From Data to Insights to Drive Sustainable Change in Philips' Global Road Freight CO2e Emissions

Document status and date:
Published: 04/10/2022

Document Version:
Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

Download date: 17. Nov. 2023

EngD THESIS REPORT

From Data to Insights to Drive Sustainable Change in Philips' Global Road Freight CO2e Emissions

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October/2022
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EngD SOFTWARE TECHNOLOGY

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

From Data to Insights to Drive Sustainable Change in Philips' Global Road Freight CO2e Emissions

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October 2022

Eindhoven University of Technology
Stan Ackermans Institute – Software Technology

EngD Report: 2022/065

Confidentiality Status:
Public

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The design that is described in this report has been carried out in
accordance with the rules of the TU/e Code of Scientific Conduct.

Abstract   Climate change is becoming a more severe issue nowadays, and
                      Royal Philips has committed to develop business responsibly and
                      sustainably with respect to the planet's environment. The main fo-
                      cus is the emissions produced in the company's logistics process.
                      To fulfill such a goal, a dashboard that tracks down air, ocean, and
                      parcel shipment CO2e emissions was established. However, there
                      was still a gap to complete the picture: analysis of road shipment
                      emissions. This report documents the solution to the problem: a
                      new dashboard, being compatible with the existing system, com-
                      pensates the need in analyzing road shipment data. Moreover, the
                      new architecture we designed for road freights was also adopted by
                      the current system for performance improvement.

Foreword

Philips is a health technology company improving people's health and well-being through meaningful innovation. At Philips, we see climate change as a serious threat. One that is expected to cause some 250,000 additional deaths per year globally if we do not deal with it today. Therefore, we are taking action to rethink our business models and decouple economic growth from the impact we have on the environment and society.

With growing global concerns about the impact of climate change, there is a pressing need for industry and business to manage and reduce CO2 emissions across the entire value chain. This ambition requires an active tracking instrument to ensure we will deliver on our ambitions. With the help of Leon we were able to create valuable insights in one of our bigger emissions categories, our transportation- and distribution in our operations.

With this project we aimed to build a hands-free progress for our emission performance tracking for Philips' entire transportation- and distribution activities in the 4 main modes of transport, namely ocean freight, air freight, road freight and parcel shipments. The project was planned to replace the current calculation methodology - which required significant amount of manual work – with a full-automated calculation method, and additionally multiple validations checks to ensure completeness and accuracy of our CO2e emission calculations. Creating an interactive interface/dashboard to continuously track performance. Allowing Philips' higher management to make data-driven decisions towards meeting its long-term climate targets.

"With the help of Leon, we were able to create a renewed logic- and tool that provides valuable (interactive) insights on where we are emitting CO2e from our transportation- and distribution movements of our goods, and where we still have to step-up to meet our long term climate ambitions. All in a manageable- and easy to access dashboard. This dashboard is now used throughout Philips as a leading KPI to track the performance against our global purpose. Thank you, Leon, for all your amazing contributions. Thanks to your skills and critical view, we were able to exceed Philips' management wildest expectations."

Siebe Trompert

October 2022

Preface

This document was written to deliver a thorough introduction to the project "From Data to Insights to Drive Sustainable Change in Philips' Global Road Freight CO2e Emissions". Within the document detailed descriptions of the problem definition, requirement evaluation, system design, design implementation, product verification, and product validation of the project deliverable - Philips road freight's carbon emissions dashboard - is described.

By reading this document, a reader without any background knowledge of the field would be able to understand the main targets of this project as well as how they were realized and achieved. For general context readers viewing from Chapter 1 to Chapter 3 would give a sufficient understanding of the defined problem and requirements, and a picture of the project result could be realized. Audience with adequate knowledge could also refer to the other chapters to recreate a similar result following the recorded design and instructions.

The document together with other project's deliverables were created under the supervision of Eindhoven University of Technology and Royal Philips N.V.

LiYang Wang

October 2022

Acknowledgements

Throughout the completion of the project, I received countless support and assistance. I would like to thank my supervisors from Royal Philips N.V., Siebe Trompert and Simon Braaksma, who had been providing enlightment and suggestions with their expertise to me. Your insightful feedback had brought the final outcome of this project to a higher level.

Next, I would like to thank my academic supervisor, Dr. Renata Medeiros de Carvalho, for the continuous guidance during my research. I deeply appreciate your input when I was uncertain with the project's methodology. Without your help I wouldn't be able to conclude the project that meets academic standards.

I want to show my appreciation toward my colleagues, the Group Sustainability, from Royal Philips N.V. It was my pleasure to work with all of you.

Furthermore, I am also grateful for the help that the EngD ST supervisor, Dr. Yanja Dajsuren, and EngD ST program management assistant, Desiree van Oorschot, provided for the duration of my study. Your effort and assistance significantly contributed to the success of the project.

Finally, I would like to thank my family as well as my friends who showed me their belief in me. It was your love and companionship that led me through the toughest time when I was hesitant and doubtful.

LiYang Wang

October 2022

Executive Summary

As a company that owns business worldwide, Philips is also dedicated to operate sustainably and environment friendly. The company set a target to reduce its carbon footprint across the value chain in line with a 1.5°C global warming scenario. To achieve such goal, one of Philips' focus is reviewing and improving the logistics processes. Following this strategy a dashboard that analyzes the logistics carbon emissions was establish. However, the analysis for road transportation logistics was still missing from the dashboard.

The outcome of the project "From Data to Insights to Drive Sustainable Change in Philips' Global Road Freight CO2e Emissions" successfully filled in gap for a complete picture of Philips' logistics carbon emissions. The new applications process and clean the raw input data, calculate emission using shipment records, and display the analysis results. These applications were integrated into the existing system and adopted an identical reload schedule. Finally, a new sheet, along with an addition section on the landing page, was created in the user interface, the Logistics Freight Dashboard, to present the road freight carbon emission statistics.

Judging from the performance of the latest design in this project, we applied the architecture to ocean-freight-related applications as refinement and achieved a success. We recommend accepting the structure depicted in this document as a new standard to improve the efficiency and maintainability of the Philips' logistics carbon emission analysis system.

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Glossary

KPI   Key Performance Indicator
EngD   Engineering Doctorate
PSG   Project Steering Group
MVP   Minimal Viable Product
BI   Business Intelligence
ST   Software Technology
TU/e   Eindhoven University of Technology
CO2   Carbon Dioxide
GLEC   Global Logistics Emissions Council
SOX   Sarbanes-Oxley Act
TEU   Twenty Equipment Unit

1 Introduction

In the introduction chapter we present the project context, containing the project intention and the project design. The chapter ends with the document outline, providing information about the report context.

1.1 Project Context

Climate change is becoming a more severe issue nowadays, and awareness toward the global warming threat is being raised among industries around the globe. Royal Philips, a worldwide leader in health technology, has committed to develop business responsibly and sustainably with respect to the planet's environment.

Philips set a target to reduce its carbon footprint across the value chain in line with a 1.5°C global warming scenario. This target was then expressed as the "Healthy People, Sustainable Planet" 2016-2020 program, and one of the most important indicators for the success of the program was being CO2-neutral within operations. Philips has been focusing on the emissions produced in the company's logistics process in particular. To fulfill such a goal, a dashboard that tracks down air, ocean, and parcel shipment CO2e emissions was established. However, there was still a gap to complete the picture.

The last piece of the puzzle was emissions from road shipments. By road shipments we are referring to non-parcel freight goods that are shipped via road transport, for example, trucks and vans. The project aimed to provide a solution to the problem mentioned above: a road freight transportation emission dashboard that allows users to examine and analyze the greenhouse gas emitted. The dashboard is composed of three parts, namely data reader, data calculator, and result display. The design was based on the existing dashboard with improvements in data cleaning, data structure, and dashboard user interface.

The main objectives of the project were designing and implementing a data analysis process, an automated data cleaning process, and an emission calculation process. The result was then integrated into the existing system, and deployed onto the viewing dashboard.

The project was a cooperative project between Royal Philips N.V. and Eindhoven University of Technology. Further details about the cooperation between the institutes and the role each project stakeholder played can be found in Appendix A.

1.2   Document Outline

This document starts with the project introduction, where the outline is framed. Next, the problem analysis, together with the requirement evaluation, are introduced to give a deeper understanding of the project context. Then, the system design is described, and detailed explanation of emission calculation methods used are also included. The document closes up with the implementation and validation and verification results. Finally, an additional chapter is placed at the end to present the renovation we applied to the existing dashboard.

