that by being able to measure the impacts, one can also show the impact of not taking the decision in the first place. Participant 8 said this would go a long way in helping to justify the value to the business and convincing them to take up the initiative. Afterwards, one can see the impact after implementation of the solution and have a feedback loop when adjustments are made. This would also help in determining which of several Greening by IT applications should be taken up at any given time.

	Enabler	Freq.	Description	Quote
Technological	Able to measure impacts	22	It is possible to measure the impact of the proposed GBIT applications	"How do you compare this between one process and the other? (…) but at least starting to measure something and comparing if it improves, decreases or stays stable, that's already something"(Participant 2).
	Technical compatibility	12	GBIT solutions can interface with the company's existing IT infrastructure	"Because whatever new technology you add in which will save sustainability...For that you need to be able to quickly add new components to your landscape…to your ecosystem of applications"(Participant 2).
	Accessibility of data	11	Data on impact of GBIT solutions is easily accessible	"I said the data is not there and we are old company, we have lots of different databases, data warehouses, data lakes and indeed we are moving to one, but faster acceleration of that would really help" (Participant 2).

Figure 6.14: Coding Results of Technological Enablers

Technical compatibility was also mentioned as an important enabler as it would lower barriers related to complexity and cost of implementation. Having a more modern IT architecture where applications can be easily connected and are modular such that they can be adapted to other use cases was frequently brought up. Participants mentioned that the current innovation velocity is quite low because a lot of resources and time are needed to make current applications compatible with new ones. Participant 2 said that the pace of the technological advancements is only ever increasing, so new applications need to be built with that in mind and shouldn't be expected to be untouched for a decade. Overall, having easily compatible and modern architecture were seen as the main aspects of this enabler.

Finally, the accessibility of data was discussed and reaffirmed as an enabler. It was stated that, as KLM is an old company, there are various databases, data warehouses, data lakes, and other locations where data is stored. Each of these can be hosted in different places with different data owners, complicating the accessibility. Having this data easily accessible was also seen as a precursor to being able to measure the impacts and then determining the value of Greening by IT solutions.

Coding Results: Organizational Barriers

For the organizational barriers, participants spoke the most about Greening by IT not being a priority, a lack of leadership from management, a lack of resources, and unclear business value. The figure including all of the barriers resulting from the coding can be seen in Figure 6.15. Six new organizational barriers were also identified during the coding analysis and are explained below:

- **Operational Management Overwhelmed:** A relatively widespread problem at D&T is that the operational management layer (e.g. product owners), where initiatives are evaluated and taken up, is very overburdened. Participants cited this as a key obstacle as this crucial management layer does not have the mental capacity nor the time to think about Greening by IT, let alone sustainability in general. They are predominantly focused on solving more-pressing operational issues. Participant 3 refereed to an example where an enthusiastic employee wanted to develop a sustainability vision for their department, but wasn't allowed to because they couldn't spare the manpower.
- **Lack of strategy:** Participants noted a lack of vision and strategy from management. They referred to the fact that there is no translation from the strategies made by strategic management into strategies pertinent to their area. They state that they need a road-map and vision for tackling sustainability the coming years with concrete aims from their management.
- **Lack of targets:** Contrary to having the metrics to measure the impact, this barrier represents having quarterly or annual targets or objectives at an organizational level to drive sustainability. Participants made clear that there is a lack of quarterly or annual targets regarding sustainability which would be useful in driving the implementation of Greening by IT solutions. Beyond simply having better targets within D&T, participants also cited the fact that the business, which drives the decision-making, does not possess these sustainability targets either.
- **Lack of awareness of Greening by IT solutions:** After hearing many times that Greening by IT wasn't taken up because people on the business side did not find it important, several participants raised the point that the business was also unaware of IT's potential in tackling sustainability challenges. They were also claimed to not have a good general understanding of IT in general which only contributes to their lack of awareness.
- **Sustainability very siloed:** Although not brought up extensively, this factor was found to be very obstructive and was reinforced by findings from the desk research carried out in Chapter 5. Participant 4 mentioned that tackling sustainability is handled in a very decentralized way where the various parts of the airline do not communicate about their sustainability solutions, which leads to missed opportunities. This leads to little to no collaboration on some of these wicked problems and a lack of alignment between stakeholders. Where one department might have a sustainability target, the other department that they rely on might not, which only leads to challenges in collaborative efforts.

The most frequently brought up factor from those found in the literature study list was Greening by IT not being considered a priority. Interviewees cited this as the root cause for many other barriers, such as there being insufficient resources, a lack of targets, no strategy, etc... They commented that not are there so many other priorities from the business side, but that it is not seen as important compared to solving operational issues. As a result, not as many resources are allocated because strategic management is choosing to not pursue this in comparison to other things. This is related to the second most brought up barrier regarding a lack of leadership from management. Participants 3 and 6 discussed that they hear a lot of talk at the highest levels of management about it, but that there are no concrete steps taken. Closely related to this factor is there being unclear business value from developing Greening by IT solutions, which would result in it not being considered a priority.

The factors brought up less frequently included the cost of solutions being too high, there being a lack of immediate payback, ambiguity in applying regulations and responsibility, and a lack of standards. The first two are particularly surprising because the participants ranked those barriers quite high as seen in Subsection 6.5.1. The two barriers surrounding ambiguity in applying regulations and responsibilities were not raised that much in the discussions and are in line with their performance in the rankings. Similarly, there being a lack of standards was only brought up one time, representing the fact that participants found other factors more important.

Finally, two factors used in the ranking were not raised in the interviews: uncertainty regarding which initiatives would have the largest impact and there being a lack of prior experience. Participants spent more time discussing more specific barriers such as data quality, accessibility, and the metrics used to measure the

impact. These can be seen as contributing factors to the uncertainty, but perhaps the uncertainty is seen as more of a symptom of these more specific issues. Given that a lack of prior experience was the lowest ranked barrier, this makes sense given that the participants do not see this as a major barrier.

	Barrier	Freq.	Description	Quote	Barrier	Freq.	Description	Quote
Organizational	Not considered a priority	25	Developing GBIT is not seen as a priority	"No, it's not happening because we don't set put focus and priority on it"(Participant 5).	Cost of solutions too high	4	The starter costs to implement GBIT are too high	"Yeah, a cost of solutions too high. Yeah, probably also an important one because it is, it's expensive, so people don't wanna pick it up"(Participant 8).
	Lack of leadership from mgmt.	12	Management lacks vision and does not lead the organization in driving GBIT	"I would say like we have a whole organization, we have an even a VP on sustainability, but I don't see anything coming from there. That will help. They're not driving it so"(Participant 6).	Lack of immediate payback	2	There is a lack of immediate benefit from the use of GBIT	"No immediate payback because we live in an operational thing, so the organization is on fire. So they're always going for short term solutions instead of long term solutions. And that's the struggle we're in"(Participant 6).
	Lack of resources	12	There are insufficient resources to put towards GBIT	"Yeah. I think a lot of these are not even being questions because there's no priority and there's a lack of resources so…"(Participant 6).	Ambiguity on how to apply regulations	2	Not clear how to comply with regulations which involve GBIT	"So there are a lot of rules we need to apply, but no one feels responsible or knows how to apply those regulations"(Participant 6).
	Unclear business value	10	GBIT not seen as adding value for the business	"And I think the other part is that it needs to come from the business. If the business doesn't ask for it, we will not pick it up"(Participant 6).	Ambiguity in responsibility	2	Not clear who is responsible for facilitating adoption of GBIT	
	Operational mgmt. overwhelmed	8	Middle management too overwhelmed to consider GBIT	"And the thing is, people don't even have time for it. They don't even have time for it or normal jobs because they're so overloaded"(Participant 6).	**Sustainability very siloed**	1	Sustainability handled per business and not collaborated on	"battling the sustainability goals is done very siloed (...) and I think if you combine those departments, (…) that would be very beneficial because then it will accelerate and it will have an amplifying effect on each other" (Participant 4).
	Lack of strategy	7	There is no GBIT strategy in the organization	"I see that in top management we talk about it, so awareness is there, business priority is there. So that's great, but as an employee, I don't see a clear road map for OK, we do these things and that will tangibly lead to that"(Participant 3).	Lack of standards	1	No standards on how to implement GBIT solutions	"But then I think before you even can start initiative, you need to have the standards in place and you need your business to define those to work on your solution"(Participant 6).
	Lack of targets	6	GBIT is not included in quarterly targets	"And yeah, they're in these key results, there are currently… no sustainability key results. So I think that's already interesting"(Participant 5).	Uncertain which initiatives have largest impact	0	Unclear which GBIT solutions would make the largest impact	Not discussed
	Lack of awareness of GBIT solutions	6	The business is not aware of what GBIT solutions exist	"Sometimes it's not that people don't want to, but also what I notice is that you have to make people aware that there are technical opportunities. It's not that they don't want to, for example"(Participant 5).	Lack of prior experience	0	Employees do not have prior experience implementing GBIT solutions	Not discussed

*Cells in blue represent newly identified barriers

Figure 6.15: Coding Results of Organizational Barriers

Coding Results: Organizational Enablers

Next, looking at the enablers which fit within the organizational category, two new factors were found in the coding analysis and all of the factors from the literature study were discussed, albeit some only a few times. Each of the enablers are illustrated in Figure 6.16. The two new factors are setting targets for Greening by IT and that Greening by IT is prioritized. These two factors are explained as follows:

- **Set targets for Greening by IT:** A useful way to lower the barriers related to Greening by IT not being a priority and there being a lack of resources, is setting targets such as Key Performance Indicators (KPIs) and Objective and Key Results (OKRs). These could be targets specifically related to Greening by IT or at least the sustainability goals of the airline.
- **Greening by IT is prioritized:** While this enabler might seem obvious given that a lack of priority was seen as a barrier, it was not identified in previous literature. Participants 1 and 7 thought that prioritizing Greening by IT initiatives would help align stakeholders and succeed in getting resources allocated for them. They saw this as more important as it is the root of decision-making related to resource allocation.

	Enabler	Freq.	Description	Quote	Enabler	Freq.	Description	Quote
Organizational	Senior management leadership	16	Senior management leads the company in adopting GBIT	"I think we've discussed many times already, which is this strategy. So it needs to be the President of the company. The CEO needs to be clear that it has a strategic importance"(Participant 7).	IT strategy embedded in overall business strategy	4	IT featured in company's overall business strategy	"And in flight platform we have different businesses, (…) with different strategies. And then we have one IT strategy and that definitely should be all one"(Participant 3).
	Sufficient resource allocation	11	There are sufficient resources allocated for GBIT solutions	"You know that I have less and less every time and I have to share that between a lot of innovation needs and if you have a separate investment plan with (…) sufficient budget then that would…"(Participant 3).	Perceived value of technology	3	GBIT solutions are seen as value-adding	"And I think perceived value of technology, it's kinda linked to what we discussed with the awareness. So if we make them aware that we think technology can help us with this challenge"(Participant 5).
	High motivation of employees	9	Employees are motivated to implement GBIT initiatives	"Yeah, because if you don't have high motivation of employees…it's maybe not *the* enabler, but it's one of the factors that needs to be there"(Participant 2).	Prior experience	3	Employees posses prior experience with implementing GBIT	"So it's not that you will hire a lot of data experts and then it's solved, no. How are you going to do that with our current population that are working already for 25 years"(Participant 8).
	Defined GBIT Strategy in IT	9	IT department has a defined Greening by IT strategy	"I would say to have a proper investment strategy and have that greening by IT really embedded in their strategy in a tangible way"(Participant 3).	Good economic environment	2	Current economic environment is positive and fosters innovation	"Good economic environment. I think that's one of the very big bottleneck at the moment"(Participant 6).
	Org. has sustainability oriented strategy	9	Organization itself has a strategy for becoming more sustainable	"And so I think organization has sustainability oriented strategy. I think as I mentioned before, that's where it all begins"(Participant 5).	Positive org. attitude towards sustainability	2	Organization has a positive attitude towards sustainability	"Because to give it priority, I don't know if I see it now here, but for example, there's a very positive attitude towards it and that's good"(Participant 8).
	Set targets for GBIT	7	Targets are set for measuring GBIT performance	"So if we have like a certain KPI for sustainability, then you could definitely steer on sustainability"(Participant 6).	IT department size	1	IT department is sufficiently large to facilitate GBIT	"I think IT department size of course, because if you have more resources and power to innovate and to find solutions, that will always help"(Participant 4).
	GBIT is prioritized	5	GBIT solutions are specifically prioritized	"For me it's a prioritization discussion because the resources follow prioritization. So if the prioritization is there there's budget for innovation…the resource discussion is not a discussion"(Participant 7).	*Cells in blue represent newly identified enablers			

Figure 6.16: Coding Results of Organizational Enablers

The most discussed enablers which were previously identified in the literature study were senior management leadership, sufficient resource allocation, high motivation of employees, Defined Greening by IT strategy in IT, and the organization having a sustainability strategy. The interviewees tended to believe that if the C-level and other strategic management would start pushing for it, more Greening by IT initiatives would be taken up. If strategic management were to push for it, the participants claim that this would help align stakeholders throughout the hierarchy, get more resources, and then things will trickle down. Following in step, the second most-coded enabler was there being sufficient resource allocation. This is expected as having sufficient resources would enable hiring additional people or buying off-the-shelf applications.

The eight participants were nearly all in agreement that the motivation of employees is helpful in overcoming some of the obstacles. Participant 2 said that it is one of the factors that needs to be there, but is maybe not the deciding factor in this. This is similarly reflected in the overall ranking where having a high motivation of employees performed ninth. As often discussed were having a defined Greening by IT strategy and the organization having a sustainability strategy. Participant 3 commented multiple times that the key aspect missing is a translation from the KLM general strategy to an actionable strategy for how IT could contribute. Having this road map would drive resource allocation and align stakeholders accordingly. Participant 5 said that the organization having a sustainability strategy was a precursor to most of these enablers in that most of the other enablers would be working towards this more global strategy.

Less discussed was having IT featured in the overall business strategy. Participant 3 said that the IT and business strategies are currently separate and that having them integrated would contribute to driving things further. Participant 1 said that IT should be seen as an enabler for all of these sustainability challenges and that it should be seen as more than a cost center, but more as a part of the central business.

The rest of the organizational enablers were less discussed. Participant 5 commented that the perceived value of technology closely mirrors the level of awareness of the potential of Greening by IT. Participant 6 confirmed that having a good economic environment would help, as that was seen as a bottleneck at the moment. Participant 4, who works on the business side of D&T, was vocal about the impact of having a larger

IT department, but other, more tech-focused participants were not in agreement. They claimed that the IT department size is not so much the issue compared to phasing out the legacy applications which requires a lot of resources. They stated that having more modern IT architecture would free up staff to work on more value-creating things like Greening by IT and that the department would possibly even shrink.

Coding Results: Environmental Barriers

As stated in Subsection 6.1.4, despite the focus of this study being on the internal factors contributing to Greening by IT implementation, the environmental factors still play a crucial role. Although no interview questions were asked on their contribution, several participants brought up external factors anyway and are included in this analysis as a result. The environmental barriers can be found in Figure 6.17 and are described below:

- **Cumbersome aviation regulations:** Participant 4 brought up that one of the missing factors from the literature study factor list was the impact of aviation regulations on some of these initiatives. They claimed that there is a lot of regulation or even over-regulation in some cases which makes it even more cumbersome to implement new solutions as there are so many rules to comply with. The example they brought up was related to food waste as all food brought on KLM aircraft sourced from outside of the country has to be burned upon arrival. Participant 6 also brought this up and said that more work needs to be done to lobby for legislation changes.
- **Lack of external pressure:** Although only mentioned once by Participant 5, it was unique enough to still be included. Participant 5 said that the fact that there is no external pressure pushing their division to take action regarding sustainability slows things down.

	Barrier	Freq.	Description	Quote
Environmental	**Cumbersome aviation regulations**	4	Regulations specific to aviation which inhibit GBIT initiatives	"A lot of things within aviation are regulated or even overregulated and that's gonna be in conflict with achieving green goals"(Participant 4).
	Lack of external pressure	1	Lacking external pressures to propel GBIT solutions	"So we're not being… there is no external driver or something that is pushing us to say, 'hey, platform ground we want to solve...'" (Participant 5).