2 Problem Analysis

To get a deeper understanding of the project scope, the original problem was investigated from various aspects. The first step was examining the existing applications for calculating the CO2e emissions of air freight, ocean freight, and parcel shipments. After exploring the current solution, the project's main tasks were defined; also, the flaws and difficulties that we encountered are listed. Finally, the potential constraints are mentioned as the last part of the chapter.

2.1 Project Domain

To reach the Paris Climate Agreement targets and the sustainable development goals, a concerted global effort with the sector of freight transportation is critical [2]. Both the consumers and suppliers must participate in the reduction process. Royal Philips, a global leader in health technology, is also committed to developing the business responsibly and sustainably with respect to the planet's environmental limits.

Recommended by the United Nations Framework Convention on Climate Change (UN-FCCC), Royal Philips set its target as reducing the carbon footprint across the value chain in line with a 1.5°C global warming scenario. This target was then expressed as the "Healthy People, Sustainable Planet" 2016-2020 program, and one of the most important indicators for the success of the program was being CO2-neutral within operations. To fulfill such a goal, Philips was in desperate need of a precise CO2e emission tracker.

Philips' logistics is divided into four categories: the air freight, the ocean freight, the parcel shipments, and the road freight. Emissions of each freight category has to be calculated independently using corresponding factors since the emission patterns are different. The calculating application for air, ocean, and parcel were completed, and this project focused on road freight emission calculation. All the calculations should be conveyed with respect to the GLEC framework [2].

2.1.1 Air Freight, Ocean Freight, and Parcel Shipment

The applications for calculating emissions from air freight, ocean freight, and parcel freight were already completed and deployed. The calculation workflow was separated into three layers: extract, transform, and deploy. In the extract layer, all raw data was loaded, including the emission factors and original shipment detail obtained from the logistics service providers. Next, raw data was transformed into a suitable format and total emission was calculated in the transform layer. Finally, the results were published to deploy layer, or, the dashboard, for viewing. The whole process is depicted in Figure 2.1.
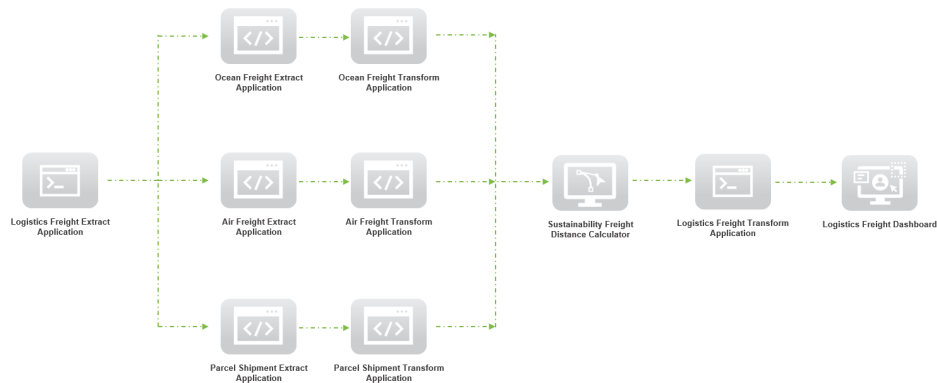
Figure 2.1: The process of existing calculation applications [1]

2.2 Road Freight CO2e Emission Calculation

As mentioned earlier, CO2e emission calculation for three out of four Philips' logistics sections were completed, and the remaining section was the road freight section. The project's goal was to fill in the last piece of puzzle that would allow the Philips Sustainability Team to provide insightful freight reports. The new application should also be integrated into the current process.

2.2.1 Necessary Data for Calculation

By definition in [2], the road freight emission falls into scope 3 emissions, the supply chain emissions. To calculate scope 3 emissions, the weight-distance value, which represents the amount of cargo moving by that distance, must be known first; then, multiply this value by corresponding emission intensity factors to obtain the total Green House Gas (GHG) emission. The whole procedure was depicted as Figure 2.2.
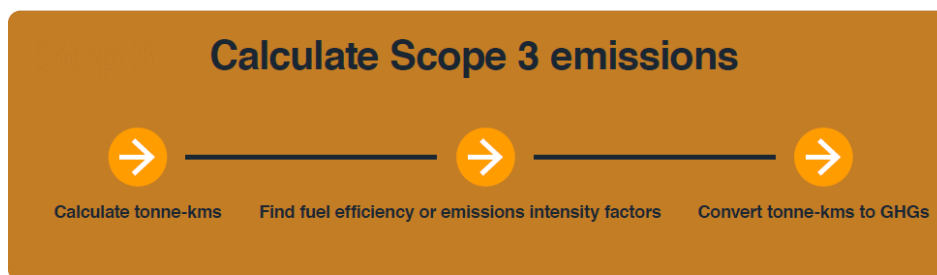
Figure 2.2: The process of calculating scope 3 emissions, adopted from [2]

To calculate the total emission, the data in Table 2.1 was necessary. Notice that in addition to the weight and shipping distance data, the vehicle details were also required to determine the most suitable emission intensity factors.

Table 2.1: Required data for scope 3 emission calculation

Required Data	Description
Chargeable Weight	The weight of the shipped freight that was charged by the shipper. Should be provided in metric tonne.
Shipping Distance	The total shipped distance of the freight. Should be provided in kilometers.
Vehicle Type	The type of vehicle used during shipment. Within field of interest it should either be van or Heavy Goods Vehicle (HVG). Whether the vehicle was refrigerated had to be specified as well.
Vehicle Load	The actual load for the vehicle during shipment. Vehicles diffuse different amount of GHG with different loads.
Vehicle Fuel	The type of fuel that drove the vehicle during shipment.

2.2.2 Automated Raw Data Processing

Ideally, the data received should be the same as the required data listed in Table 2.1; however in reality the raw data was often chaotic and deficient. To deal with the issue, processing the raw data before calculating was a crucial step. Some of the common flaws were listed below:

- Incomplete data records; null value exists.

- Missing vehicle-related details.

- Missing unit specification.

- Miss-matched cities and countries. For example, the city Eindhoven was marked as located in various countries instead of the Netherlands.

- Inconsistent format of addresses.

- Unrealistic shipment records. For example, a road shipment from China to Canada, which was apparently unachievable via specified transportation.

- Inconsistent city/country names. The spelling of cities may vary depending on language, and country names did not always follow naming conventions in [3].

One of the key tasks was developing a pipeline that automatically processes the disorganized raw data into a uniform form that allows for easy calculation. In addition to cleaning the data, enriching the data was also part of the task. This included filling empty slots with designated null values, deriving required data such as shipping distance from the origin to destination, and integrating data from other Philips departments to processed data.

2.2.3 Deploying to Dashboard

Once the total emission of road freights were calculated, the result shall be deployed to the dashboard for end users to access. The dashboard should contain the original results, insightful analysis, and future predictions. In other words, the dashboard had to serve as a reliable data source that allows

Philips to design their future plan. The user requirements for the dashboard will be described in chapter 3.

2.3 Project Goals

From the analysis in the previous sections, I defined the following project goals:

- Create and maintain a required data table.

- Create an automated data processing pipeline.

- Create a road freight emission calculating application.

- Integrate the new application to existing system.

- Maintain and improve the existing system.

- Analyze the requirements from Philips' business group.

- Create an intuitive dashboard that meets the evaluated requirements.

- Ensure the report is SOX compliant [4].

2.4 Constraints

There were several constraints within the project execution:

- Time limitation. The project lasted 10 months, including the time for defining the problem, designing and implementing solution, deploying the outcome, and other EngD events.

- Tool limitation. Since the solution should be in line with the current Philips business intelligence provider, which is Qlik Sense, there were limited abilities that the developer could utilize.

- Input quality limitation. The raw data comes from the external Philips logistics service providers, thus posing a threat on completeness of the data. There may be missing attributes in the data set provided, or the data set does not contain all shipments.

- Input time limitation. In addition to data quality, the data providers may also miss the expected data delivery date, thus delaying the calculation process.

3 Requirement Evaluation

By evaluating the requirements, the developer could propose an appropriate design with respect to the stakeholders' need. The evaluation was performed after exploring the problem domain and the related stakeholders. As indicated in stakeholder analysis, multiple Philips departments were interested in the project; thus, deriving requirements to fulfill all requests from each interest group was a necessary step.

The evaluation followed the procedure where use cases were written down first, and requirements were extracted from these use cases afterwards. The use cases were validated via direct discussions with the actors involved and the project domain expert. The result was then used as a reference when designing the system architecture.

The chapter starts with the use cases for the project, containing a table with case names and brief descriptions of each case. Following section 3.1 are two sections for functional and non-functional requirements.

3.1 Use Cases

A use case describes how a system interacts with its users in various scenarios and can be used to analyze and evaluate requirements. Within the project scope, the use cases in Table 3.1 were considered. The Philips management group, reporting group, and sustainability group were involved as main actors. The relation between each use case and the actors are depicted in Figure 3.1.

Table 3.1: Summary for main use cases

ID	UC01
Name	Authenticate user
Actors	Management group, reporting group, sustainability group
Summary	The system checks the user's authority and provides user with access to corresponding applications.

ID	UC02
Name	Export emission report
Actors	Reporting group
Summary	The user applies filters to the system to view desired fields and export an emission report containing these fields.

ID	UC03

Name	View all information
Actors	Management group, reporting group, sustainability group
Summary	The user removes all filters and reviews every information related to CO2 emissions provided by the system.

ID	UC04
Name	View CO2e emission by year
Actors	Reporting group, sustainability group
Summary	The user reviews the CO2e emission for the past 3 years, split by year.

ID	UC05
Name	View CO2e emission by market
Actors	Reporting group, sustainability group
Summary	The user reviews the CO2e emission for the past 3 years, split by markets.

ID	UC06
Name	View CO2e emission by business unit
Actors	Reporting group, sustainability group
Summary	The user reviews the CO2e emission for the past 3 years, split by business units/groups.

ID	UC07
Name	View CO2e emission by carrier load
Actors	Reporting group, sustainability group
Summary	The user reviews the CO2e emission for past 3 years by the carrier load type.

ID	UC08
Name	View raw data
Actors	Sustainability group
Summary	The user reviews raw data input to the system to verify correctness of the data.

ID	UC09
Name	Read raw data
Actors	System
Summary	The system reads the raw data from data source as input data.

ID	UC10
Name	Process input data
Actors	System
Summary	The system cleans the input raw data and process it into calculation-ready status.

ID	UC11
Name	Calculate distance
Actors	System
Summary	The system calculates the shipping distance of freights shipped via road transportation based on the shipping city names.

ID	UC12
Name	Calculate CO2e emission
Actors	System
Summary	The system calculates the CO2e emission with respect to input data.
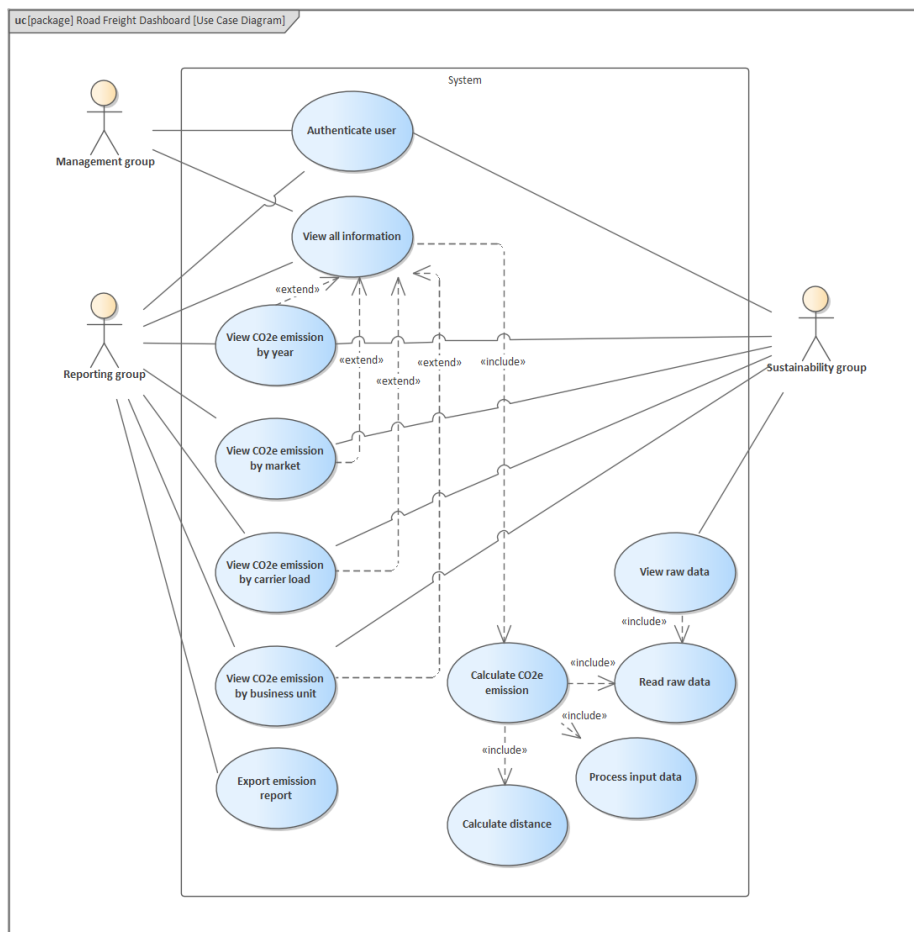
Figure 3.1: The use case diagram.

3.2 Non-functional Requirements

Non-functional requirements are the requirements that judge whether the system is operating as expected in various criteria. The non-functional requirements evaluated from the use cases in the previous section are listed in Table 3.2. The table was created with respect to Table 3.1.

Table 3.2: The non-functional requirements

NFR-1 The system shall be accessible to authorized users with respect to the internal security procedures.	*must-have*
NFR-2 The system user interface shall be similar to previously developed dashboards.	*must-have*
NFR-3 The system shall be able to display information drawn from the raw data completely and precisely.	*must-have*
NFR-4 The system architecture shall be clearly documented for future extensions, improvements, and maintenance.	*must-have*
NFR-5 The system shall allow for extension/integration with other Philips' existing solutions and products.	*must-have*
NFR-6 The system shall be robust to chaotic raw data.	*must-have*
NFR-7 The system shall be separated into different layers where modifying each layer does not affect other layers.	*must-have*
NFR-8 The system shall respond to the users' actions timely.	*should-have*
NFR-9 The system shall present the requested information correctly regardless of the display size.	*should-have*
NFR-10 The system shall allow for multiple users operating simultaneously without disruption.	*should-have*
NFR-11 The system architecture shall be reusable for refining existing solutions and creating other similar solutions in the future.	*could-have*
NFR-12 The system allows the user to review the input data quality from different aspects.	*could-have*

3.3 Functional Requirements

In contrast, instead of defining the performance, functional requirements depict the system's capabilities regarding the use cases written. By the requirements listed in Table 3.3, all the required functions for the project are described. The table was created with respect to Table 3.1 as well.

Table 3.3: The functional requirements

FR-1	*must-have*
The system shall verify the user's authority upon his access.	
FR-2	*must-have*
The system shall calculate the CO2e emission based on the input data.	
FR-3	*must-have*
The system shall display the business group target KPIs.	
FR-4	*must-have*
The system shall display the shipping route with the most CO2e emission.	
FR-5	*must-have*
The system shall display the change in total CO2e emission in a yearly trend.	
FR-6	*must-have*
The system shall provide a filter that allows user to extract certain information by selecting desired reporting years.	
FR-7	*must-have*
The system shall provide a filter that allows user to extract certain information by selecting desired markets.	
FR-8	*must-have*
The system shall provide a filter that allows user to extract certain information by selecting desired business units/groups.	
FR-9	*must-have*
The system shall provide a filter that allows user to extract certain information by selecting desired transport modes.	
FR-10	*must-have*
The system shall display relevant data within a 3-year time span.	
FR-11	*must-have*
The system shall be able to manage data flaws such as unallocated data and null data automatically.	
FR-12	*must-have*
The new system shall be integrated into the existing system.	
FR-13	*must-have*
The new system shall calculate shipping distance between cities.	
FR-14	*should-have*
The system refreshes and starts calculation automatically when new data arrives.	

FR-15	*should-have*
The system displays the business units where each shipment was allocated to.	
FR-16	*could-have*
The system tracks the amount of invalid data and calculates its proportion.	