*Cells in blue represent newly identified barriers

Figure 6.17: Coding Results of Environmental Barriers

Coding Results: Environmental Enablers

The final grouping to be displayed is the environmental enabler that was found in the coding analysis, which can be seen in Figure 6.18. The enabler was regarding external coercive pressure in the form of regulations or the media. The most striking example from the interviews was from participant 5, who said that the only time they saw tangible steps taken within their area regarding sustainability was when there had been a negative article in the media. Participant 6 said that there being more regulatory coercive pressure would help drive Greening by IT further as then it wouldn't matter whether their business stakeholders would see it as value-adding or not, it would just be something that they would need to comply with.

	Enabler	Freq.	Description	Quote
Environmental	External coercive pressure	4	External pressure from regulatory bodies or the media	"Yeah, for me in my five years at KLM, I never saw us run so hard on physical labor as it was being pushed by external news media, etc…"(Participant 5).

Figure 6.18: Coding Results of Environmental Enablers

6.5.3. Generalizability

After reviewing all of the factors with the participants, it was always asked whether or not these results could be extended to the rest of KLM and other airlines as well. Participants 3 and 7 said that they did think that

these results would be generic for most airlines. Participant 3 commented that their answer to this question might even be biased because they think KLM's management is actually quite aware of sustainability and that this would be even less in other airlines.

Participants 2 and 5 raised the point that the results could probably be extended to other legacy, European airlines, but that the answers would change either for newer airlines or airlines from different parts of the world. Participant 5 mentioned that European society is pushing for many of these sustainability transitions, but that they don't see as much traction with airlines from the U.S., for example. Participant 2 took a slightly different approach and talked about the impact of the different working cultures on Greening by IT implementation. They said that the Dutch working culture likes a lot of discussion on big decisions and that actually choosing a direction can be difficult. They compared this with the French way of working, which has a more strictly-followed hierarchy of decision-making in their opinion, which could even be helpful for implementing Greening by IT solutions. They said that if the management in such companies chooses the direction, the rest will follow suit more easily, which would help in the case that strategic management was pushing for Greening by IT solutions.

6.6. Validation of Results

The results from the quantitative and content analyses were presented several times to various stakeholders throughout KLM in order to gather feedback. One director within D&T was surprised that the technological factors were not ranked higher. For example, they had expected that the enablers regarding accessible data or being able to measure the impacts would have appeared higher than the enablers on making strategies. This was reiterated by one of the VPs within IT, who was also surprised that participants ranked a lack of resources as a major obstacle. They stated that since there is always a lack of resources, be it financial or human, that they expected a lack of resources to be seen more as a constant obstacle instead of the leading one. Correspondingly, one VP within IT was very surprised that operational management sees having a strategy as such a key enabler. They expected people to rank the most practical things that would help most as higher, like having more resources. One member of IT's executive management was surprised to hear that sustainability was not accounted for within the project portfolio process, as they thought that had already been implemented.

Many KLM employees within D&T and the CIO Office said that many of the results were to be expected and did not come as a surprise. The fact that Greening by IT is not being considered a priority, does not receive enough resources, and has unclear business value was not seen as that surprising. One VP stated that you could probably extend the key factor results to a majority of Air France - KLM. Overall, some of the same conclusions about the different perspectives between operational and strategic management on the influencing factors were confirmed when having validation discussions on these results. With this in mind, the final decision support framework developed in the next chapter could be used to facilitate these discussions in the future and investigate the different perceptions that were encountered.

6.7. Conclusion of Sub-Question 3

This chapter answered the third sub-question which asked: "What are the barriers and enablers of Greening by IT implementation within airlines?"" Through the factors identified during the literature study and the recognition of additional factors through the stakeholder interviews, the final list of influencing factors can be seen in Figure 6.19. These factors are similarly grouped by barriers, enablers, and the TOE categories provided by the conceptual model in Chapter 4. The coding analysis demonstrated the relevance of many of the factors found in the literature study and highlighted several new factors which the participants brought up. These new barriers and enablers can be seen in Figure 6.19 written in bold.

In addition to the final list, several conclusions were made on the most relevant factors identified by the participants and comparisons between the stakeholders from strategic and operational management, which can be found in Subsection 6.5.1. Thus, this chapter provided an analysis of the key factors which influence the implementation of Greening by IT. These factors are used for developing the strategies for the fourth sub-question which is covered in Chapter 7.

	Barriers	Enablers
Technological	➢ Long development time ➢ Lack of technical infrastructure ➢ Lack of metrics to measure impact ➢ Technological complexity ➢ **Difficulties from experiment to execution** ➢ **Hard to express data** ➢ **Lack of data quality** ➢ **Lack of data accessibility**	➢ Able to measure impacts ➢ Accessibility of data ➢ Technical Compatibility
Organizational	➢ Lack of prior experience ➢ Lack of standards ➢ Ambiguity on how to apply regulations ➢ Ambiguity in responsibility ➢ Uncertain which initiatives have largest impact ➢ Lack of immediate payback ➢ Lack of resources ➢ Cost of solutions too high ➢ Unclear business value ➢ Not considered a priority ➢ Lack of leadership from management ➢ **Operational management overwhelmed** ➢ **Lack of strategy** ➢ **Lack of targets** ➢ **Lack of awareness of Greening by IT solutions** ➢ **Sustainability very siloed**	➢ Positive organizational attitude towards sustainability ➢ High motivation of employees ➢ Prior experience ➢ IT department size ➢ Senior management leadership ➢ IT strategy embedded in overall business strategy ➢ Sufficient resource allocation ➢ Good economic environment ➢ Perceived value of technology ➢ Defined Greening by IT strategy in IT ➢ Org. has sustainability-oriented strategy ➢ **Set targets for Greening by IT** ➢ **Greening by IT is prioritized**
	Drivers	
Environmental	➢ Coercive pressure (gov't regulations, suppliers, customers, shareholders) ➢ **Cumbersome aviation regulations & Lack of external pressure** ➢ Mimetic pressure (competitors' practices, strategies, and structures) ➢ Normative pressure (media, public opinion, industry standards)	

Figure 6.19: All Barriers & Enablers for Greening by IT Implementation (Newly Identified Factors in **Bold**)

7 Devising Strategies for Greening by IT Implementation

After developing an understanding of the barriers impacting the application of Greening by IT, it becomes necessary to look at the strategies which can be used to overcome them. The objective of this chapter is to answer sub-question four which asks ”Which strategies can be used to overcome the identified barriers and drive Greening by IT implementation in airlines?” This is accomplished through the same stakeholder interviews used in Chapter 6, where subsequent questions were asked to explore strategies in relation to the enablers that the participant identified. In Section 7.1, the interview results regarding the strategies are presented. Then, the strategies are analyzed and mapped to the barriers in Section 7.2. Finally, the validation performed for these results and the conclusions for this chapter are shown in Section 7.3 and Section 7.4.

7.1. Interview Results: Greening by IT Strategies

As described in Section 2.3, it was clear from the literature study that there is a lack of concrete strategies which can be used for Greening by IT implementation. Given this gap, the interviews used the enablers established in Chapter 6 as starting points to develop concrete strategies together with practitioners. Instead of having each participants comment on the effectiveness of conceptual adoption theories from prior research, it is decided to keep it similarly practical to the line of questioning on the factors influencing Greening by IT. Referring to Figure C in Appendix C, the questions pertaining to the enablers, strategies, and decision support framework are used for generating the results in this section. These questions were posed to each of the participants during the same interviews explained in Chapter 6. After evaluating the enablers, each participant was asked what strategies could make use of these enablers and lower the identified barriers. For example, after having discussed the barrier ”Not Considered a Priority,” the participant could identify being ”Able to Measure Impacts” as an effective enabler to overcome the barrier and correspondingly propose a strategy in overhauling legacy architecture to improve the data quality. Following the interviews, the transcripts were analyzed to identify proposed strategies by the participants and map them to the corresponding barriers. Due to how closely related the answers on the enablers and then the corresponding strategies were, there is naturally some overlap when discussing the results in this section and the results of the key factors in Section 6.5.

The results of the coding analysis for strategies can be seen in Figure 7.1. For each strategy, the frequency of its corresponding code is included along with the definition and a quote from one of the interviews. The frequency is no measure of the strategy’s effectiveness, but merely represents what the participants discussed most. In line with the tables created for the barriers and enablers, the strategies are grouped by the same TOE categories. Further analyzing the strategies that resulted from the interviews, it can be seen that 2 strategies were devised within the technological category, 14 in the organizational category, and 2 in the environmental category. Some initial conclusions can be made from these frequencies in that the most identified codes were for strategies related to an increase in management leadership, having a defined Greening by IT strategy, and having improved data quality/access.

Technological Strategies

Improve Data Quality/Access: The two technological strategies were some of the most often mentioned ideas in the interviews. Improving data quality/access was recommended for a variety of reasons, such as being able to measure potential impacts between Greening by IT solutions, justifying action to business stakeholders, and for adjusting the solutions after implementation. Participant 3 described it as a ”super power” to be able to predict the impact on the operations and see which options can be prioritized. Quality and access were grouped together for this strategy as they go hand in hand. Participant 1 clarified this because having the data is great, but it’s useless if not accessible.

Improve Architecture: This strategy is complemented by the other technological strategy, improve architecture, which participants brought up as a crucial step. They frequently mentioned how many resources must go into overhauling old architecture and how much it limits their innovative capacity. Having more modern architecture would enable better connectivity between applications, make them more modular for various uses, and enable faster innovation. Participant 3 stated that this would also lead to more initiatives being taken up because more employees would be available instead of being focused on overhauling legacy applications.

Organizational Strategies

Increase Management Leadership, Commit Resources, & Prioritize GBIT Initiatives: More leadership from management was seen as a way to overcome multiple barriers as it would help align stakeholders, cement Greening by IT as a priority, and assist in formulating a strategy. Participant 8 was adamant that having C-level stakeholders aligned on its importance would almost guarantee its prioritization and implementation. Participant 4 even went as far to say that they were concerned that if no progress is made and management doesn't step up, that the airline's existence would be threatened in the future. Participant 5 mentioned that it would also help inspire people to take on the complex challenges related to sustainability. Participants saw this as a precursor to several other strategies. Management's support would lead to it being prioritized, included in targets, a strategy being defined, and finally resources being committed. Participant 3 added that without additional resources, laying out a strategy won't accomplish anything either. This would inhibit tangible steps from being taken in implementation. However, Participant 7 made clear that the root issue to resource constraints, a lack of a strategy, and general inaction is that Greening by IT simply isn't prioritized.

	Strategy	Freq.	Definition	Quote
Technological	Improve data quality/access	18	Improve the data quality and access needed for GBIT solutions	"Yeah, but your first need to find as well what the data is that you need for your next step. So you first need to have your initiative there and then you need to see OK, which data, what is it that we need?" (Participant 6).
	Improve architecture	13	Improve existing architecture to enable GBIT adoption	"And definitely the right infrastructure. So if we buy new tools to, for example, the tool that we are now implementing for predictions, you know, having less kerosene for all of the catering things. If we don't have the right, IT and data infrastructure, it will not work. It's very important"(Participant 3).
Organizational	Increase management leadership	19	Management takes stronger leadership role on GBIT adoption	"I think also to senior management leadership, I think if they push for it, it will help"(Participant 5).
	Define GBIT strategy	18	Create GBIT strategy	"But I see that also in top management we talk about it, so awareness is there, business priority is there. So that's great, but as an employee, I don't see a clear road map for OK, we do these things and that will tangibly lead to that."(Participant 3).
	Designate people responsible	15	Make specific people responsible for sustainability	"It is important to have somebody responsible for this to make sure we get enough attention on the topic and to facilitate innovation and progress on it"(Participant 7).
	GBIT Hackathons /Challenges	12	Host internal hackathons focused on developing GBIT solutions	"For D&T, we also for example have hack week. So then it could be also nice because in Hack Week (...), we do the sustainability challenge and then we explore different technologies that can measure, for example, the sustainability index"(Participant 5).
	Commit resources	11	Commit resources to adopting GBIT	"Yeah, suppose we create a strategy and we don't have money to implement it, then we created a strategy for our desk. Yeah, it doesn't work"(Participant 3).
	Include GBIT in targets	10	Include KPIs or targets related to GBIT	"But I think where it starts, it needs to be inserted in all our OKR framework, also of the business"(Participant 5).
	Create GBIT Platform	9	Create a platform solely focused on developing GBIT solutions	"Then, as a second step, I would also create what I mentioned, the whole lab and dedicated team to really explore possibilities and experiment and test and validate new technologies"(Participant 5).
	Prioritize GBIT Initiatives	5	Prioritize developing GBIT initiatives	"Well I think the strategy is putting it as a priority. I think that's the main thing to get things going. In essence, we always translate our priorities from the KLM strategy"(Participant 7).
	Include sus. criteria in projects	4	Include sustainability criteria in project evaluation process	"Also, what I would say is that it becomes mandatory in every epic I check mark. Simple as that. Does it help make it greener? Yes or no? And if it's a no, why? (...) so every epic that should have how do you make it greener" (Participant 1).
	Collaborate internally	3	Collaborate with other departments internally	"it needs to be transparent and visible on what everybody is doing. It will also create cooperation. It's alignment, but it also will boost ideas and reusability. A tech technique is not restricted to one process. You can use the similar technique in multiple processes"(Participant 2).
	Combine GBIT with other goals	3	Combine GBIT with other business goals to drive acceptance	"So for the initiatives where we can take into account sustainability and in line with our business objectives, we're including it"(Participant 5).
	Raise awareness	2	Raise awareness about the potential of GBIT solutions	"The first step for me would be to raise awareness. And so I would do roadshows and making it more explicit, also within the IT or the product teams, what's all possible with technology in regards to sustainability"(Participant 5).
	Improve idea loops	2	Improve idea feedback loops	"So how can we uh… in the past sometimes you had like a small wooden box which said ideas and then everyone who was working in the company could say, 'hey, I have a great idea!' (...) I don't see that today where you can… I don't see the box"(Participant 4).
	Develop standards	2	Develop standards for facilitating GBIT initiatives	"And it also goes with impact, setting a norm. So you have a standard design… standardization, yes, certain formulas that you need to use or you need to align on so that everyone is competing or working on the same way"(Participant 8).
Environmental	Scout externally for techs	10	Look external to the org. for GBIT solutions	"Like what we do with ground lab, but then maybe it's sustainability lab with the sustainability department to make sure that we're also really scouting for technologies that can help us in our being more sustainable"(Participant 5).
	Collaborate externally	7	Collaborate with external parties to more easily facilitate GBIT solutions	"Maybe work together within the Sky Team format, for example with other carriers who also have the same ambitions to work together"(Participant 5).

Figure 7.1: Greening by IT Strategies Identified in Stakeholder Interviews Grouped by TOE Categories

Define GBIT Strategy & Include GBIT in Targets: Defining a strategy for Greening by IT is useful for a variety of reasons and is a first step in working out the complexity involved. Participant 4 described it as crucial in aligning strategic managers with operational managers, allocating resources for it, and how to engage with other stakeholders on it. It would fill in the missing gap which currently exists between the higher level KLM sustainability strategy and IT. If this strategy was incorporated within the overall strategy with the business side, it would make it even more powerful as both sides would be aligned, as raised by Participant 7. Participant 7 also raised the point that if people are motivated, but if there is no strategy associated with it, nothing is likely to happen. Creating a strategy would also likely come with associated targets to measure progress, which was another strategy identified in the interviews.

Designate People Responsible & Create GBIT Platform: Participants saw having designated employees responsible for Greening by IT as crucial in making sure that it is not deprioritized. Given that so many saw the operational management layer as completely overwhelmed with issues related to operations, having specific people whose sole job is to work on developing digital sustainability solutions would help ensure progress is made. Participant 7 followed up saying that these people would then have the time to enable collaboration on sustainability across the airline and look externally for solutions. Similar reasoning was used for the strategies for creating a Greening by IT platform. Having a separate platform to work specifically on digital sustainability solutions would overcome many of the identified barriers as it would have a separate budget which wouldn't constantly compete with other business goals and the freedom to explore solutions.