4   System Design

In this chapter, an overview of the system design is given. The chapter starts with introducing the system environment, Qlik Sense, followed by scanning through the road freight dashboard architecture. The main architecture is separated into three subsections, where each subsection contains details of the layers: a) Extract, b) Transform, and c) Display.

4.1   Qlik Sense

Since we accepted road logistics data from all Philips' departments as input, an environment that allows us processing, analyzing, and visualizing data in large quantities was needed. Furthermore, the environment had to also allow for integration with the existing system, as specified in Chapter 3. Taking these into consideration, the Business Intelligence (BI) tool, Qlik Sense, was selected as the system environment.

Qlik Sense is a web-based BI tool that Philips is currently using across different groups for various intentions. The tool adapts a layered architecture, separating the database, the business processing procedure, and the presentation, i.e., the end user interface into three layers, as shown in Figure 4.1. This design benefits in being able to detach the database from the user, thus preventing unauthorized access to the back end. On the other hand, this architecture is also commonly used by developers having similar data-related requirements; the fact that field experts are familiar with the layered design would benefit in maintenance and development in the future.
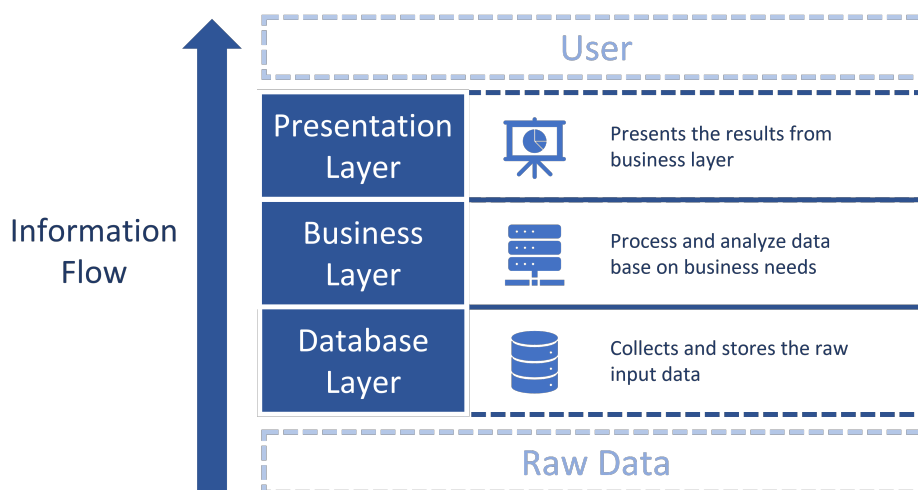

Figure 4.1: The Qlik Sense layered architect.

Finally, developers can also create an intuitive user interface for displaying the data processed in the business layer. An intuitive user interface is an interface that allows target users to understand its behavior and effect without use of reason, memorization, experimentation, assistance, or training [5]. Qlik Sense allows for building such interface by providing a various collection of KPI and graph templates. By mapping the business layer output to corresponding templates, the analysis results are shown directly to the user without explanation needed. Moreover, our target users, being the stakeholders listed in Section A.1, are also familiar with it, thus requiring even less effort in learning and exploring.

4.1.1 Non-Functional Requirement Evaluation

To further investigate whether Qlik Sense is the ideal candidate for the development environment, we reviewed the list of non-functional requirements in software engineering [6] and mapped the *must-have* and *should-have* non-functional requirements defined in Chapter 3 to the corresponding attributes. We discovered that all the non-functional requirement attributes existing in the project can be satisfied by Qlik Sense and concluded Qlik Sense was a proper BI tool for the project. Table 4.1 shows the investigation result.

4.2 The Existing Design

Since there were applications operating for other modes of transport, we considered taking the design of these applications as the foundation of the new applications. However, after a deep inspection, we found the following structural issues in the existing design:

- **Lacking modularization:** instead of dividing the system into individual modules with clear purpose and loose coupling with other blocks, the original processes were designed in a strongly dependent style. Much more effort must be paid in replacement or maintenance with such design.

- **Low level of abstraction:** almost all the settings, parameters, and file locations were coded as fixed values in the current applications. This would not only increase the difficulty in changing the system behavior, but also limit the developer from testing and validating newly arrived data.

- **Customized processes:** the processes in the subsystems were designed accordingly to the transport mode, each being unique and exclusive. This would increase the difficulty of integrating the subsystems in one, and impact our plan to merge the shipment data sources.

- **Duplicated processes:** when it comes to data cleaning and emission calculation, each of the transport modes shared similar even identical processes. Again, these processes were duplicated in each subsystems, decreasing the system efficiency and increasing the execution time of the dashboard significantly.

- **Scattered reference data:** beside the raw shipment data, we also need additional reference data to assist calculation and enrich end result. However, since these data were contributed by various parties, they were all stored in different folders. This increased the maintenance difficulty and created challenge for external expert when reviewing them.

Beside these architectural problems, we also saw several shortcomings from the users' perspective:

- **Inconsistent naming conventions:** since the shipment records came from different sources, we set up various corresponding subsystems to process data from each of them. However, the naming conventions within subsystems were inconsistent, resulting in a confusing data set after integration; it was full of different field names referring to identical features.

- **Unfocused dashboard:** although the dashboard facing the user displayed a lot of information, for users it was too overwhelming. Even though different users had divergent interests, pivoting on main features such as total emission that every stakeholder wanted was still desired.

In order to solve the problem we had in the current architecture, brand new structures for all layers were proposed and implemented for road freight shipment applications.

4.3 Dashboard Architecture

In order to operate our dashboard with the Qlik Sense environment, we created a three-layer logic where each layer corresponds to one Qlik layer. The layers are: a) extract layer, b) transform layer, and c) display layer. Extract layer was mapped to the Qlik database layer, where all the raw input data were collected and stored as a designated format. Next, the transform layer, resembling the business layer, holds the data cleaning, data enriching, and emission calculation processes. Finally, the display layer presents the calculation results from the transform layer to the user.

The process flow of the road freight dashboard is presented in figure 4.2. In the process we also depicted additional applications and steps for data acquisition and result integration. These additional parts, together with the defined three layers, will be explained thoroughly in the following sections.

4.3.1 Extract Layer

This section depicts the process running inside the "Road Freight Extract App" block from Figure 4.2. The main goal of the extract layer was loading raw input data and selecting the required subset from it, and the whole process is depicted in Figure 4.3. The layer started with loading the data, where the master data was the shipment data from Philips' Integrated Warehouse Distribution (IW&D) Group. The set contained every detail such as route and price for each Philips' shipment. The raw data was separated into two files, where one of them held all shipments happened in the current year and the other contained records from previous years. The reason for keeping historical data independent was to prevent changes to past reports. Considering we are generating the emission report on a yearly basis, it was reasonable to update only the shipment data of current year. The additional information, which was the business unit ID and flow specification, was also loaded in this step for further format changes.

After loading the data, the next step was selecting an appropriate subset from both time and field aspects. We first filtered out data that fell in the range of year of interest. As we specify in FR-10, Chapter 3, the coverage of the data shall be 3 years dating back from current date. After filtering out outdated data, we selected and renamed fields that were required attributes. We mention first the fields that are directly involved in the emission calculation process:
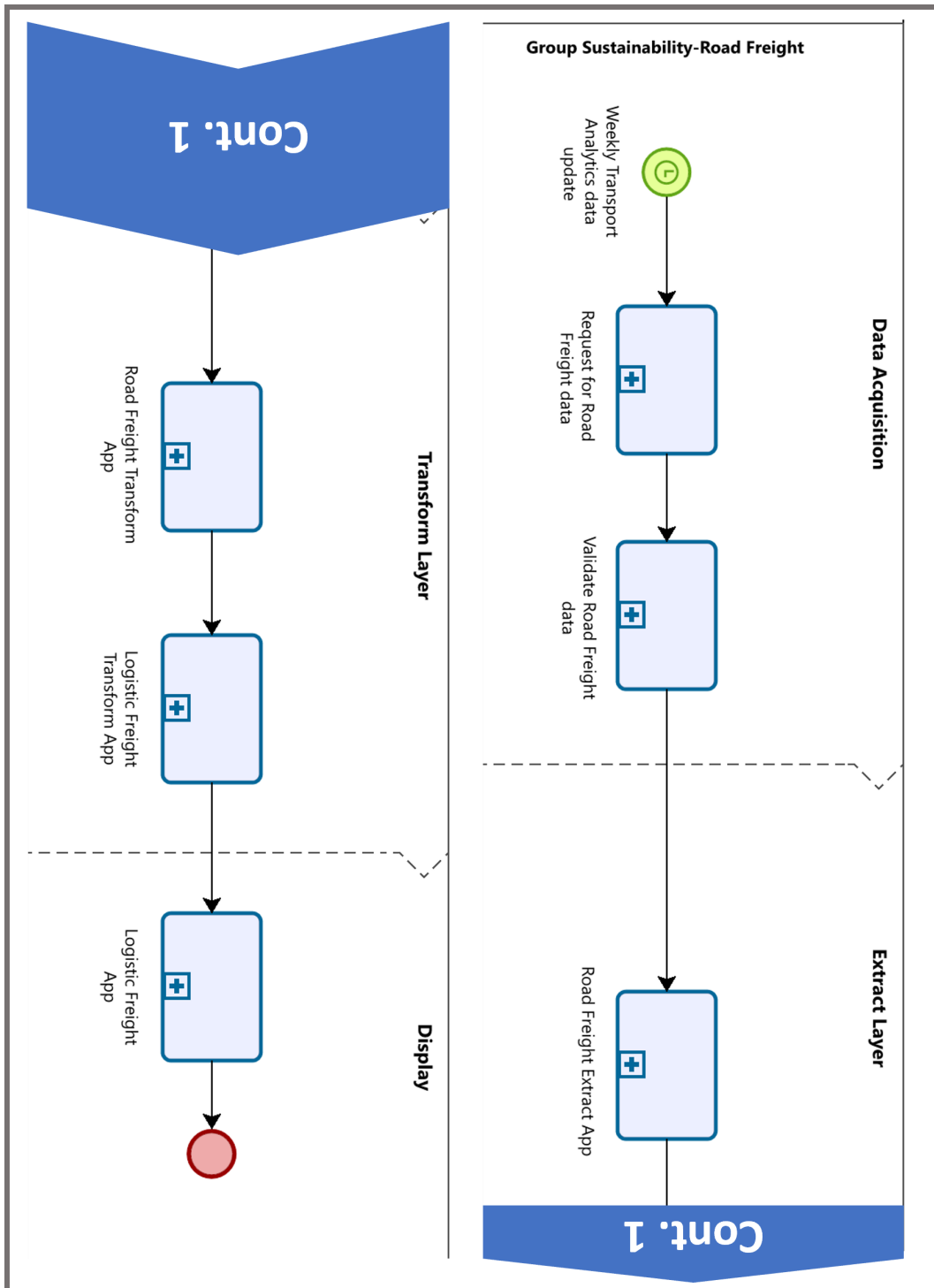
Figure 4.2: The process flow of the road freight dashboard-related applications.
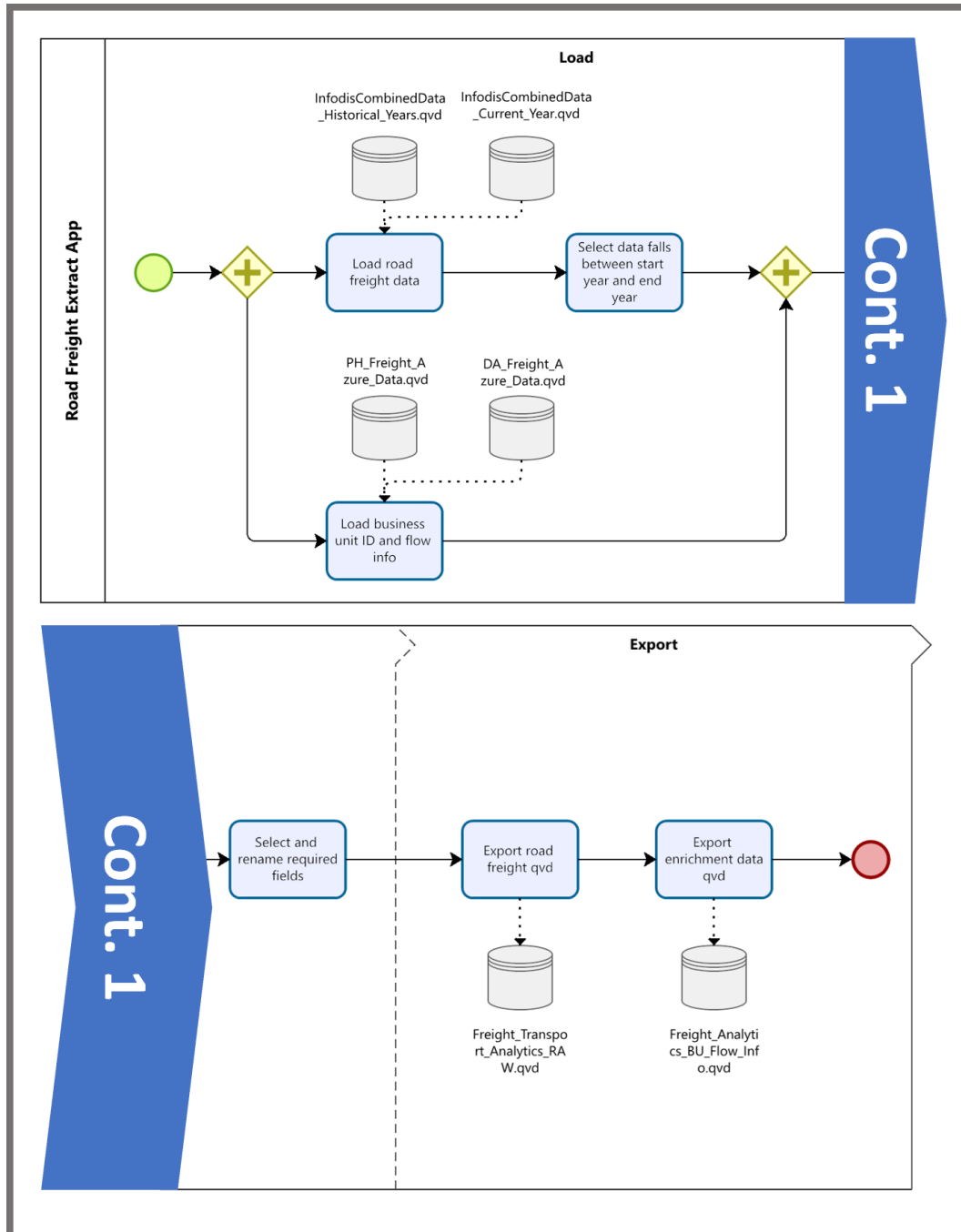
Figure 4.3: The extract layer process. Starting from loading raw data input, the process then selects required data and saves it into the Qlik format.

1. **Shipment date**: the date when the shipment was completed. Since the emission factor changes on a yearly basis, we need the date to decide the correct factor.

2. **Shipment origin & destination**: the places where the freight was shipped from and to. We need this information to calculate the shipping distance.

3. **Chargeable weight**: the weight that was charged for the shipment. Considering there were shipments having large size but small weight as well as the opposite, it was specified as "chargeable weight" rather than simply "weight."

4. **Mode of transport**: the transport mode that was used for the shipment. This field was also used in deciding the correct emission factor as the factor is vehicle-sensitive.

In addition to these calculation-related attributes, there was also shipment information that we thought would assist in establishing an insightful analysis, namely

1. **Shipment ID**: the unique ID that was assigned to each shipment.

2. **Shipper**: the business party that ordered the shipment.

3. **Forwarder**: the forwarder/carrier that completed the shipping process. If we want to allocate the emission factor even more precisely, this information would come in use.

4. **Receiver**: the business party that received the shipment.

Finally, the last step of the extract layer was storing the chosen subsets into Qlik format files. Changing the format benefited in reading and processing speed in the following layer.

4.3.2 Transform Layer

This section depicts the process running inside the "Road Freight Transform App" block from Figure 4.2. As mentioned earlier, the transform layer, as shown in Figure 4.4 corresponded to the Qlik business layer, and all the data-transforming-related steps were taken within this layer. The first step was loading the Qlik files exported from the extract layer and from other Qlik applications that would assist the calculation process. The files we introduced here were the raw shipment data, the emission factors, and the enriching data, and the average weight table. In addition, following the functional requirement *FR-13*, the distance table together with the average country distance table were imported to provide the dashboard with the ability to calculate distance by utilizing the shipment information.