GBIT Hackathons/Challenges & Collaborate Internally: Many of the measures discussed are long term options, but one of the useful ideas for short term gains was hosting Greening by IT hackathons or challenges internally. Examples included the most sustainable ground operation or a hackathon trying to setup sustainability criteria in portfolio management. Participant 7 stated that the challenge could arrange various groups of employees from around the company, give them time every Friday to work on the topic, and then share the ideas at the end of it. It wouldn't have to be a massive topic, but something doable which could be solved by carrying this out. It was impressive that four participants brought this up as an idea without being prompted, demonstrating its potential and existing support. Participants were very taken with the KLM Sustainable Flight Challenge and its success in raising awareness, creating novel ideas, and putting them to the test. In a separate discussion at SkyTeam, the airline alliance which hosts the sustainable flight challenge, it was brought up that 40% of airlines did not even have a single person dedicated towards sustainability until the challenge started three years ago. Reflecting on this, hosting these types of challenges on an internal level could lead to more collaboration, more ideas being picked up, and also more employees working on sustainability. Participant 7 also drew a comparison to the barrier regarding difficulties between experimentation to implementation in that by doing the challenge, one can already show the business stakeholders a successful experiment. The broader strategy connected to this is to collaborate on Greening by IT internally, as stated by Participant 2. They made clear that it needs to be transparent what different departments do in order to develop cooperation. Participant 4 said that sustainability is tackled in a very "siloed" way, where the various departments don't cooperate on it, which leads to decreased collaboration.

Include Sustainability Criteria & Combine GBIT with other Goals: Including sustainability criteria in the project evaluation process was also raised a couple times. Participant 1 saw this as a core step to take to ensure that even non-sustainability-related projects still have to consider the sustainability impact. Including the criteria would also make Greening by IT solutions more competitive and more likely to get taken on. This strategy can be associated with the one on combining Greening by IT with other goals. Participant 5 was clear that technological advancement and sustainability should be seen as a common goal and that other initiatives can be combined to create more progress. Participant 7 reinforced this in that the most likely Greening by IT options to be implemented are those that are in line with business goals.

Raise Awareness, Improve Idea Loops, & Develop Standards: The rest of the strategies were only mentioned a couple of times and fulfill similar roles. Raising awareness about the potential of Greening by IT was seen to help align stakeholders. Participant 5 stated that it's not that people are against digital sustainability ideas, but that sometimes they just aren't aware of the possibilities with IT. Participant 4 also raised the point of having better idea feedback loops between strategic management and the rest of the hierarchy to increase the innovation speed. This was reinforced with other discussions with stakeholders around the company such as pilots who signaled that they already have many ideas of tiny improvements which could yield big changes

and that strategic management was not aware of. Finally, developing standards for Greening by IT solutions was brought up by Participant 8 to help lower the barriers involved with developing the solutions. Having a ”standard design” as they called it would help align different stakeholders and lead to more initiatives being taken up.

Environmental Strategies

Scout Externally for Techs: Two strategies focused on efforts outside the organization were brought up: scouting externally for technologies and collaborating externally. Participant 4 said that scouting externally for new technologies to be used for Greening by IT, even outside the aviation sector, could lead to more innovation taking place. There could be solutions in other sectors which could be directly applicable or at least adaptable to some of the sustainability challenges within the airline. Off-the-shelf applications could even be used to find solutions quicker instead of developing it in-house. Participant 6 said that scouting externally would also help inspire the company to see transitions which have occurred successfully elsewhere.

Collaborate Externally: Collaborating with external parties to KLM was also selected as a strategy. This could be with other stakeholders within aviation such as airlines in the SkyTeam alliance, Schiphol group, or suppliers. Cooperation and taking on different aspects of the issue could lead to more gains than otherwise, given the lack of resources available for Greening by IT currently.

7.2. Analysis of Strategies Based on Key Factors

The subsequent step in this chapter is to map the selected strategies to the identified barriers. This was done partly during the interviews and during the analysis phase afterwards. During the interviews, the participants were asked to suggest strategies based on the enablers which could be used to mitigate the primary barriers they had identified. This led to some notable connections between strategies and barriers which were observed in the content analysis. Beyond this, the applicability of all the strategies to each barrier was evaluated and reviewed with employees at KLM within the CIO Office and D&T. The result is a table which indicates the applicability of each strategy for each barrier, with both strategies and barriers being organized by the TOE groupings. Two tables were made due to the large amount of factors, one for the barriers identified in the literature study and another for the new factors which were determined in the content analysis. Both can be found in Appendix D as Figure D.1 and Figure D.2. To demonstrate an example in this chapter, the technological strategies mapped to the technological barriers identified in the literature study are shown in Figure 7.2.

		Technological Barriers			
		Lack of tech. infrastructure	Lack of metrics to measure impact	Tech. complexity	Long dev. time
Technological Strategies	Improve data quality/access	☑	☑	☑	
	Improve architecture	☑		☑	☑

Figure 7.2: Example of Technological Strategies Identified in Stakeholder Interviews Mapped to Technological Barriers

Several impressions can be made from the full tables on the applicability of the various strategies. One cannot judge their effectiveness as that was out of the scope, but can evaluate the strategies based on which are most applicable to the greatest amount of barriers. First of all, creating a separate Greening by IT platform was found to be applicable for 24 out of the 26 total barriers. The total number of barriers each strategy is applicable to can be found in Appendix D under Figure D.3. Many of the barriers revolve around something being lacking or challenges with implementing Greening by IT solutions. Having a dedicated platform with its own designated employees, separate budget, and strategy would go a long way to implementing Greening by IT solutions. Such a platform could also aim to solve other challenges in implementation like choosing the right metrics to measure performance, formulating strategies for different departments in IT, or setting up the necessary standards. A Greening by IT platform could also facilitate collaboration with internal and external parties, which are the other two most applicable strategies to a majority of the barriers. Similar to the platform,

any form of collaboration is a great way to break down the complex challenges and make the most of other parties' core competencies, hopefully speeding up implementation. Setting up a Greening by IT strategy was also pertinent for overcoming many of the barriers as it would help align priorities, setup targets, and allocate resources.

Analysis between Short-term & Long-term Strategies

Next, one can look at these strategies and analyze them from a short-term to long-term perspective, which takes inspiration from Dao et al.'s (2011) "today" and "tomorrow" classifications of strategies. Some of these strategies require alignment from a wide-variety of stakeholders and are inherently difficult to setup, which makes them likely to not be solved quickly. Other things could be considered small steps, but could still yield some results in the short term. This analysis was performed based on the answers given by the participants when asked how they would break down implementation into several levels and what things they would do first. Some of the classifications were then inferred based on these answers and the other results of the interviews. These strategies are used to develop the maturity levels of the decision support framework, which is treated in Chapter 8.

Short-Term Strategies

- Greening by IT Hackathons/Challenges
- Increase management leadership
- Scout externally for technologies
- Combine Greening by IT with other goals
- Raise awareness

Long-Term Strategies

- Improve data quality/access
- Improve architecture
- Develop standards
- Commit Resources
- Designate people responsible
- Prioritize Greening by IT initiatives

Looking first at the short term strategies, these make up the measures that organizations should be able to implement rather quickly without many resources. Holding the hackathons is likely to take the most time to organize and carry out, but is maybe the most effective measure in the short term to start raising awareness, solving issues, and collaborating internally. Management could also increase the awareness and affirm their commitment to the topic in the short term. Departments could already start looking externally for quick, off-the-shelf solutions or see what else could be added on to existing software. On a strategic level, the Greening by IT solutions which are most aligned with business goals could be prioritized along with more awareness campaigns. Switching focus to the long term, these would be the strategies which one should strive for over several years. Improving data quality or modernizing architecture will not happen overnight. Existing efforts in these areas could incorporate Greening by IT elements, such as already considering what emission or waste data would be needed. Eventually, certain Greening by IT solutions will be prioritized, people should be designated as responsible, and more resources should be allocated specifically for Greening by IT. Together with internal and external parties, consortia can be arranged to develop standards for Greening by IT.

There are also several strategies which have both short-term and long-term applications. For example, applying some sort of basic sustainability criteria in the project portfolio management could already help for people to begin considering it when taking on new projects. In the long run, more specific metrics and criteria to comply with can be worked out. Collaborating internally and externally can also take on various levels over time. In the beginning, having initial, low-committal conversations with other leads around the company to see how they incorporate Greening by IT or sustainability could help. Externally, one could speak with the closest partners or suppliers during normal meetings to inquire about possibilities for Greening by IT. In the long run, these conversations could become more firm commitments or collaborations for actually taking on certain projects. Lastly, defining a strategy for Greening by IT also has short-term and long-term implications. In the short-term, it would be most helpful to align the most important stakeholders on the value of Greening by IT and laying the necessary groundwork to enable Greening by IT solutions within the organization. Defining a basic strategy such as having high employee awareness or taking on the initiatives which can be quickly implemented with few resources early on would already help. These can be translated into corresponding plans for awareness campaigns, portfolio adjustments, or hackathons while a more worked-out strategy is developed in parallel.

7.3. Validation of Results

When carrying out some informal validation discussions for this chapter, all of the strategies were seen as potential options. After presenting the results, several directors within D&T supported creating a sort of sustainability lab to explore these solutions. They were also in favor of designating employees responsible and selecting ambassadors to assist in user adoption of new solutions. For example, certain pilots could be the ambassadors for rolling out new fuel consumption algorithms. They could collect feedback from other pilots and facilitate improvements together with D&T.

They also raised concerns about what would happen if you did create such a lab and did perform several experiments, but that the business stakeholders still did not choose to pursue them. This demonstrated the need to also have added pressure from the highest levels of management.

One expert colleague provided the idea that for designating people responsible for it and making a firmer organizational structure, airlines could look at similar things which must be complied with like security. For example, every new application must be compliant with certain data regulations and KLM-specific security requirements. There is a hierarchy of responsibility established throughout the airline for ensuring security compliance. Going forward, more comparisons could be drawn with how other transversal topics are handled within the airline to get input on how to structure sustainability and Greening by IT.

7.4. Conclusion of Sub-Question 4

This chapter answered the fourth sub-question which asked ”Which strategies can be used to overcome the identified barriers and drive Greening by IT implementation in airlines?” Through the stakeholder interviews, strategies were developed to make use of the enablers and overcome the barriers established in Chapter 7. The main result is a list of strategies to be used in implementing Greening by IT, which can be found in Figure 7.1. It was elected to use the TOE framework to group the strategies similar to what was used for the factors in Chapter 6. These strategies were then mapped to each of the barriers from the literature study as well as the new ones identified in the interviews, which can be found in Appendix D.

The strategies were also analyzed based on which would be short-term or long-term options. The short-term strategies, options that practitioners could put into practice relatively quickly, included setting up Greening by IT hackathons, increasing management leadership, scouting externally for technologies, combining Greening by IT with other goals, and raising awareness. The long-term strategies included improving data quality/access, improving architecture, developing standards for Greening by IT, committing resources, and designating people responsible. These strategies and their connections to certain barriers are then used in creating the decision support framework in Chapter 8.

8 Developing a Decision Support Framework

This chapter answers sub-question 5 which prompts ”What is the corresponding decision support framework which integrates the identified key factors and strategies?” In order to answer this, the conclusions from the previous chapters are used such as the conceptual model in sub-question 1, the practical takeaways in sub-question 2, the barriers identified in sub-question 3, and the corresponding strategies developed in sub-question 4. To begin, the purpose and intended users of the decision support framework are described in Section 8.1. The interview results which contributed to the maturity levels in the framework are discussed in Section 8.2. Next, the decision support framework is shown and explained in Section 8.3. Finally, the validation steps performed and the conclusions of this chapter are outlined in Section 8.4 and Section 8.5.

8.1. Purpose of the Decision Support Framework

Based upon the main research question and sub-question 5 as outlined in Chapter 3, a decision support framework which incorporates the key factors and strategies is needed. The conclusions of the literature study shown in Chapter 2, illustrated that the adoption phase is under-researched, that there is a lack of understanding between barriers and strategies, and insufficient information on measures practitioners can take. The purpose of this decision support framework is to fill in these gaps by guiding practitioners in the implementation of Greening by IT and providing a foundation for which future research can be based upon. To align with the practical goal, it must be practically relevant and easy to understand for users. This was kept in mind during the development of the framework and multiple rounds of validation were performed with several KLM employees within the CIO Office and D&T to ensure its practical use. From an academic perspective, it must also be based on founded adoption theory and supported findings in scientific literature.

8.1.1. Description of the Intended Users

The intended users of this decision support framework are the operational and strategic managers of IT departments within airlines. The operational management layer consists of the Product Owners, Project Managers, and Program Managers within the airline, while the strategic management layer is made up of the Directors, VPs, and C-level management such as the CIO. The operational management layer is focused more on the day-to-day operation and actual implementation of the Greening by IT solutions. They must make decisions on which resources, human and capital, to allocate for certain solutions and ensure that they are implemented successfully. They must also navigate stakeholder needs between the business objectives related to the operation and the potential sustainability goals on a routine basis.

The strategic management layer is responsible for fulfilling business objectives, enabling IT to have what they need to implement Greening by IT, and devising the long-term strategy. They must make decisions on what strategic themes to incorporate in the short-term and long-term vision. They play a large part in deciding which direction to take and asserting Greening by IT’s importance. They decide on the resource allocation for different streams within IT. They will evaluate the performance and impact of the Greening by IT solutions.

From this framework, both management layers should be able to identify their maturity level, most relevant barriers, and potential strategies. The factors and strategies most relevant for them might be inherently different. Operational managers might focus on those directly related to implementation such as difficulties from experiment to execution. Strategic managers could focus on the lack of targets for Greening by IT for example. The strategies also have different meanings as operational managers could make a Greening by IT strategy specific to their department, while managers at the strategic level could develop a strategy for IT as a whole.

8.2. Interview Results: Maturity Levels

The interview results which contributed to the design of the maturity levels in the decision support framework are supplemented in this subsection. Towards the end of the stakeholder interviews, participants were asked to breakdown the discussed strategies into three steps, in line with the three maturity levels in the conceptual model. For the first stage, Participant 5 recommended raising awareness through presentations around the company and make Greening by IT more visible within product teams. Similarly, Participant 4 said people who are very passionate about Greening by IT and sustainability should become ambassadors for the rest of the organization. Both them and Participant 2 said that it was crucial to get ”the basics right” early on, referring to having the proper data available and having your architecture set up to enable Greening by IT solutions.

Participant 7 furthered this by stating that beginning to set up the metrics or being able to measure the impacts of the solutions would also be a crucial early step. They also stated that the highest level executives of the company need to make it clear that Greening by IT is a strategic theme. The bottom layer would then focus on its implementation and measuring its impact.

For the second strategy phase, participants focused on measures which would integrate Greening by IT into the core of the organization. Participant 5 recommended creating a dedicated team or lab to explore the possibilities and carry out the experiments. They also said that they should expand on collaborations within SkyTeam or other external partners who have similar ambitions. Participant 4 said that whereas the first phase would be mostly volunteer-based, the second phase would be making sure that every department has integrated sustainability in some sort of way. They said that you need to form a clear strategy and have data available which can back it up. Furthermore, they stated that the concrete learning points from the experiments in the first phase should be compiled into standards for going forward. Participant 7 called the middle layer the ”enabler layer.” They said that one should focus largely on the technological and organizational enablers needed to integrate it fully. This comprises of making sure that the definition, availability, and quality of the data should be worked out and that the strategy is complete.

For the final stage, Participant 5 said that sustainability should be fully integrated into the organization. Dedicated teams are no longer needed as it is fully fused within the process of writing new epics, testing, and validating new technologies for implementation within the airline. Participant 4 said that this level would be reached when there is a complete turnaround in aviation and which Greening by IT has helped enable. The strategy discussions and these suggestions by the participants for breaking them down were used to create the level descriptions and recommended activities in the framework.

8.3. Decision Support Framework

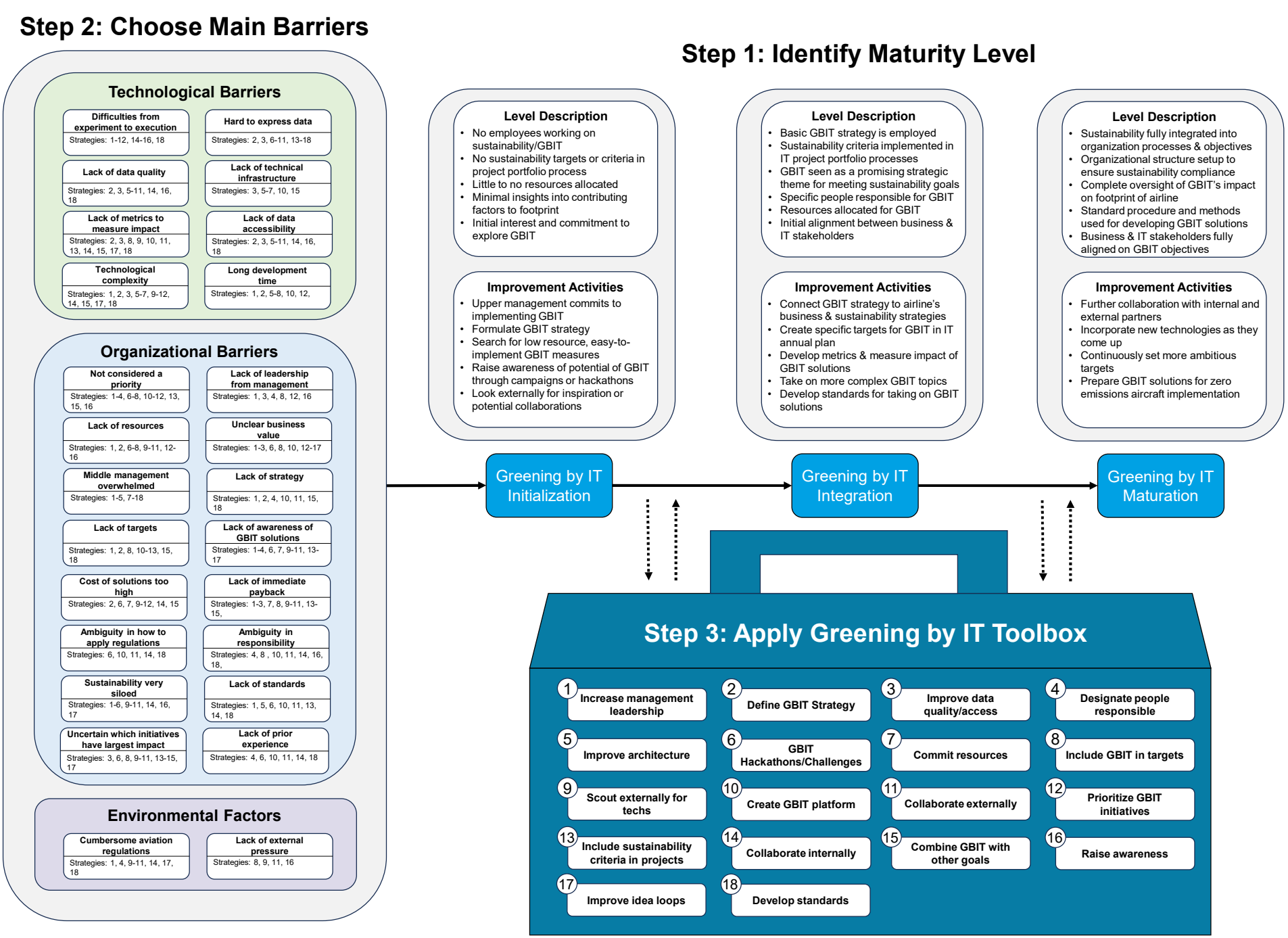
The decision support framework for Greening by IT implementation can be seen on the following page. There are three main steps for using the framework. The first is to identify the maturity level that the organization in question currently has for Greening by IT implementation. This helps orient the practitioner to their current level of Greening by IT implementation and identify some potential steps they should take to develop it further. Yet, given that these steps are quite broad and the situation might be different at the airline in question, practitioners can review the barrier list in step two. Here, they can identify and select the most relevant barriers preventing them from developing Greening by IT further. Each barrier is accompanied by a list of strategies which correspond to the strategies shown in the ”Greening by IT Toolbox” shown in step 3. Then, the practitioners can review the suggested strategies and select those that they would wish to apply. These steps are now explained in more detail below.

Step 1: Identify Maturity Level

These three maturity levels are based on the phases from Innovation Diffusion theory which was used in the adapted conceptual model from Bose and Luo (2011) in answering the first sub-question in Chapter 4. The levels are broken down into Greening by IT Initialization, Integration, and Maturation. These levels are not definitive and are not representative of the situation for every airline, but can be used as a baseline for understanding the implementation process. **If practitioners would like to see examples of Greening by IT applications, they can review the applications list in Figure 5.4 in Chapter 5.** The levels were developed through the application of Innovation Diffusion theory, interview results, and discussions with KLM employees.

Each level includes a description and recommended activities to mature to the next one. The content used in the levels was generated based on the answers provided by the interview participants on breaking down implementation into stages and the original model description provided by Bose and Luo (2011). For example, in Initialization, there are no employees working on Greening by IT, there are no resources allocated for it, and there are no targets. In order to mature to the Integration stage, upper management must commit to implementing Greening by IT, a strategy must be formulated, and initial solutions must be developed. These initial solutions should require few resources and ideally also not conflict with business goals.

In the Integration stage, a basic strategy should be employed, there should be sustainability criteria for project evaluation, and both human and financial capital should be allocated for implementation. To improve to the Maturation level, the Greening by IT strategy must be fused with the overall business strategy, targets within IT must be made explicit, and the impact of Greening by IT solutions must be measured. More complex Greening by IT solutions can also must be taken on, especially those that might conflict with business goals. Standards should be developed to normalize the implementation process of Greening by IT initiatives.


Step 2: Choose Main Barriers
Technological Barriers
Difficulties from experiment to execution
Strategies: 1-12, 14-16, 18
Hard to express data
Strategies: 2, 3, 6-11, 13-18
Lack of data quality
Strategies: 2, 3, 5-11, 14, 16, 18
Lack of technical infrastructure
Strategies: 3, 5-7, 10, 15
Lack of metrics to measure impact
Strategies: 2, 3, 8, 9, 10, 11, 13, 14, 15, 17, 18
Lack of data accessibility
Strategies: 2, 3, 5-11, 14, 16, 18
Technological complexity
Strategies: 1, 2, 3, 5-7, 9-12, 14, 15, 17, 18
Long development time
Strategies: 1, 2, 5-8, 10, 12,
Organizational Barriers
Not considered a priority
Strategies: 1-4, 6-8, 10-12, 13, 15, 16
Lack of leadership from management
Strategies: 1, 3, 4, 8, 12, 16
Lack of resources
Strategies: 1, 2, 6-8, 9-11, 12-16
Unclear business value
Strategies: 1-3, 6, 8, 10, 12-17
Middle management overwhelmed
Strategies: 1-5, 7-18
Lack of strategy
Strategies: 1, 2, 4, 10, 11, 15, 18
Lack of targets
Strategies: 1, 2, 8, 10-13, 15, 18
Lack of awareness of GBIT solutions
Strategies: 1-4, 6, 7, 9-11, 13-17
Cost of solutions too high
Strategies: 2, 6, 7, 9-12, 14, 15
Lack of immediate payback
Strategies: 1-3, 7, 8, 9-11, 13-15,
Ambiguity in how to apply regulations
Strategies: 6, 10, 11, 14, 18
Ambiguity in responsibility
Strategies: 4, 8 , 10, 11, 14, 16, 18,
Sustainability very siloed
Strategies: 1-6, 9-11, 14, 16, 17
Lack of standards
Strategies: 1, 5, 6, 10, 11, 13, 14, 18
Uncertain which initiatives have largest impact
Strategies: 3, 6, 8, 9-11, 13-15, 17
Lack of prior experience
Strategies: 4, 6, 10, 11, 14, 18
Environmental Factors
Cumbersome aviation regulations
Strategies: 1, 4, 9-11, 14, 17, 18
Lack of external pressure
Strategies: 8, 9, 11, 16
Step 1: Identify Maturity Level
Level Description
No employees working on sustainability/GBIT
No sustainability targets or criteria in project portfolio process
Little to no resources allocated
Minimal insights into contributing factors to footprint
Initial interest and commitment to explore GBIT
Improvement Activities
Upper management commits to implementing GBIT
Formulate GBIT strategy
Search for low resource, easy-to-implement GBIT measures
Raise awareness of potential of GBIT through campaigns or hackathons
Look externally for inspiration or potential collaborations
Level Description
Basic GBIT strategy is employed
Sustainability criteria implemented in IT project portfolio processes
GBIT seen as a promising strategic theme for meeting sustainability goals
Specific people responsible for GBIT
Resources allocated for GBIT
Initial alignment between business & IT stakeholders
Improvement Activities
Connect GBIT strategy to airline's business & sustainability strategies
Create specific targets for GBIT in IT annual plan
Develop metrics & measure impact of GBIT solutions
Take on more complex GBIT topics
Develop standards for taking on GBIT solutions
Level Description
Sustainability fully integrated into organization processes & objectives
Organizational structure setup to ensure sustainability compliance
Complete oversight of GBIT's impact on footprint of airline
Standard procedure and methods used for developing GBIT solutions
Business & IT stakeholders fully aligned on GBIT objectives
Improvement Activities
Further collaboration with internal and external partners
Incorporate new technologies as they come up
Continuously set more ambitious targets
Prepare GBIT solutions for zero emissions aircraft implementation
Greening by IT Initialization
Greening by IT Integration
Greening by IT Maturation
Step 3: Apply Greening by IT Toolbox
1 Increase management leadership
2 Define GBIT Strategy
3 Improve data quality/access
4 Designate people responsible
5 Improve architecture
6 GBIT Hackathons/Challenges
7 Commit resources
8 Include GBIT in targets
9 Scout externally for techs
10 Create GBIT platform
11 Collaborate externally
12 Prioritize GBIT initiatives
13 Include sustainability criteria in projects
14 Collaborate internally
15 Combine GBIT with other goals
16 Raise awareness
17 Improve idea loops
18 Develop standards

Within Maturation, sustainability is fully integrated into the organization and is represented in its core objectives. The organizational structure is setup to ensure compliance with these objectives and facilitate Greening by IT solutions. There is detailed oversight into the impact made by Greening by IT initiatives on the airline's footprint and the effects of adjustments can be seen. Additionally, the business and IT stakeholders are fully aligned on its use and strategic relevance for the future. To progress even further beyond this, airlines can seek out collaboration with internal and external parties to tackle even more complex issues. They can focus on exploring the use of more advanced technologies and continuously set more ambitious targets for Greening by IT's reduction on the airline's footprint. Finally, airlines should also prepare for the introduction of new zero emissions aircraft and setup Greening by IT applications to assist in their integration into the airline.

Step 2: Choose Main Barriers

Different departments or management layers within KLM will encounter different types of challenges in implementing Greening by IT, as made clear in Chapter 6. The second step in the framework then becomes relevant, where users select the most impactful barriers to their situation. These obstacles are shown on the left of the framework and are grouped using the same TOE groupings used throughout this report. These barriers, in addition to several new ones which were identified during the stakeholder interviews, were factors mentioned in previous research.

Step 3: Apply Greening by IT Toolbox

Once users have selected the most relevant barriers, they can review the suggested strategies for each one of them at the bottom of each barrier card. These strategy-barrier connections are the same as those presented in Chapter 7. Users can comb through the various strategies and pick those that are most relevant to their situation or those that would be most effective. It is suggested to refer to the framework every so often in practice to review the maturity level, barriers, and strategies, as this can change over time. Strategies used to go from Initialization to Integration could be completely unique or done in a different way than those that would be used to go onward to Maturation.

8.4. Validation of Results

For validating the framework, it was shown to several KLM employees within the CIO Office and D&T for feedback. Several encouraged that one should not just wait for a strategy to be created or for the right architecture to be in place. They suggested to carry out many of these things in parallel. Focusing on first "getting the basics" right in the operations was criticized because they stated that there will always be more things to improve in the operation, but that these sustainability challenges must be tackled now.

Several of the final additions to the level descriptions and improvement activities were made based on feedback from employees. Starting with low-resource, easier-to-implement solutions and then seeking out more complex issues which might conflict with business goals was recommended to add. One member of strategic management was particularly curious of how this could be put to practice when sustainability objectives start conflicting with business goals. An example that was given was the conflict between using flight planning algorithms to lower fuel consumption and needing to make up for a potential delay mid-flight for connecting passengers. They were interested what could be done to help navigate these conflicting objectives later on and align the necessary stakeholders. This could be a promising adaption for the framework or for additional research. Other than these minor points, most employees who reviewed the results were impressed were the framework and were curious to see it be put to use.

Another change that was made which impacted the final version of the framework came from feedback from several D&T employees. Whereas an earlier version of the framework included only the top rated barriers from the study, it was decided to include the whole range of barriers after D&T employees brought up that some of the top rated barriers are not applicable in their context. This resulted in the inclusion of all of the barriers to make the framework modular for various stakeholders within the company.

8.5. Conclusion of Sub-Question 5

This chapter was devoted to answering the final sub-question which asked: "What is the corresponding decision support framework which integrates the identified key factors and strategies?" The decision support framework which was developed to answer this question can be seen in Section 8.3. The framework incorporates the conceptual model shown in Chapter 4, the key factors established in Chapter 6, and the strategies

developed in Chapter 7. The intended users for the framework are stakeholders within the strategic and operational management layers within airlines. Both levels of management can use the framework to understand the three maturity levels, identify the barriers most relevant to them, and select the strategies that would help in overcoming them. This framework is used directly in answering the main research question, which is treated in Chapter 9.

9 Conclusion

This study analyzed the barriers, enablers, and strategies for Greening by IT implementation within the airline context and incorporated them into a decision support framework. This answered the governing research question with asked ”What is the decision support framework which can support airlines in stimulating Greening by IT initiatives?” This main objective was broken down into sub-questions by creating a conceptual model for Greening by IT implementation, understanding its applicability for airlines, understanding the key factors, mapping these to strategies, and finally designing the decision support framework. This study was largely accomplished through a case study done within KLM’s Data & Technology platform which enabled access to a wide variety of documentation, stakeholders, and feedback opportunities. The research approach consisted of a comprehensive literature study, a desk research of KLM documentation, stakeholder interviews, and both qualitative and semi-quantitative analyses. The conclusions of the five sub-questions can be found at the end of each corresponding chapter, but the answer to the main research question as posed in Chapter 3 can be found in Section 9.1. Following this, the societal and academic contributions are outlined in Section 9.2 and Section 9.3. Next, the limitations of the study are described in Section 9.4. Then, recommendations are made for practitioners and conducting future research in Section 9.5. In Section 9.6, the study’s relevance and connection to the Management of Technology master program is highlighted.

9.1. Answer to Main Research Question

What is the decision support framework which can support airlines in stimulating Greening by IT initiatives?

The objective of this study was to integrate influencing factors and potential strategies into a decision support framework to assist airlines in implementing Greening by IT. As shown in Section 8.3, the decision support framework is based on the Greening by IT conceptual model created in Chapter 4, which uses established theories such as the TOE framework to group influencing factors and three phases of adoption from Innovation Diffusion theory. The three phases each feature description and recommended activities sections which offer practitioners a chance to determine the current outlook for their airline. The framework incorporates both the barriers from literature and those newly determined during the stakeholder interviews. It then maps these to strategies which are rooted in the identified enablers. This creates a useful tool whose elements are deeply rooted in practical findings from the industry and well-established theories used in research. The subsequent steps to use the framework are described below:

1. **Step 1 - Identify Maturity Level:** The first step for using the decision support framework is to orient oneself with the maturity levels of Greening by IT implementation. The framework describes three phases: Greening by IT Initialization, Integration, and Maturation. Founded in Innovation Diffusion theory and based on a conceptual model devised for *Green IT* by Bose and Luo (2011), these levels were developed through stakeholder interviews. Practitioners can read the description fields to understand what each level entails and select which level can best describe Greening by IT in their organization. Then, they can review the improvement activities bubbles to see recommended steps for maturing to the next phase. Overall, these levels offer the opportunity to review the trajectory of implementing Greening by IT, something which the influencing factors and strategies alone cannot provide.
2. **Step 2 - Choose Main Barriers:** Next, one can review the barriers and select those which are most influential for them. The framework features 26 barriers grouped by the TOE framework, some of which are based on prior research and others who were determined through this study. The barriers are listed according to by how often they were mentioned in the stakeholder interviews, improving the ease-of-use of the framework as the first barriers practitioners read in each category are likely to be applicable. On each barrier card, there is also a list of potential strategies which is used in step 3.
3. **Step 3 - Apply Greening by IT Toolbox:** Taking the recommended strategies mentioned with each barriers in step 2, practitioners can then review the Greening by IT toolbox, which is comprised of 18 strategies to overcome the barriers. These strategies are based on the enablers evaluated during the stakeholder interviews and offer additional unique solutions which were brought up specifically by the stakeholders.