After reading the files, a series of variables was set for restraining the value of attributes and quality control. We set the distance levels, invalid data percentage, leg 1 to 3 distance percentages, maximum chargeable weight, and maximum distance. The distance levels were used to categorize shipments into different ranges, namely short-range, medium-range, long-range, and extra-long-range, based on the shipping distance. The invalid data percentage was a number that could be used to push notification even stop the system from loading if the data quality fell below this standard. As for the maximum numbers, they were used to replace invalid values when needed.

The leg 1 to leg 3 distance percentages were used to evaluate shipping distances in different phases. According to the definitions depicted in Figure 4.5, the shipping distance is composed of three parts,
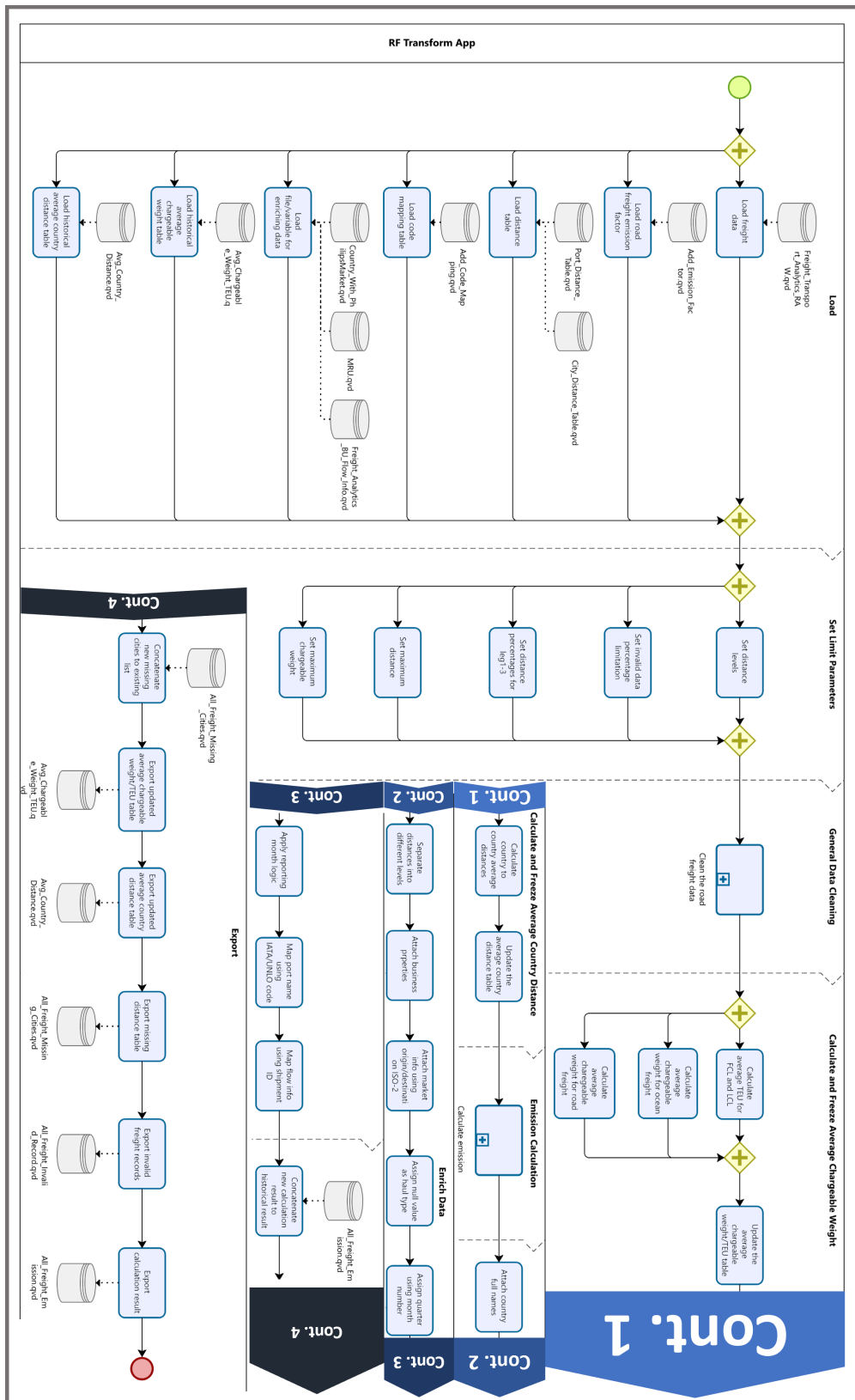
Figure 4.4: The transform layer process.

the leg 1 to leg 3 distances. Leg 1 and leg 3 distance refers to distance between cities and ports, while leg 2 being distance between ports. The precise leg 1 and leg 3 distances were never evaluated but assigned as a portion of the shipping distance using the percentages mentioned previously. Since road freights were shipped by single shipments directly between cities, we considered all road shipments as leg 1 shipment, and set the leg 1 distance percentage to 100% with others zero.

Once the variables were set, we initiated the data cleaning process to raise the data quality for further calculation. The implementation detail of this process is described in the "Data Cleaning Process" section below. The calculation process, together with evaluating chargeable weight and shipping distance, are also kept in an independent section "Emission Calculation."

Finally, the transform layer ended with enriching data, where associating shipments with the Philips business units, as required by *FR-15*, was also part of the step. Various information was attached during this stage, including shipment country full names, distance levels, business properties, market info, and internal reporting date logic. Merging everything together formed the final outcome, and wrapped up the transform layer by exporting them into a collective file for the display layer.

Figure 4.5: The distance definitions within the project.

Data Cleaning Process

This subsection describes the process running inside the "Clean the road freight data" block from Figure 4.4. We designed this block to flag the wrong values in the data set and replace them with context in desired formats. The cleaning process started with picking out the invalid data, as shown in Figure 4.6. We examined different attributes of the raw data, and marked with various labels if any unwanted content was seen. The conditions which we defined as invalid are listed below:

1. **Chargeable weight**: considered invalid if the number is lower or equal to zero.

2. **Twenty Equipment Unit (TEU)**: considered invalid if the number is lower or equal to zero. This attribute is not applicable for road shipments.

3. **Spend**: considered invalid if the number is lower or equal to zero.

4. **Date**: considered invalid if the date is later than today.

5. **City name**: considered invalid if it contains number or symbols other than English alphabets.

6. **Country ISO-2 code**: considered invalid if it contains number or symbols other than English alphabets.
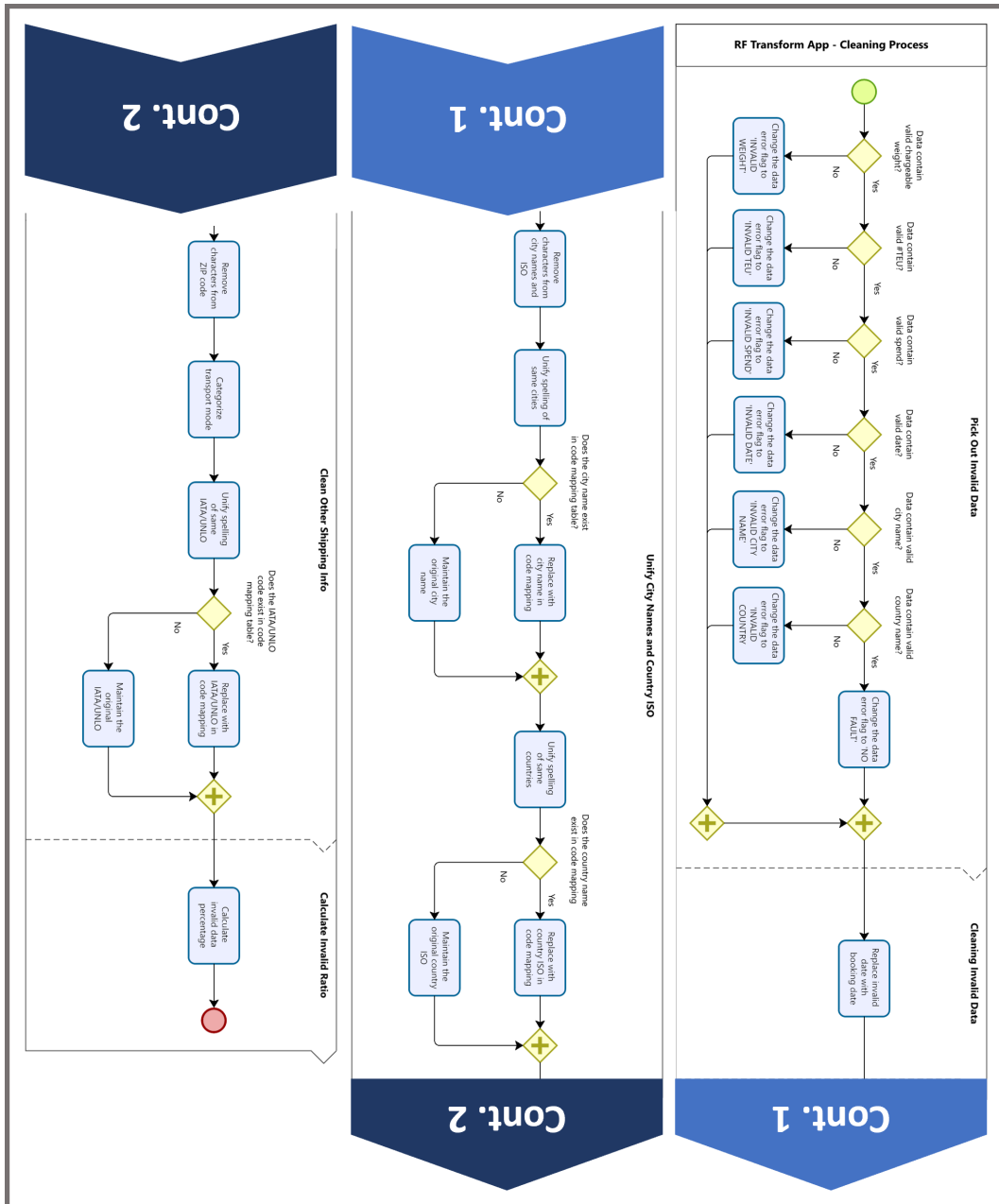
Figure 4.6: The data cleaning process in the transform layer.