This decision support framework should by no means be seen as a final version to be used and never adjusted, but as a first start. It is encouraged that other researchers and practitioners apply it, evaluate, and adjust it as needed. It can subsequently be used as a foundation to further investigate Greening by IT within airlines further or its application in other contexts. The recommendations and future research avenues are explained further in Section 9.5.

9.2. Societal Contribution

As discussed in Chapter 5, airlines face a massive, uphill battle in overcoming their sustainability challenges and meeting their objectives. Given the projected passenger growth, tight resources, and zero-emission aircraft still likely many years away, there is no easy single solution to transition aviation to becoming more sustainable. More specifically to Greening by IT at KLM, initial observations found that despite it being a promising option to reduce emissions, the current efforts still need guidance and encounter substantial resource constraints. This study contributes to these issues by developing a decision support framework which can be used by a wide variety of practitioners within airlines to guide Greening by IT implementation. This directly serves the greater societal needs in tackling the emissions which contribute to climate change, but also the practical challenges within KLM in implementing these digital solutions for sustainability.

The power of the decision support framework is that it can be used by anyone within airline IT to understand the implementation process of Greening by IT, identify the factors most relevant to them, and select some potential strategies to employ. For example, it can be used by junior employees to convince their manager to take certain steps. It can be used by a CIO to understand where to focus their efforts to drive Greening by IT further. It can also be used by business stakeholders who want their IT department to take up Greening by IT, but don't know what to recommend. All in all, the usefulness of this decision support framework lies in its adaptability, beyond the primary users being the strategic and operational managers within IT. Be it a junior developer or a VP within IT, this decision support framework can be useful in some way for developing Greening by IT. Although it must be further researched, the adaptability of this framework can aid in its use in other airlines, where the challenges encountered may be different.

Specifically to KLM, this study has highlighted several key issues with the execution of its IT sustainability strategy and the dynamics involved with implementing Greening by IT in practice. Most of the focus within IT goes to Green IT measures, which only subside a fraction of a percent of KLM's absolute emissions. So not only was it demonstrated that Greening by IT is currently underutilized, but that there is a gap in the understanding of how IT could be used for tackling sustainability among business stakeholders. Through the stakeholder interviews, it was shown that Greening by IT and by extension, sustainability, are simply not seen as priorities as do not receive sufficient resources or attention from management as a result. Operational managers are also so overwhelmed with solving issues that they do not have the time to consider sustainability within their work and they complained that there is no translation of the overarching KLM sustainability strategy into an actionable version at their level. This results of this study contribute to these issues directly by delivering a decision support framework which can be used within KLM to understand Greening by IT implementation, identify relevant barriers, and select strategies.

Altogether, this study has far-reaching implications for airline sustainability and demonstrates many of the issues obstructing further progress from being made. It offers several avenues for practitioners to gain more insight into the contributing factors and dynamics at play for Greening by IT implementation. The decision support framework serves as a foundation for practitioners to understand how to implement Greening by IT and correspondingly lower their airline's footprint.

9.3. Academic Contribution

As mentioned in Section 2.3, this study sought out to contribute to the lack of research into Greening by IT's adoption phase, barriers, strategies, and application within the airline industry. To help fill these gaps, this study delivers a decision support framework which can be applied within the airline industry to identify barriers and select potential strategies to overcome them. The significance of the study is that it weaves together the prior research from these several streams and applying it to a specific case study, which has been seldom performed in prior Greening by IT research. This enriches the academic landscape by both the development of the decision support framework which can be used to conduct further research, but also the interrelations between different the research streams which were previously lacking. These interrelations between the barriers, enablers, and strategies serve as promising avenues for additional research in their own right and are further discussed in Subsection 9.5.2. Furthermore, this study reinforced the understanding of Greening by IT implementation within the airline context and highlighted several unique considerations which should be taken into account in practice or for conducting future research. Fundamentally, this study contributes important insights into the contributing factors to Greening by IT implementation and provides a useful foundation for conducting future research through the decision support framework it developed.

The significance of this study is that it has integrated these several research areas on Greening by IT into a single framework, setting up a strong foundation for future research. This framework can subsequently

be used to evaluate the effectiveness of the various strategies, test the results within other industries, or be adapted to include other organizational theories.

9.4. Limitations

Greening by IT Definition & Literature Use

Even with the rigorous protocols and method designs followed in this study, there are still several limitations to this research and its findings which must be mentioned. Looking first at the literature used in this study, through the use of the term of Greening by IT and applying results from research on closely-related Green IT, there are a couple limitations. There are still several terms and definitions used in literature such as Green Information Systems, Green IT/IS, Greening for IT, etc..., each often with its own, slightly different definition used by the author. While it can still be argued that many of the Green IT results are applicable, the main difference is that Greening by IT involves many more stakeholders outside of IT, which naturally results in additional barriers when compared to Green IT. While it would be handy to just assume that these differences cancel out by combining many of the results, there is still an inherent limitation in that the intermediary elements used in generating the results, such as the key factors, can affect the reliability of the findings. This is further demonstrated by the fact that the literature used in this study was not limited by region, industry, or scope.

Conceptual Model

There are also several limitations due to the conceptual model used in this research. First off, the categorizations provided by the TOE framework are helpful for grouping factors at a high level, but proved very general given the large amount of factors identified in the end. As a result, it might be helpful for future research to make more specific groupings within these categories, or at least mention any observable trends. Additionally, the three stages of adoption based on Innovation Diffusion theory are applicable for organizing strategies in theory, but might different from how things are done in practice. Certain strategies and measures will likely need to be taken on parallel and will not mirror the series-like order shown in the conceptual model. This will require future research to explore which factors are most relevant at what stage.

Process of Compiling Key Factors

It is also worthwhile to comment further on the process used in synthesizing and applying the key factors in this study. There is a possibility for information loss through the process of synthesizing them from prior research, analyzing them through several participants' interpretations, and coding their results. For example, when conducting the rankings of the different factors, one participant might interpret a lack of technical infrastructure as the interference from legacy applications, while another might see it differently. Furthermore, when performing a ranking analysis, it is recommended to use a more specific method such as the Bayesian Best Worst method to reduce anchoring bias in the order of appearance of the factors. To mitigate these concerns, it is recommended to dedicate more research into analyzing the factors from prior research, improving the accuracy of consolidating them into concrete factors, and evaluating them.

KLM Case Study

Looking next at the use of KLM in the case study, some findings are likely limited to KLM or similar, legacy airlines. Due to the age of KLM and the organizational complexity from the merger with Air France, some of the obstacles faced with implementing Greening by IT could be unique to this context. Other, newer airlines who do not have the same legacy applications or complicated structure might find that implementing Greening by IT is more simple than this study makes it out to be. This requires additional research in applying the findings of this study in different airlines, based on their age and size. Furthermore, some of these intricacies can limit these findings in their applicability to other industries, as some of the findings are not only very specific to airlines, but to KLM as well. This warrants additional investigation into the suitability of these findings and methods in other industries.

Additionally, as pointed out in the interviews, the factors influencing Greening by IT implementation will likely be different for airlines based in different parts of the world. The interview participants brought up that different working cultures, respect for hierarchy, and organizational structures could lead to very different factor rankings and corresponding strategies. Also suggested is that there is a limitation in that Dutch society is relatively concerned with the impact of climate change, which may not be the same case in other countries. This may lead to the obstacles observed in other airlines to be quite different than the ones identified in this

study, which requires additional research.

This study is also limited due to the internship position used to conduct it. Since it was positioned within the CIO office, already very high up within the hierarchy of KLM IS, the feedback gained during validation discussions could sway or misrepresent the actual reality of the barriers encountered when implementing Greening by IT. While efforts were made to review the findings with other stakeholders lower in the hierarchy, one cannot ignore the influence of having more exposure to strategic management employees while carrying out the research. For future research, it is suggested to evaluate these findings in a lower level department or to conduct a survey to investigate the results from various stakeholder groups.

9.5. Recommendations for Practitioners & Future Research

In this section, recommendations for both practitioners and future researchers are made. The suggestions for IT practitioners can be found in Subsection 9.5.1 and those for future research can be seen in Subsection 9.5.2.

9.5.1. Recommendations for IT Practitioners

For practitioners, it is suggested to first apply the framework to your area. Use it to understand the process of implementing Greening by IT, figure out the obstacles that are most impactful, and select several strategies. This is by no means a final product and should be treated as just a tool. Similar to the list of Greening by IT application supplied in Chapter 5, these strategies are unproven and should be treated as such. Iterate upon the framework as you see fit and consider conducting polls within your team based on the barriers it identifies. One might consider reviewing the barriers other key decision-makers to align on where difficulties lie.

It is suggested to refer to the framework and the general results of this thesis several times a year to re-evaluate the current situation. If you face many obstacles and implementation still seems far away, put your efforts into gathering and organizing the data needed to display the impact of potential Greening by IT solutions and the impact of the continued decision to *not* implement it. Do your best to make it hard for business stakeholders to avoid taking it up. If approval is given and budget is allocated, focus on the initiatives which are easiest and the least costly to implement. Demonstrate successful experiments and use this to generate more support for taking on more complex initiatives.

9.5.2. Recommendations for Future Research

Beyond the several suggestions made to mitigate the limitations mentioned in Section 9.4, more recommendations for future research can be made. In the short term, it is recommended to extend the findings of this research to other parts of KLM. For example, one could conduct a survey or workshops with various departments, either within D&T, IT in general, or within the business departments to get the best picture of the perspectives of the key stakeholders. Given the feedback that decision-making surrounding sustainability is quite siloed within KLM, inspiration could be taken from Participatory Action Methods to include a wider variety of stakeholders in developing Greening by IT and working together to create tangible results. Due to some of the conflicts between IT and business stakeholders or different layers of IT management in tackling sustainability, Participatory Action Methods could be helpful in bringing about change in a more democratic way and aligning the different stakeholders (Cathy MacDonald & MacDonald, 2012). More specifically, it is recommended to set up focus groups of IT and business employees to better understand the conflicts and come up with ways to foster better cooperation on sustainability goals. Setting up a process to continually reflect and collect feedback outside of the CIO Office would also be crucial as more complex transitions are embraced. This would also lead to more opportunities to conduct research into the dynamics at play within the company when implementing Greening by IT and to understand how to better prescribe strategies to overcome the challenges.

Many of the influencing factors were largely based on the perspectives and importance that stakeholders placed on sustainability in general, so a study looking specifically into sustainability as a concept within airlines would also be promising. As suggested by a KLM colleague, one could also investigate how other transverse themes such as security are organized within airlines and evaluate its applicability for integrating sustainability within the organization.

In order to develop this framework further and increase its relevance, conducting research into the effectiveness of the proposed strategies, and not just their relevance to certain factors, is advised. More specifically, a question often posed in discussions with KLM employees within D&T was also on how to best implement sustainability criteria within the project evaluation and decision-making process. Navigating the challenges

regarding a lack of impact data or weighing the value of different aspects of sustainability such as emissions, noise pollution, or waste creation is currently a major obstacle. Also of interest for future research is how to incentivize choosing for certain measures within the organization. This can also be extended to forming measurable KPIs and annual targets for Greening by IT within IT departments, which is currently unclear.

Furthermore, as suggested in the Limitations section, applying this framework and this study's findings to other airlines would be critical for validating the conclusions made. Analyzing the generalizability based on airline age, working culture, business model or country they are based is recommended. For example, it would be of interest to research how Greening by IT implementation is different for budget airlines, given their typically more streamlined operational processes and more uniform fleets. In the long term, it would be useful to conduct a longitudinal study of an airline or other company in implementing Greening by IT to gather empirical data on the barriers and enablers observed in practice. This research can be extended and applied to other industries as well to test the differences with the airline industry.

9.6. Relevance to Management of Technology Program

This thesis topic was well-aligned to the goals of the MOT program as it evaluates the use of a technology as a corporate resource to improve an outcome, which was the sustainable transition of airlines in this case. It was comprised of an exploratory study within the technological context of airline IT. It made use of various qualitative research methods such as desk research and stakeholder interviews. While it was an analysis of the application of a technology, the content of the study largely revolved around the organizational processes involved with implementing the technology, in line with the criteria for an MOT master thesis.

Besides the obvious relevance to the Preparation for Master Thesis and Research Methods courses, the content from the Leadership & Technology, Technology, Strategy, & Entrepreneurship and Emerging & Breakthrough Technologies courses were integral to this study. These courses gave me a great foundation of knowledge to build off of when analyzing the factors and strategies in this research. Through the creation of the decision support framework to support Greening by IT implementation, this study demonstrated the role IT technologies can play in enabling the sustainable transition of airlines. On the whole, through its topic, methods used, and final deliverable, this study reflects the core theme of the Management of Technology program to investigate the application of technology through a scientific study for bettering a corporate or societal goal.

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A Appendix: Literature Study

Year	Author	Title	Publication Title
2024	Kirchner-Krath, Jeanine; Morschheuser, Benedikt; Sicevic, Nevena; Xi, Nannan; von Korflesch, Harald F. O.; Hamari, Juho	Challenges in the adoption of sustainability information systems: A study on green IS in organizations	International Journal of Information Management
2023	Esfahbodi, Ali; Zhang, Yufeng; Liu, Yang; Geng, Duanyang	The fallacy of profitable green supply chains: The role of green information systems (GIS) in attenuating the sustainability trade-offs	International Journal of Production Economics
2023	**Chen, Adela; Roberts, Nicholas**	**Joint drivers of different shades of green IT/IS practices: a strategic cognition perspective**	**Information, Technology & People**
2022	Carvalho, Victor Diogho Heuer de; Poleto, Thiago; Verde, Salvatore; Nepomuceno, Thyago Celso Cavalcante	Multicriteria Model for Organizational Green Information Technology Maturity Assessment and Benchmarking: Defining a Class Structure	ASEC 2022
2022	Almeida, Rodrigo Pessotto; Ayala, Néstor Fabián; Benitez, Guilherme Brittes; Neto, Francisco José Kliemann; Frank, Alejandro Germán	How to assess investments in industry 4.0 technologies? A multiple-criteria framework for economic, financial, and sociotechnical factors	Production Planning & Control
2022	Farkas, Mária; Matolay, Réka	Decision support for corporate sustainability: systems and stakeholders	Journal of Decision Systems
2021	Asadi, Shahla; Nilashi, Mehrbakhsh; Samad, Sarminah; Rupani, Parveen Fatemeh; Kamyab, Hesam; Abdullah, Rusli	A proposed adoption model for green IT in manufacturing industries	Journal of Cleaner Production
2021	Bryan, Julies David; Zuva, Tranos	A Review on TAM and TOE Framework Progression and How These Models Integrate	Advances in Science, Technology and Engineering Systems Journal
2021	Singh, Monika; Sahu, Ganesh P.	Key Factors for Green IS Acceptance in Banking Segment: Pragmatic Analysis	International Journal of Electronic Government Research
2021	**Laranja Ribeiro, Marcos Paulo; Tommasetti, Roberto; Gomes, Monica Zaidan; Castro, Aline; Ismail, André**	**Adoption phases of Green Information Technology in enhanced sustainability: A bibliometric study**	**Cleaner Engineering and Technology**
2020	Yang, Xue; Li, Yan; Kang, Lele	Reconciling “doing good” and “doing well” in organizations’ green IT initiatives: A multi-case analysis	International Journal of Information Management
2020	**Singh, Monika; Sahu, Ganesh Prasad**	**Towards adoption of Green IS: A literature review using classification methodology**	**International Journal of Information Management**
2019	Teske, Sven	Achieving the Paris Climate Agreement Goals: Global and Regional 100% Renewable Energy Scenarios with Non-energy GHG Pathways for +1.5°C and +2°C	Springer Cham
2019	Carberry, Edward J.; Bharati, Pratyush; Levy, David L.; Chaudhury, Abhijit	Social Movements as Catalysts for Corporate Social Innovation: Environmental Activism and the Adoption of Green Information Systems	Business & Society
2019	Baggia, Alenka; Maletič, Damjan; Maletič, Matjaž; Žnidaršič, Anja; Brezavšček, Alenka	Drivers and Outcomes of Green IS Adoption in Small and Medium-Sized Enterprises	Sustainability
2018	Seidler, Anna-Raissa; Henkel, Christopher; Fiedler, Marina; Kranz, Johann	Encouraging Pro-Environmental Behaviour: Affordances and Institutional Logics in IS-enabled Organisational Sustainability Transformations	European Conference on Information Systems
2018	Hernandez, Alexander	Exploring the Factors to Green IT Adoption of SMEs in the Philippines	Journal of Cases on Information Technology
2018	Bokolo, Anthony; Mazlina, Abdul Majid; Awanis, Romli	A proposed model for green practice adoption and implementation in information technology based organizations	Problems of Sustainable Development (Problemy Ekorozwoju)
2017	Yang, Zhaojun; Sun, Jun; Zhang, Yali; Wang, Ying; Cao, Lisha	Employees’ Collaborative Use of Green Information Systems	Hawaii International Conference on System Sciences
2017	Jongsaguan, Salakjit; Ghoneim, Ahmad	Green IT/IS investments evaluation within the aviation industry - A focus on indirect cost management	Journal of Enterprise Information Management
2017	**Asadi, Shahla; Hussin, Razak Che; Dahlan, Halina Mohamed**	**Organizational Research in the Field of Green IT: A Systematic Literature Review from 2007 to 2016**	**Telematics and Informatics**
2017	Henkel, Christopher; Seidler, Anna-Raissa; Kranz, Johann; Fiedler, Marina	How to become a Sustainability Leader? The Role of IS Affordances in Enabling and Triggering Sustainability Transformations	International Conference on Interaction Sciences
2017	Nanath, Krishnadas; Pillai, Radhakrishna R.	The Influence of Green IS Practices on Competitive Advantage: Mediation Role of Green Innovation Performance	Information Systems Management
2017	Loeser, Fabian; Jan Recker; Recker, Jan C.; Brocke, Jan vom; Molla, Alemayehu; Zarnekow, Ruediger	How IT executives create organizational benefits by translating environmental strategies into Green IS initiatives	Information Systems Journal
2016	Bokolo, Anthony Jr.	Green Information Systems Integration in Information Technology Based Organizations: An Academic Literature Review	Journal of Soft Computing and Decision Support Systems

Figure A.1: Articles Used in Literature Study (1) - Literature Reviews Shown in **Bold**

Year	Author	Title	Publication Title
2016	**Gholami, Roya; Watson, Richard T.; Hasan, Helen; Molla, Alemayehu; Bjørn-Andersen, Niels**	**Information systems solutions for environmental sustainability: How can we do more?**	**Journal of the Association for Information Systems**
2016	Hu, Paul Jen-Hwa; Hu, Han-fen; Wei, Chih-Ping; Hsu, Pei-Fang	Examining Firms' Green Information Technology Practices: A Hierarchical View of Key Drivers and Their Effects	Journal of Management Information Systems
2016	Bohas, Amélie; Nicolas Poussing; Poussing, Nicolas	An empirical exploration of the role of strategic and responsive corporate social responsibility in the adoption of different Green IT strategies	Journal of Cleaner Production
2015	Deng, Qi; Ji, Shaobo	Organizational Green IT Adoption: Concept and Evidence	Sustainability
2015	**Khor, Kuan Siew; Thurasamy, Ramayah; Ahmad, Noor Hazlina; Halim, Hasliza Abdul; Lo, May-Chiun**	**Bridging the Gap of Green IT/IS and Sustainable Consumption**	**Global Business Review**
2014	Savita, K. S.; Dominic, P. D. D.; Ramayah, T.	The adoption of green information technologies and systems as a driver within green SCM	2014 International Conference on Computer and Information Sciences (ICCOINS)
2013	Molla, Alemayehu	Identifying IT sustainability performance drivers: Instrument development and validation	Information Systems Frontiers
2013	Gholami, Roya; Sulaiman, Ainin Binti; Ramayah, T.; Molla, Alemayehu	Senior managers' perception on green information systems (IS) adoption and environmental performance: Results from a field survey	Information & Management
2013	**Loeser, Fabian**	**Green IT and Green IS: Definition of Constructs and Overview of Current Practices**	**Americas Conference on Information Systems**
2013	Cai, Shun; Chen, Xi; Bose, Indranil	Exploring the role of IT for environmental sustainability in China: An empirical analysis	International Journal of Production Economics
2013	**Sarkis, Joseph; Koo, Chulmo; Watson, Richard T.**	**Green information systems & technologies – this generation and beyond: Introduction to the special issue**	**Information Systems Frontiers**
2012	Molla, Alemayehu; Abareshi, Ahmad	Organizational Green Motivations for Information Technology: Empirical Study	Journal of Computer Information Systems
2012	Buchalcevova, Alena; Gala, Libor	Green ICT drivers and inhibitors perceived by the Czech SMEs	Journal of Systems Integration
2012	Ijab, Mohamad Taha; Molla, Alemayehu; Cooper, Vanessa A.	Green Information Systems (green IS) practice in organisation: tracing its emergence and recurrent use	Americas Conference on Information Systems
2012	Loeser, Fabian; Erek, Koray; Zarnekow, Ruediger	Towards a Typology of Green IS Strategies: Insights from Case Study Research	International Conference on Interaction Sciences
2012	Harmon, Robert R.; Moolenkamp, Nora	Sustainable IT Services: Developing a Strategy Framework	International Journal of Innovation and Technology Management
2012	**Brooks, Stoney L.; Wang, Xuequn; Sarker, Saonee**	**Unpacking Green IS: A Review of the Existing Literature and Directions for the Future**	**International Conference on Business Process Management**
2011	Bose, Ranjit; Luo, Xin	Integrative framework for assessing firms' potential to undertake Green IT initiatives via virtualization - A theoretical perspective	Journal of Strategic Information Systems
2011	**Jenkin, Tracy A.; McShane, Lindsay; Webster, Jane**	**Green Information Technologies and Systems: Employees' Perceptions of Organizational Practices**	**Business & Society**
2011	Chen, Adela J.; Watson, Richard T.; Boudreau, Marie-Claude; Karahanna, Elena	An Institutional Perspective on the Adoption of Green IS & IT	Australasian Journal of Information Systems
2010	Seidel, Stefan; Recker, Jan C.; Pimmer, Christoph; Brocke, Jan vom	Enablers and barriers to the organizational adoption of sustainable business practices	Americas Conference on Information Systems
2010	Chen, Daniel Q.; Mocker, Martin; Preston, David S.; Teubner, Alexander	Information systems strategy: reconceptualization, measurement, and implications	Management Information Systems Quarterly
2010	Schmidt, Nils-Holger; Koray Erek; Erek, Koray; Kolbe, Lutz M.; Zarnekow, Rüdiger	Predictors of Green IT Adoption: Implications from an Empirical Investigation	Americas Conference on Information Systems
2008	Watson, Richard; Boudreau, Marie-claude; Chen, Adela; Huber, Mark	Green IS: Building Sustainable Business Practices	Information Systems Journal

Figure A.2: Articles Used in Literature Study (2) - Literature Reviews Shown in **Bold**

B Appendix: Key Factors

Paper	Method	Barrier
Schmidt, Erek, Kolbe, & Zarnekow (2010)	Survey of 116 IT managers in Germany	Lack of experience
		Lack of metrics
		Lack of standards
		Perception as overrated
		Uncertainty
Chen, Watson, Boudreau, & Karahanna (2011)	Survey of 75 companies worldwide	Lack of immediate economic gains
		Lack of experience
		Lack of metrics
		Lack of standards
		Perceived as overrated
		Uncertainty
Bose & Luo (2011)	Theoretical review	Cost of solutions
		Unclear business value
		Lack of government incentives
		Lack of business leadership
		Extent of IT sophistication
		Inadequate skills and training
		Extent of GIT adoption in industry
		Absence of enforceable gov't regulations
Jenkin, Webster, & McShane (2011)	Literature review	Knowledge gap
		Practice gap
		Opportunity gap
		Knowledge-action gap
Volkoff, Bertels, & Papania (2011)	Case study of Canadian energy company	Ongoing changes to existing regulations
		Ambiguity on how to apply regulations
		Ability to transform regulations into tasks
		Amibuity in responsibility
		Unfamiliarity with system
		Lack of IT access
Molla & Abareshi (2013)	Survey of 176 Australian companies	Small IT Budget
		Unsure which initiatives have largest impact
Buchalcevova & Gala (2013)	Survey of 61 Czech SMEs	Low level of awareness
		Poor national & governmental strategies
		Unclear business value
		Cost of solutions
Savita, Dominic, & Ramayah (2014)	Interviews with 3 Malaysian manufacturing companies	Lack of immediate payback
		Lack of metrics to measure performance
		Ambiguity in added value
		High implementation cost
		Long development time
Deng & Ji (2015)	Literature review	Technological Complexity
Bokolo (2016)	Literature review	Cost of solutions
		Unclear business value
		Lack of government incentive
		Lack of senior management leadership
		Technological Complexity
		Lack of prior experience
		Lack of Green IS adoption in industry
		Lack of government regulation
		Lack of demand
		Not considered a priority
		Lack of resources
		Absence of Green competition
		Fear of failure on implementation
Schmermbeck et al. (2020)	Survey completed by 55 German companies	Lack of relevance for organization
		Lack of resources
		Benefits unclear
		Unsuitability
		Lack of demand
		Other priorities
		Missing potential
Singh & Sahu (2021)	Survey of 303 IT departments in India	Performance Expectancy
		Effort Expectancy
Kirchner-Krath et. al. (2024)	Qualitative field study of 4 German SMEs	Additional resources required
		Upfront costs
		Lack of expertise
		Ambiguity in responsibility
		Lack of technical infrastructure

Figure B.1: Barriers Identified from Each Article

Paper	Method	Enabler
Schmidt, Erek, Kolbe, & Zarnekow (2010)	Survey of 116 IT managers in Germany	Initiative from IT staff
		Corporate engagement
		Environmental engagement
		Prior experience
		Importance of Green IT
Seidel, Recker, Pimmer, & Brocke (2010)	Case study of a leading IT software company	Defined Green IS strategy
		Strategy embedded in business strategy
		Top management support
		Bottom-up support
		Intrinsic motivation of employees
		Extrinsic motivation of employees
		Measurement of impact
		Transparency of data
Jenkin (2011)	Literature review	Org. Climate & Culture
Molla & Abareshi (2011)	Survey of 176 Australian companies	Manager commitment
		Resource allocation
		Employee attitude
Brooks, Wang, & Sarker (2012)	Literature review	Good economic environment
		Attitude towards Green IS initiatives
Gholami, Sulaiman, Ramayah, & Molla (2012)	Survey of 405 Malaysian companies	Management attitude
Deng & Ji (2015)	Literature review	Relative advantage of technology
		Technological Compatibility
		Top management support
		Green organizational culture
		Defined strategy
Bokolo (2016)	Literature review	Corporate strategy
		Maturity of Green IS in organization
		Senior manager vision
		Defined strategy
Yang et. al. (2017)	Survey of 279 Chinese companies	Defined Green IS strategy
Carberry, Bharati, Levy, & Chaudhury (2017)	Survey of 400 IT Managers at U.S. firms	Managerial commitment
		IT size
Hu, Hu, Wei, & Hsu (2017)	Survey of 304 manufacturing companies in Taiwan	Industry norms
		Environmental engagement
		Corporate engagement
		Prior experience
		Internal readiness
Baggia, Maletič, Žnidaršič, & Brezavšček (2019)	Survey of 156 Slovenian SMEs	Sustainability-oriented strategy
		Organizational attitude
Singh & Sahu (2020)	Literature review	Leadership
		Employee stewardship
Singh & Sahu (2021)	Survey of 303 IT departments in India	Leadership
Kirchner-Krath et. al. (2024)	Qualitative field study of 4 German SMEs	Corporate social culture
		Employee attitude

Figure B.2: Enablers Identified from Each Article

Paper	Method	Drivers
Chen, Watson, Boudreau, & Karahanna (2010)	Survey of 75 companies around the world	Mimetic pressure
		Coercive pressure
Molla & Abareshi (2011)	Survey of 176 Australian companies	Efficiency
		Cost-saving
		Environmental thought leadership
Brooks, Wang, & Sarker (2012)	Literature review	Cost savings
		Shareholder pressure
		Regulatory pressure
		Economic environment
		Government regulations
Gholami, Sulaiman, Ramayah, & Molla (2012)	Survey of 405 Malaysian companies	Coercive pressure (gov't, suppliers, & customers)
Buchalcevova & Gala (2013)	Survey of 61 Czech SMEs	Reducing cost of IT
		Pressure from vendors
		Green strategy
		Market demand
		Competitor & client pressure
		Manager vision
		Employee creativity
Cai, Chen, & Bose (2013)	Survey of 82 Chinese MBA graduates	Reducing cost of IT
		Differentiation
Deng & Ji (2015)	Literature review	Coercive pressure
		Mimetic pressure
		Normative pressure
Loeser et. al. (2016)	Survey of 250 senior IT managers worldwide	Pro-environmental beliefs
		Environmental standards
		Organization's Environmental Orientation
		Executive's Beliefs
Bokolo (2016)	Literature review	Reducing cost of IT
		Social acceptance
		Government incentives
		Organizational associations
		Client/consumer pressure
		Actions of competitors
		Environmental importance
		Government regulations
		Economic environment
Carberry, Bharati, Levy, & Chaudhury (2017)	Survey of 400 IT Managers at U.S. firms	Regulative institutional pressure
		Normative institutional pressure
		Cognitive institutional pressure
Hu, Hu, Wei, & Hsu (2017)	Survey of 304 manufacturing companies in Taiwan	Environmental Awareness
		Customer/equity attitude
		Competitor actions
		Initative from IT staff
		Government regulations
Baggia, Maletič, Žnidaršič, & Brezavšček (2019)	Survey of 156 Slovenian SMEs	Mimetic Pressure
		Coercive Pressure
Singh & Sahu (2020)	Literature review	Cost Reduction
		Government incentives
		Market pressure
		Environmental impact of industry
		Commitment & attitude & belief
		Competitive strategy & advantage
		Relative advantages
		Scalability
		Reliability
		Laws & Regulations
		Rate of resource removal
		Regenerative capacity of resources
		Media
		Public awareness
		Competitiveness
		Legitimacy
		Social responsibility
Singh & Sahu (2021)	Survey of 303 IT departments in India	Vision & strategy
		Government regulations
		Competitive pressure
		Social influence
Chen & Roberts (2023)	Survey of 306 organizations	Individualistic identity orientation
		Coercive pressure
		Normative pressure
		Cost reduction orientation
		Mimetic pressure
		Revenue expensaion orientation
Kirchner-Krath et. al. (2024)	Qualitative field study of 4 German SMEs	Changes in regulation
		Universal IT access

Figure B.3: Drivers Identified from Each Article

C Appendix: Interview Results

Interview Consent Form

Interview Informed Consent Form

Research Project Title: A Decision Framework for Stimulating Greening by IT Initiatives at Airlines: A Case Study at KLM IT

Lead Researcher: Alex van Roon

Research Supervisor at TU Delft: Fátima Delgado Medina

Research Supervisor at KLM: Marja Veentjer

Study Description: You are being invited to participate in a study titled "A Decision Framework for Stimulating Greening by IT Initiatives at Airlines: A Case Study at KLM IT." This study is being conducted by Alex van Roon for the completion of the MSc Management of Technology program at the TU Delft. KLM has approved this study and the researcher is a graduate intern within the CIO Office. This study will investigate the application of Greening by IT within airlines, the key factors which impact its adoption, and which strategies can be used. These elements will be integrated into a decision support framework for airlines to use as a guide for Greening by IT adoption.

Interview Purpose: This interview will be used to gain insight into the key factors influencing the use of Greening by IT solutions and what strategies can be used to drive it further within airlines. You will be asked about these themes in an interview that will take approximately one hour to complete. This data will be used to further analyze findings from academic literature and develop the corresponding decision support framework.