After marking invalid data, we had to repair it following the logic we defined. If there was invalid date, replace it with the booking date of the shipment since the booking dates were normally earlier than shipping date. Repairing erroneous city names and country ISO-2 codes required a different strategy that was entitled as "code mapping." The code mapping logic was mapping various entries to desired context by referring to a constantly-updated list; if two different entries were meant to be replaced with identical value, putting them under same map-to value in the list would accomplish the goal. By referring to the code mapping list, we were able to unify the spellings of city names and ISO-2 codes, while the original values were inherited if they were not on the list.

The cleaning process ends with a invalid data percentage calculation step. We calculated the ratio of such data as a means to monitor the quality of the input. Notice that the step before, the cleaning shipping info step, was not applicable to road freight shipments; it was designed for other modes of transport.

Emission Calculation

This subsection describes the process in "calculate and freeze average chargeable weight", "calculate and freeze average country distance", and the "Calculate emission" block from Figure 4.4. These processes are all related to evaluating important numbers in emission calculation, thus must be designed clearly and comprehensible so external auditors could verify their correctness and further approve our emission reports.

The process started with calculating the average weight and the average distances between countries. The former was used to replace the marked invalid chargeable weights, and the latter was considered as an alternative when the exact shipping distance could not be assessed. The average numbers were all calculated with respect to the shipping date and mode of transport and stored into separate tables. To reflect the most precise value, whenever these numbers were being used to replace input context, the shipment details, which were date and mode, must be considered as additional searching indices.

Next step would be emission calculation, which is shown in Figure 4.7. The sub process initiated with finding the chargeable weight, one of the crucial elements for emission calculation. First we examined if the chargeable weight was valid; the check was completed via the fault flag. If the record was marked with invalid weight, we then looked up the average chargeable weight table with the date and transport mode as search key. In case that the quest was unsuccessful, the maximum chargeable weight, which was defined in the variable setting stage, would be introduced to succeed the original incorrect value.

Similar logic was also applied for extracting the shipping distance with minor changes. Before initiating the search in the distance table, we first compare the origin and destination, and placed the "same-city distance" if they were identical. Due to the fact that our distance table would return zero in such case, we assign the distance of shipment happened within same city to a specific length. Afterwards, we utilized the leg distance percentages to calculate the distances in each shipping leg. The distance evaluation ended with specifying which distance were used as shipping distance: precise distance, average country distance, or maximum distance.

Considering the emission factors are also vehicle-dependent, the evaluation of factors started with checking the freight load. If the load was not specified, zero value will take place to raise awareness. Once emission factors for each leg were realized, we then moved on to calculate the emission as the last step of the calculation process.
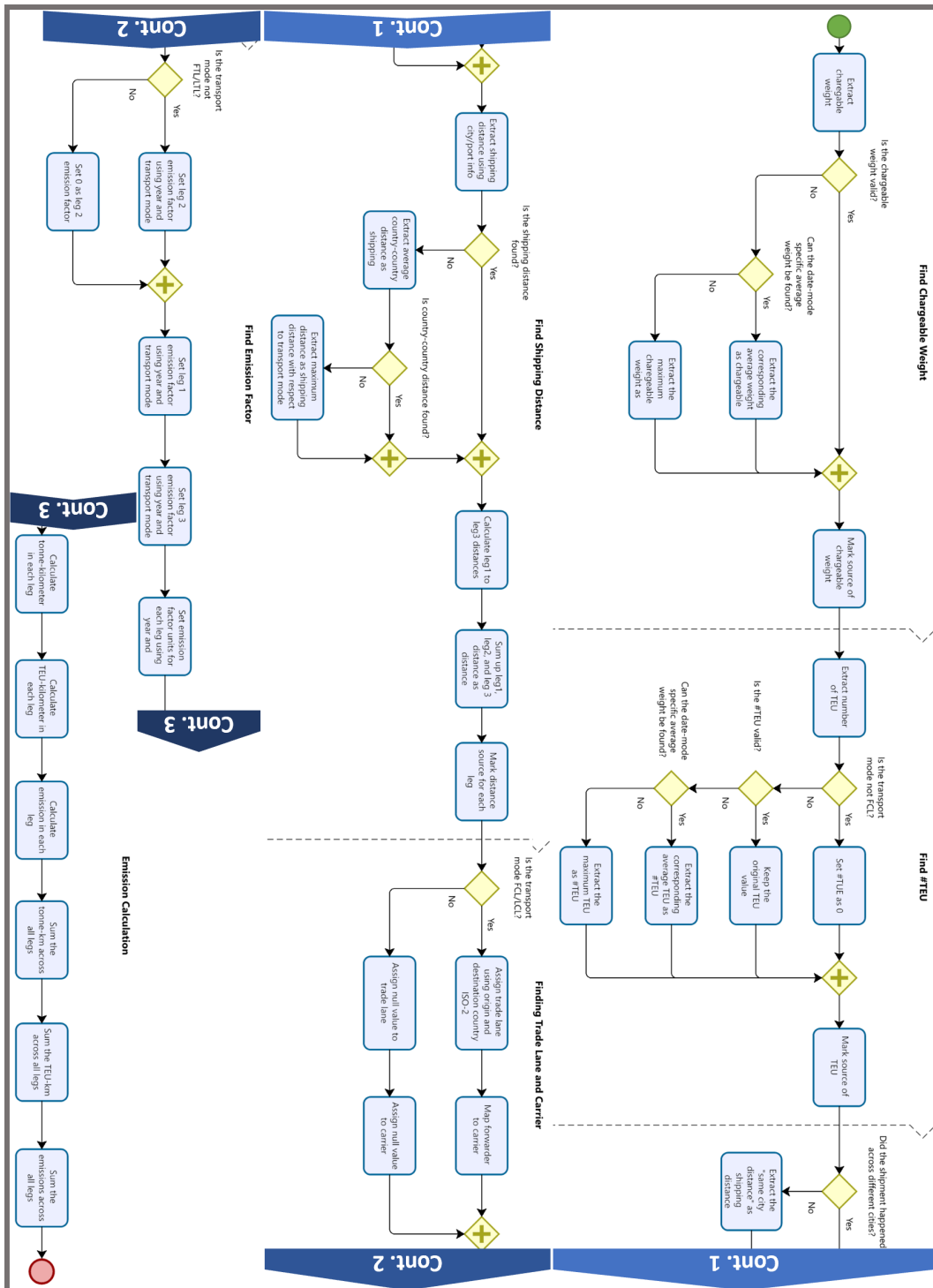
Figure 4.7: The emission calculation process in the transform layer.