Consent: This consent form is used to inform you of the study, the purpose of your involvement, and that you agree to the following conditions. Please read the following and sign this form to indicate your agreement to the following:

1. The interview will be recorded and a transcript will be created by the Lead Researcher Alex van Roon.
2. You will be sent the transcript afterwards to review and correct any factual errors.
3. This transcript will be analyzed by Lead Researcher Alex van Roon for use in the study.
4. Access to the recordings and transcript will be limited to Alex van Roon and the supervising professors.
5. Any summaries generated from the interviews or direct quotations that are made available through the publication of the study will be anonymized so that you cannot be identified. The strictest care will be taken to ensure that other information in the interview that could identify you is not revealed. Information regarding your participation will not be shared with KLM.

Risk Mitigation: As with any online activity, the risk of a breach is always possible. To the best of our ability your answers in this study will remain confidential. The following measures will be taken to mitigate any risks:

1. As little personal information will be collected as possible and will be limited to your name, email address, job title/description, and video/audio recordings of the interview to be used for transcriptions.
2. You will be given the option of not having video recording (only audio) for the interview.
3. If not done in person, the interview will be carried out via a secure platform such as Microsoft Teams and a private internet network will be used.
4. All data collected will be kept on a personal drive accessible only by the researcher.
5. In the published work, your contribution will be anonymized and only your position and area of expertise will be mentioned (can be omitted if too easily re-identifiable). All participants will be referred to as they/them and will appear in the text as follows: "Participant 1 is an IT Project Manager" and "Participant 1 stated that the main barriers are...".
6. All personal data used for admin purposes, interview transcripts, and interview recordings will be deleted upon publishing of the thesis (expected date September 2024).

Your participation in this study is entirely voluntary and **you can withdraw at any time**. You are free to omit any questions and request that your interview not be used in data analysis before 1 July 2024.

Figure C.1: First Page of the Consent Form

By signing this form, I agree that:

1. I am taking part in this study voluntarily. I understand that I don't have to take part and can stop the interview any time;
2. The transcribed interview or extracts from it may be used as described above;
3. I have read the Information sheet;
4. I don't expect to receive any benefit or payment for my participation;
5. I can request a copy of the transcript of my interview and may make edits I feel necessary to ensure any confidentiality is preserved;
6. I have been able to ask any questions I might have and I understand that I am free to contact the researcher with any questions I may have in the future.

_____

Printed Name

_____ _____

Participant's Signature Date

_____ _____

Researcher's Signature Date

Should you have any questions or need to contact us, you can do so using the following details:

Alex van Roon

Figure C.2: Second Page of the Consent Form

Interview Questions

The interviews aimed to explore the key factors influencing implementation, potential strategies, and relevant points for creating the Decision Support Framework as posed in Sub-questions 3, 4, and 5. For carrying out the interviews, the researcher began by explaining the process and reiterating the points outlined in the consent form. With the participant's approval, the researcher began recording the interview and started with the first questions. During the interview, if the participant wanted clarification on a question or cannot think of an answer, they were provided with an example as needed. However, detailed examples were not provided in advance to avoid biasing the participant towards a certain answer.

Introduction

This section of the questions briefly covered the participant's function within KLM, their experience, their involvement in D&T projects or strategy formation, and what sustainability challenges their department faces. This was useful in demonstrating the relevance of the participant's interview answers and understanding any potential differences between their answers and those of others. Answers might differ between someone who has worked at KLM for 20 years and someone who has just completed one year. Knowing their involvement in D&T projects or strategy formation would also be useful in further understanding their perspective and any examples which they might provide. Finally, they were asked what sustainability challenges their department faces to demonstrate if there is an initial concern regarding sustainability. The first group of questions is as follows:

1. Could you briefly describe your function?
2. How long have you worked at KLM? And in your current function?
3. What influence do you have on the selection of projects or strategies within D&T?
4. What are the primary sustainability challenges your department faces?

Key Factors

This section of the questioning explored the key factors influencing Greening by IT implementation within D&T. It covered the barriers which prevent Greening IT solutions from being taken up and the enablers which can help facilitate them. They were also followed up with on their answers and asked to supply examples. If relevant, the researcher used the examples from Figure 5.4 in Section 5.4 to present some past or potential initiatives. After posing several questions to the participant on the barriers and enablers that they identified, they were next shown the tables with the factors from the literature study. This was done as a last step in order to not bias the participant in a certain way from the start and to ask them to rank the factors. Follow-up questions were asked they saw the tables to inquire which factors were missing from the table. The questions can be found below:

1. How would you describe D&T's progress with sustainability?
2. What are the main obstacles preventing Greening by IT solutions from being implemented?
3. Is there a historic example of a solution which was rejected? Why was it rejected?
4. What are the main enablers which help facilitate Greening by IT solutions?
5. Is there a historic example of a solution which was accepted? What factors influenced this?
6. *Show the two factor lists to the participant.* Could you rank the barriers and enablers from most relevant to the least? *Discuss the most relevant if necessary.*
7. Are there any factors which are missing?
8. Are these factors unique to D&T (or KLM) or are they extendable to the entire airline industry?

Strategies

Similar to the previous section, this line of questioning expanded on the enablers that the participant just identified and translated them into potential strategies. Initially, it was asked what strategies have been used in the past or if any are currently being used. The participant was then be asked what additional strategies they could identify beyond these. Next, they were asked to prescribe strategies specific to upper management and those for employees lower in the hierarchy. The questions are as follows:

1. What strategies could be used to improve the situation? Have any steps already been taken?
2. Would you prescribe the same strategies for upper management as you would for lower in the hierarchy?

Decision Support Framework

The final section aimed to investigate the relevant aspects for creating the decision support framework for upper IT management as posed in Sub-question 5. The participant was first asked how they would break down the strategies into three stages of implementation. This helped in developing the framework to include descriptions for the successive Greening by IT maturity levels. Finally, they were asked if there was anything else which was not asked about which they found relevant to bring up. The questions for this section can be found below:

1. If you could break down the steps for implementation into three levels, what would you do at each stage?
2. Is there anything I have not asked about which you would find relevant for this topic?

Ranking Results

Barriers	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7	Participant 8
Ambiguity in responsibility	6	10	12	10	6	6	11	14
Ambiguity on how to apply regulations	13	12	10	13	13	7	9	12
Cost of solutions too high	8	2	3	5	14	8	1	11
Lack of immediate payback	15	5	8	9	9	4	8	7
Lack of leadership from management	2	7	14	11	2	3	13	13
Lack of metrics to measure impact	7	6	4	4	8	10	5	9
Lack of prior experience	14	15	13	15	7	15	14	15
Lack of resources	9	4	1	2	5	2	2	5
Lack of standards	3	14	11	8	11	9	10	10
Lack of technical infrastrucutre	11	13	2	3	12	12	3	1
Long development time	12	9	6	1	10	14	7	3
Not considered a priority	1	3	15	12	1	1	15	4
Technological complexity	10	8	5	14	15	13	12	2
Uncertain which initiatives have largest impact	4	11	9	6	3	11	6	8
Unclear business value	5	1	7	7	4	5	4	6

Figure C.3: Barrier Ranking All Participants (#1 = most relevant, #15 = least relevant)

Enablers	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7	Participant 8
Able to measure impact	2	0	3	2	10	5	3	1
Accessible impact data	7	0	4	1	11	9	4	3
Defined Greening by IT strategy in IT	3	2	2	6	6	13	0	5
Good economic environment	11	3	6	5	8	2	0	9
High motivation of employees	6	4	9	4	7	12	0	10
IT department size	13	14	14	10	14	8	0	14
IT strategy embedded in overall business strategy	1	0	1	8	4	4	2	7
Org. has sustainability-oriented strategy	4	1	12	3	1	3	1	6
Perceived value of technology	12	0	5	13	3	11	0	4
Positive org. attitude towards sustainability	8	13	11	11	2	6	6	8
Prior experience	14	6	13	9	9	14	0	12
Senior management leadership	5	0	10	7	5	1	5	13
Sufficient resource allocation	10	5	7	12	13	7	7	11
Technically compatible	9	0	8	14	12	10	0	2

*Participants 2 & 7 have partial rankings from running out of time

Figure C.4: Enabler Ranking All Participants (#1 = most relevant, #14 = least relevant)

Interview Summaries Per Participant

Participant 1 Interview Summary	Executive Manager KLM IT	Barrier Ranking	Enabler Ranking
Participant 1 viewed D&T's sustainability progress as generally good, but that it's complicated. One of the major things the organization is working on is improving the epics management process such that the epics which add the most value are chosen and not those that are for the stakeholders which complain the most. They see issues with being able to measure impacts and having the right data to do so. There are also political issues in upper management from aligning business and IT upper management. It would also help if sustainability was just integrated into the decision-making process. They didn't see lack of resources as a major barrier because there is always a shortage within IT. The reaffirmed that there is no shortage of ideas, but that the problem lies in the execution. Similar to other participants, they complained about a lack of a road map for how KLM plans on meeting their sustainability objectives. They could then translate this roadmap into tangible targets for each department within D&T. For enabling the initiatives, it would help if every team was aware of their applications' impact on the environment and how they can improve things. Upper management could help them in creating OKRs and KPIs for this. They added that the hierarchy is relatively flat within D&T such that when the management team agrees on something, it gets implemented. If they had more independence from the C-level on decision-making, they could do things even more efficiently. They also confirmed that the middle management layer is overwhelmed. More needs to be done to see IT as more than a cost center, but as a major enabler for sustainability. Working with external parties on these goals would also help.		Not considered a priority	IT strategy embedded in overall business strategy
		Lack of leadership from management	Able to measure impact
		Lack of standards	Defined Greening by IT strategy in IT
		Uncertain which initiatives would have largest impact	Org. has sustainability-oriented strategy
		Unclear business value	Senior management leadership
		Ambiguity in responsibility	High motivation of employees
		Lack of metrics to measure impact	Accessible impact data
		Cost of solutions too high	Positive org. attitude towards sustainability
		Lack of resources	Technically compatible
		Technological complexity	Sufficient resource allocation
		Lack of technical infrastrucutre	Good economic environment
		Long development time	Perceived value of technology
		Ambiguity on how to apply regulations	IT department size
		Lack of prior experience	Prior experience
		Lack of immediate payback	

Figure C.5: Participant 1 Interview Summary

Participant 2 Interview Summary	Upper management D&T (Tech Side)	Barrier Ranking	Enabler Ranking
Participant 2 described D&T's progress with sustainability as steady, but slow. Most of the considerations have to do with there being enough budget, making the right decisions, and having the people to do it. Regarding barriers, they saw the biggest issues have to do with not having proper data, which they claimed to lead to the business value being unclear. This could also then result in a lack of leadership. They were very vocal about the complications going from experimentation to wide-scale adoption. They said that it takes a lot of time to integrate applications fully and comply with all regulations. They said that the business is often initially excited with the experiment, but then loses patience and doesn't understand why integration takes so long. The business side needs to understand that IT needs the support and that there is also a lack of awareness from their side. Participant 2 also said that they think these results would be less generalizable based on airlines with a different working culture, such as American carriers. This is due to their more hierarchical way of working where the decisions of upper management are not contested as much. They said that decision-making and implementation can be slow within KLM due to the widespread discussion that always occurs after a big decision. For strategies, they said to focus on getting the basics right first by centralizing data, improving its visibility, and implementing the modularity of applications. Since the life cycle of applications is growing shorter due to the pace of innovation, they said that having more modernized architecture would help a lot. They recommended that upper management focus on making a long-term vision and improve communication with other areas.		Unclear business value	Org. has sustainability-oriented strategy
		Cost of solutions too high	Defined Greening by IT strategy in IT
		Not considered a priority	Good economic environment
		Lack of resources	High motivation of employees
		Lack of immediate payback	Sufficient resource allocation
		Lack of metrics to measure impact	Prior experience
		Lack of leadership from management	-
		Technological complexity	-
		Long development time	-
		Ambiguity in responsibility	-
		Uncertain which initiatives would have largest impact	-
		Ambiguity on how to apply regulations	-
		Lack of technical infrastrucutre	Positive org. attitude towards sustainability
		Lack of standards	IT department size
		Lack of prior experience	

Figure C.6: Participant 2 Interview Summary

Participant 3 Interview Summary	Upper management D&T (Tech Side)	Barrier Ranking	Enabler Ranking
Participant 3 believed that D&T had good progress on sustainability, that there are clear examples of where it is being done and that the OKR's mentioned it as well. Regarding the barriers, they thought that there are so many things to fix and so many other priorities that sustainability is naturally less important. Cost saving is seen as a key driver. KLM infrastructure which naturally makes it tougher to innovate, gather data, etc… Improving this would naturally lead to more initiatives. Regarding enablers, they saw having a clear investment roadmap from top management as a crucial step as there is currently a lack of a roadmap from the higher level vision to implementation. They feel that there is a lot of awareness and discussion, and that people are hurrying to do things because of external pressure, but that there is no central strategy. For strategies, they said that the first focus should be on an investment plan with tangible results, getting the right infrastructure and tools, and investing in ways to measure impacts. Then form a specific IT strategy which embeds Greening by IT, which isn't good unless you have the resource commitments from the previous steps. Beyond these things they criticized that there is no overall business IT architecture and that things are very siloed between the KLM businesses. The idea to have GBIT hackathons is nice, but that alone won't cause large change. They recommended to outsource more trivial IT work which doesn't add competitive advantage and develop better infrastructure such that IT can work more on value creating tasks. An example they gave from catering is that the planning there is still done based on feeling at not based on data.		Lack of resources	IT strategy embedded in overall business strategy
		Lack of technical infrastructure	Defined Greening by IT strategy in IT
		Cost of solutions too high	Able to measure impact
		Lack of metrics to measure impact	Accessible impact data
		Technological complexity	Perceived value of technology
		Long development time	Good economic environment
		Unclear business value	Sufficient resource allocation
		Lack of immediate payback	Technically compatible
		Uncertain which initiatives would have largest impact	High motivation of employees
		Ambiguity on how to apply regulations	Senior management leadership
		Lack of standards	Positive org. attitude towards sustainability
		Ambiguity in responsibility	Org. has sustainability-oriented strategy
		Lack of prior experience	Prior experience
		Lack of leadership from management	IT department size
		Not considered a priority	

Figure C.7: Participant 3 Interview Summary

Participant 4 Interview Summary	Upper management D&T (Business Side)	Barrier Ranking	Enabler Ranking
Participant 4 described D&T's progress with sustainability as not fast enough. They said that there are many ideas and people are open to working on it, but that they are hampered by the speed of innovation. This is due to a lot of legacy applications, complexity, and the data being scattered. Regarding the barriers, they said that they would recommend adding a lack of data quality and compliance with aviation regulations. They also mentioned that there are many experimental solutions, but that there is complexity to really integrate it into the business. They said that IT is too scattered and that novel solutions often don't fit easily within existing infrastructure. Additionally, they said that tackling sustainability is done in a very siloed way where the different businesses don't collaborate. Participant 4 said that these results would be generalizable to most airlines. For strategies, they were really in favor of the concept of the sustainable flight challenge and holding similar challenges internally. They recommended that upper management communicate the urgency of the issue and that there should be positions there which are specifically for sustainability. They also said that since the middle layer is so overwhelmed, Greening by IT needs to appear in the main targets and upper management needs to help enable them to be able to take it on. Participant 5 was also in favor of improving idea feedback loops between the lowest parts of the hierarchy and upper management. They also saw it as crucial to look externally at other industries to get ideas for Greening by IT solutions. In the end, there must be clear strategies, dashboards, and databases to be able to make Greening by IT fully integrated in the airline.		Long development time	Accessible impact data
		Lack of resources	Able to measure impact
		Lack of technical infrastrucutre	Org. has sustainability-oriented strategy
		Lack of metrics to measure impact	High motivation of employees
		Cost of solutions too high	Good economic environment
		Uncertain which initiatives would have largest impact	Defined Greening by IT strategy in IT
		Unclear business value	Senior management leadership
		Lack of standards	IT strategy embedded in overall business strategy
		Lack of immediate payback	Prior experience
		Ambiguity in responsibility	IT department size
		Lack of leadership from management	Positive org. attitude towards sustainability
		Not considered a priority	Sufficient resource allocation
		Ambiguity on how to apply regulations	Perceived value of technology
		Technological complexity	Technically compatible
		Lack of prior experience	

Figure C.8: Participant 4 Interview Summary

Participant 5 Interview Summary	Senior Product Owner	Barrier Ranking	Enabler Ranking
Participant 5 stated that D&T's progress on sustainability is limited because there are no targets for it. If there were targets, people will beave accordingly, but it currently isn't being prioritized. Regarding the main obstacles, they saw not having targets and a central organ in the organization who things about this. They also cited that there is a lack of external pressure driving them to take Greening by IT up, as there is no pressure coming from business stakeholders. They also said that there is a large gap between the vision of the highest levels of management to actual execution. They see many of the Greening by IT solutions as very doable, but that there is no time or resources to work on them. Regarding enablers, the only time they saw pressure from upper management was when there was pressure from external media who reported on it. Additionally, the issue is not always that people are against these solutions, but that they aren't aware of the capabilities of IT. Referring to the generalizability of these results, they said that there would be differences between European airlines and other airlines as European society is pushing harder for these changes than other places. For strategies, they said that including criteria in the project evaluation process and in the targets would help. They suggested to create a sustainability lab to raise awareness, develop these solutions, and convince the business. They also brought up hosting hackathons to start solving simpler issues and to seek out ideas from outside the airline. Starting out, they would focus on raising awareness first, then move onto having a dedicated team or lab, and then eventually phasing it out as sustainability would then be fully integrated within the organization.		Not considered a priority	Org. has sustainability-oriented strategy
		Lack of leadership from management	Positive org. attitude towards sustainability
		Uncertain which initiatives would have largest impact	Perceived value of technology
		Unclear business value	IT strategy embedded in overall business strategy
		Lack of resources	Senior management leadership
		Ambiguity in responsibility	Defined Greening by IT strategy in IT
		Lack of prior experience	High motivation of employees
		Lack of metrics to measure impact	Good economic environment
		Lack of immediate payback	Prior experience
		Long development time	Able to measure impact
		Lack of standards	Accessible impact data
		Lack of technical infrastrucutre	Technically compatible
		Ambiguity on how to apply regulations	Sufficient resource allocation
		Cost of solutions too high	IT department size
		Technological complexity	

Figure C.9: Participant 5 Interview Summary

Participant 6 Interview Summary	Product Management Improvement Lead	Barrier Ranking	Enabler Ranking
Participant 6 was really convinced that there has been no progress related to sustainability within D&T. There are ideas which come up, but they get shot down by business stakeholders. Teams are fully occupied with phasing out legacy applications, that there is no time to be creative and innovate. They claimed that having a lack of financial and human resources and people being overloaded with their current tasks as the main barriers. They said that having prior experience was not a big factor as you can always hire someone external for that. They also would like to see a factor about having a dedicated team working on Greening by IT. Regarding strategies, they see a large gap in guidance and steering from the sustainability office at the corporate level. They said that the sustainability office should be more involved in also creating the solutions to the issues and not just reporting on it. Like other participants, they commented that the translation from the sustainability office's strategy to a strategy at their level is missing. Being able to measure and present the data of potential impacts would help overcome the barriers with business stakeholders. They also suggested to create a sustainability lab within D&T to tackle these issues and guarantee that these issues get picked up. They suggested that this lab should work in conjunction with the corporate sustainability office. They were also very much in favor of creating a start-up incubator to take on the more complex issues. They were very passionate about having a more entrepreneurial and innovative team working on Greening by IT to really make the large steps. This would allow more freedom to come up with creative solutions and actually innovate compared to the current situation.		Not considered a priority	Senior management leadership
		Lack of resources	Good economic environment
		Lack of leadership from management	Org. has sustainability-oriented strategy
		Lack of immediate payback	IT strategy embedded in overall business strategy
		Unclear business value	Able to measure impact
		Ambiguity in responsibility	Positive org. attitude towards sustainability
		Ambiguity on how to apply regulations	Sufficient resource allocation
		Cost of solutions too high	IT department size
		Lack of standards	Accessible impact data
		Lack of metrics to measure impact	Technically compatible
		Uncertain which initiatives would have largest impact	Perceived value of technology
		Lack of technical infrastrucutre	High motivation of employees
		Technological complexity	Defined Greening by IT strategy in IT
		Long development time	Prior experience
		Lack of prior experience	

Figure C.10: Participant 6 Interview Summary

Participant 7 Interview Summary	Portfolio Manager	Barrier Ranking	Enabler Ranking
Participant 7 saw D&T's sustainability progress as good. They said that there is a clear strategy from the top of KLM on sustainability and that that is what is needed to get the right prioritization for Greening by IT. When discussing the barriers, they said that the main issue came from having to balance a large number of issues and priorities within D&T. There is a constant battle between the cost of solutions and the value they add, which was seen as a major obstacle for Greening by IT solutions which might add less business value. These initiatives naturally lose priority compared to solving issues related to the operation. There is also a lot of old IT systems which limit D&T's innovative capacity. For enablers, although they said it was very complex, being able to measure and show the impact of the solutions would help a lot. They were very adamant that there must be a strategy and pressure from upper management as this shifts priorities. They said that this always determines resource allocation, so it is the root of these other issues. For data collection, they also said that things must be automated as there is the potential for data loss if you add it as an extra step for busy ground personnel. They said that is was absolutely key to have people responsible for sustainability or Greening by IT as then you trust that they work on it and it is not deprioritized. They were in favor of using internal sustainability challenges as a way to speed up the experimentation process for Greening by IT solutions. They recommended to start with strategy formation initially and then move onto enabling the initiatives. This would look like improving data access and having the metrics to demonstrate the impact.		Cost of solutions too high	Org. has sustainability-oriented strategy
		Lack of resources	IT strategy embedded in overall business strategy
		Lack of technical infrastrucutre	Able to measure impact
		Unclear business value	Accessible impact data
		Lack of metrics to measure impact	Senior management leadership
		Uncertain which initiatives would have largest impact	Positive org. attitude towards sustainability
		Long development time	Sufficient resource allocation
		Lack of immediate payback	
		Ambiguity on how to apply regulations	
		Lack of standards	
		Ambiguity in responsibility	
		Technological complexity	
		Lack of leadership from management	
		Lack of prior experience	
		Not considered a priority	

Figure C.11: Participant 7 Interview Summary

Participant 8 Interview Summary	Sustainability Program Manager	Barrier Ranking	Enabler Ranking
Participant 8 said that D&T's current progress with sustainability was good, but that it was a lengthy process to fully implement some of the initiatives. Regarding barriers, they said that most of the needed data is generally scattered and having it more accessible would help. For accessing the data, there is often a wide variety of stakeholders involved which just makes it more complicated than needed. After the experimentation phase, complying with all the necessary regulations such as those specific to aviation or GDPR adds a lot of time as well to implementation. They also added the unique perspective to the legacy phase out as it not only requires more modern systems, but a shift in human resources. People need to adjust to new roles and responsibilities as old systems are phased out. They also said that these phase outs are sometimes so long that the interim solutions made along the way end up being legacy when the original phase out is complete. It's also hard enough already making do with current resources to solve the operational challenges, so there is no room for sustainability. For strategies, they said it's also important to focus on establishing the right way to express the data, be it in euros, liters of fuel, etc… It's important to have Greening by IT reflected in the organization's targets and that it should also be seen as something that must be complied with. They were adamant that having C-level backing would drive this much further. Regarding choosing strategies, they stated that you shouldn't just wait to have enough resources or a strategy made, but that it is better to just start somewhere and iterate. The airline also needs to focus more on having good human resources to enable these new innovations.		Lack of technical infrastructure	Able to measure impact
		Technological complexity	Technically compatible
		Long development time	Accessible impact data
		Not considered a priority	Perceived value of technology
		Lack of resources	Defined Greening by IT strategy in IT
		Unclear business value	Org. has sustainability-oriented strategy
		Lack of immediate payback	IT strategy embedded in overall business strategy
		Uncertain which initiatives would have largest impact	Positive org. attitude towards sustainability
		Lack of metrics to measure impact	Good economic environment
		Lack of standards	High motivation of employees
		Cost of solutions too high	Sufficient resource allocation
		Ambiguity on how to apply regulations	Prior experience
		Lack of leadership from management	Senior management leadership
		Ambiguity in responsibility	IT department size
		Lack of prior experience	

Figure C.12: Participant 8 Interview Summary

D Appendix: Strategies

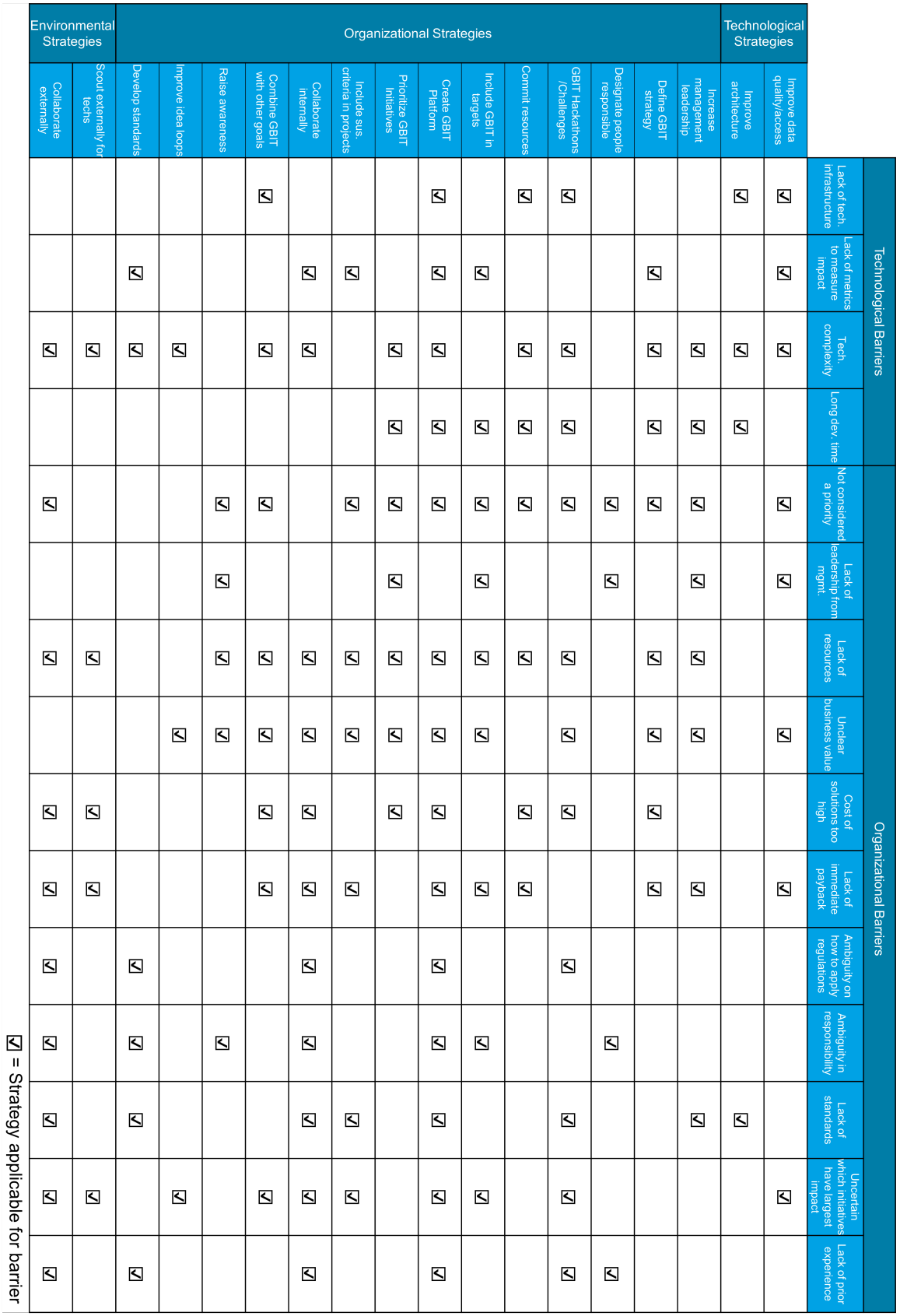

Figure D.1: GBIT Strategies Mapped to Barriers Identified in Literature Study

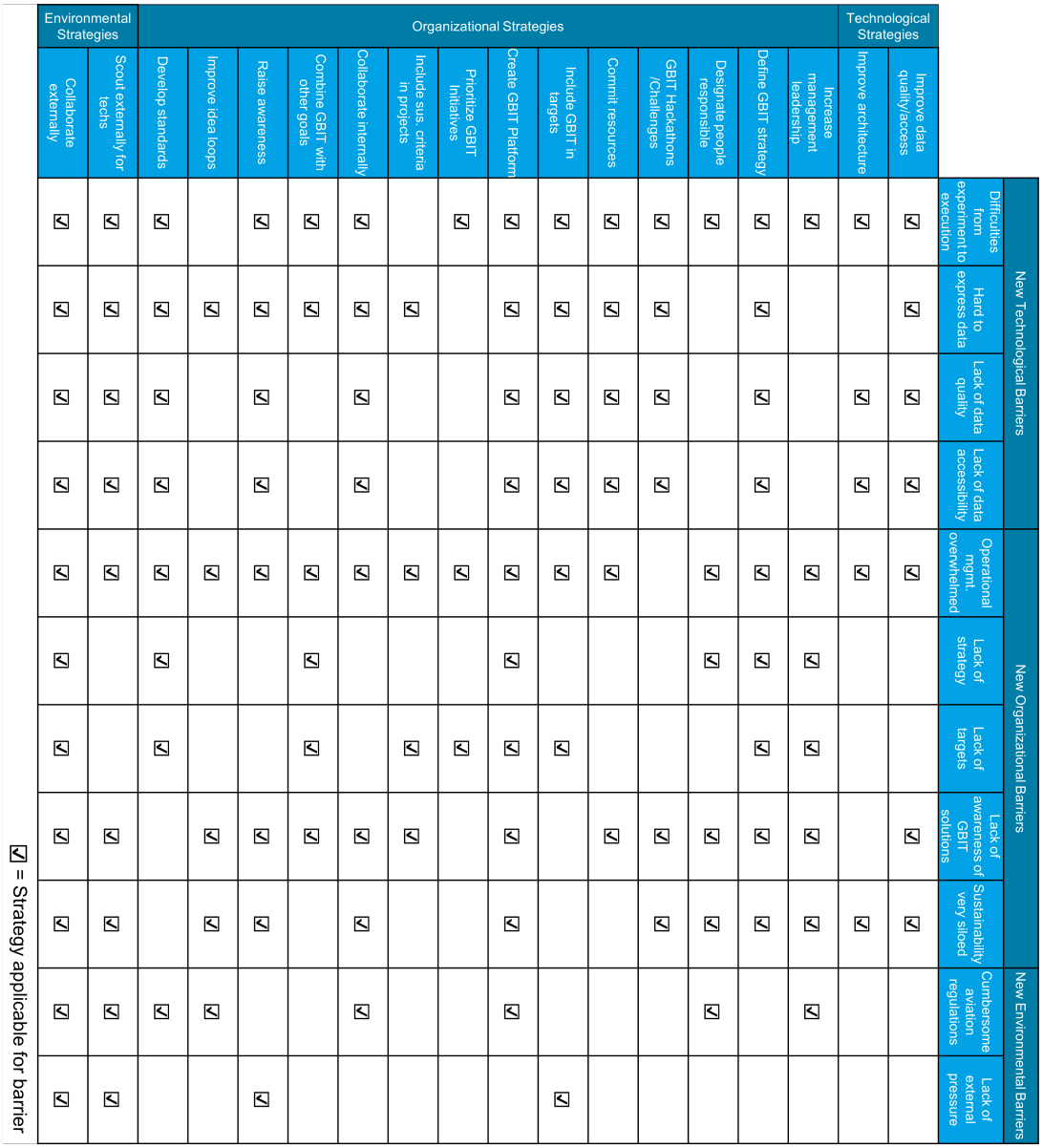

Figure D.2: GBIT Strategies Mapped to Barriers Identified in Literature Study

Number of Barriers Each Strategy is Applicable to			
Create GBIT Platform	24	Develop standards	14
Collaborate externally	21	Scout externally for techs	14
Collaborate internally	19	Commit resources	13
Define GBIT strategy	17	Raise awareness	13
GBIT Hackathons /Challenges	17	Include sus. criteria in projects	11
Include GBIT in targets	16	Designate people responsible	10
Improve data quality/access	15	Prioritize GBIT Initiatives	10
Increase management leadership	15	Improve architecture	9
Combine GBIT with other goals	14	Improve idea loops	8

Figure D.3: Number of Barriers per Strategy