The section "Find #TEU" and "Finding Trade Lane and Carrier" does not apply to road freight shipments; they were designed as extensions for involving other modes of transport in the future.

4.3.3 Display Layer

The data flow ended in the display, i.e., the presentation layer. This layer contains the analysis dashboard that directly faces the users. Following *FR-12*, the new system shall be integrated into the existing system, and we achieved this requirement by introducing the road freight calculation results into a running collective application: the Logistics Freight application. Showing in Figure 4.8, the emission files from all modes of transport were loaded into this application and integrated. The outcome was then attached with enriching data, and fed to the user interface. the dashboard.

According to the display-related functional requirements (*FR-3* to *FR-9*), the dashboard must display the elements below:

1. Target KPIs

2. Shipping route

3. Emission trend line

4. Shipment year filter

5. Shipment market filter

6. Shipment business unit filter

7. Shipment transport mode filter

We completed the viewing dashboard with all the elements above, and adjusted the appearance with respect to existing dashboards in order to fulfill requirement *FR-12* from the users' perspective.

Figure 4.8: The collective application: Logistics Freight.

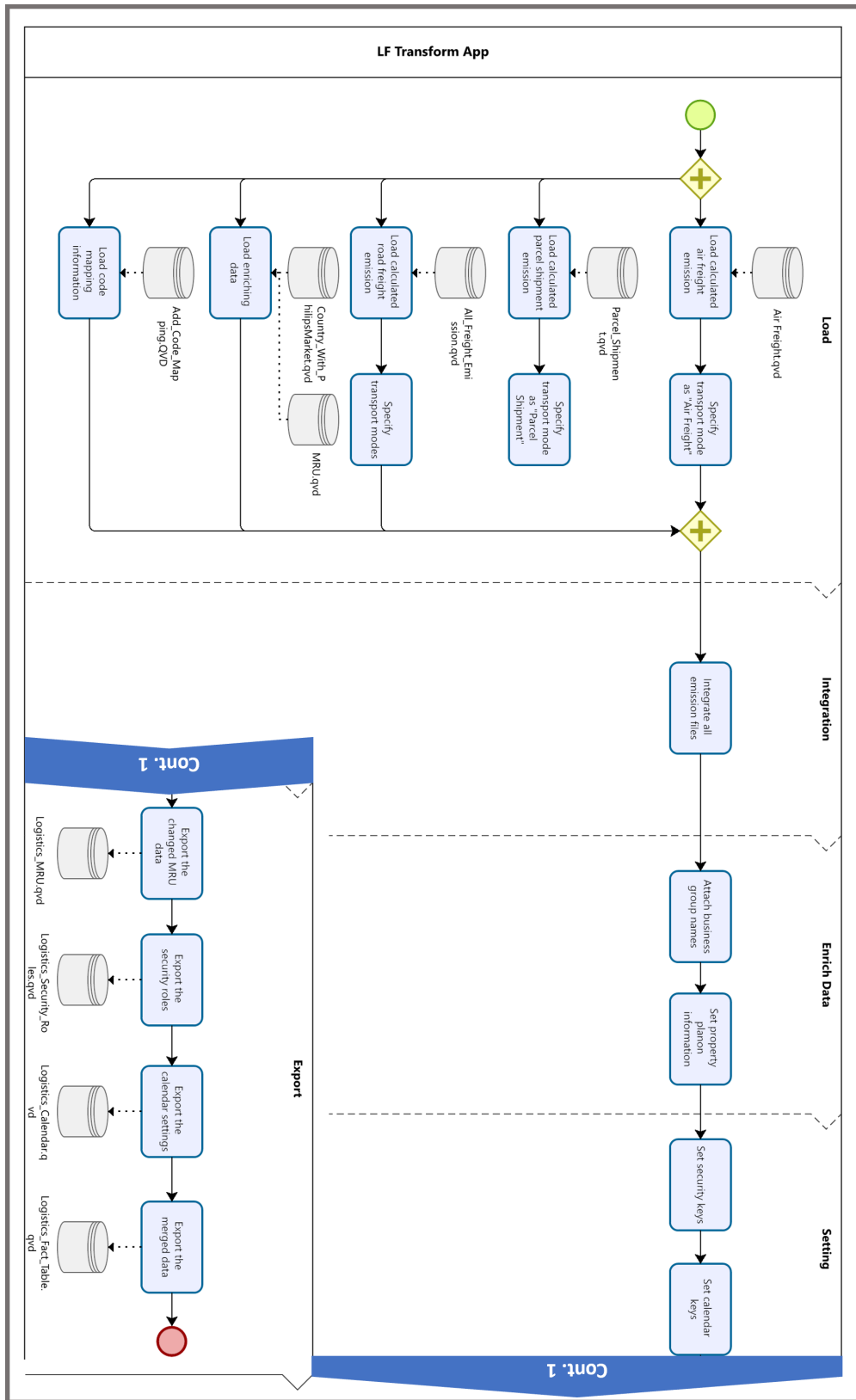Table 4.1: Investigation result of how Qlik Sense is satisfying requirements.

Requirement	Attribute	Qlik Sense Investigation	Does Qlik Sense Support?
NFR-1	Security	Qlik Sense provides a Qlik Management Console (QMC) service that allows the developer to manage user access. In addition, the QMC service can also be used to set up user access rules.	Yes
NFR-2, NFR-5	Compatability	Qlik Sense was used for previous dashboards as well, thus making it easy to create a similar presentation sheet and integrate into existing dashboards.	Yes
NFR-3	Integrity	Qlik Sense can connect directly to the data source, preventing data from being distorted.	Yes
NFR-4, NFR-7	Maintainability	Qlik developers need only to focus on the business for maintenance, the rest are maintained by the Qlik operator.	Yes
NFR-6	Robustness	Qlik Sense provides a series of functions that the developer can utilize to increase the robustness of the system in the business layer.	Yes
NFR-8	Responsiveness	If the data and analysis results are prepared in the business layer, Qlik Sense sheet responds immediately to any action by the user. The wellness of responsiveness depends on developers' design in the business layer. In addition, the Qlik Sense Performance Benchmark shows that a complicated application with ten million rows of data will respond less than one second when there are 300 concurrent users [7].	Yes
NFR-9	Usability	Qlik Sense automatically adjusts text and display size with respect to viewing window size.	Yes
NFR-10	Scalability	Qlik Sense automatically acquires the necessary CPU and RAM resources whenever needed. According to the Qlik Sense Performance Benchmark, it occupies less than 70% of CPU and RAM resource when there are 300 concurrent users on a complicated application with ten million rows of data [7].	Yes

5   Emission Calculation

Another key segment of the dashboard was calculating the emission, and we would like to present a thorough insight to this part of the process. According to the GLEC framework, the emissions should be calculated using chargeable weight, shipping distance, and the corresponding emission factor [2]. Since every shipment had different weight and distance, the emission was computed independently by each load. The process starts with obtaining the tonne-kilometer value, which is the product of chargeable weight and shipping distance. Then, this number is multiplied by the emission factor to acquire the emission of the shipment. Finally, emissions from all shipments are summarized as the total emission. The emission calculation process is depicted in Figure 5.1.
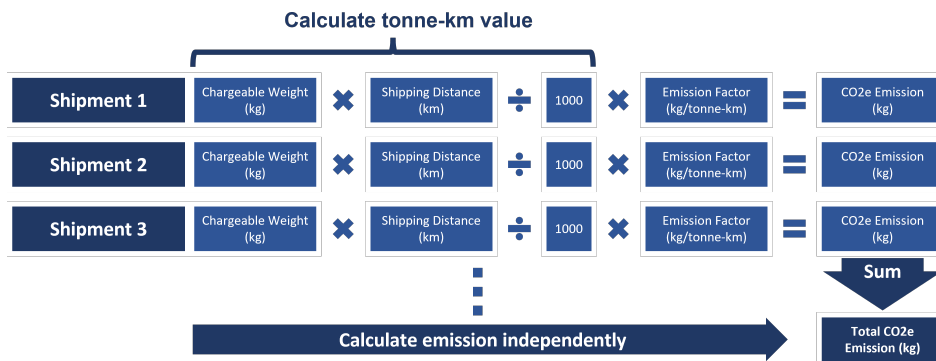
Figure 5.1: The emission calculation process. Emission for each shipment was calculated independently, starting from obtaining the tonne-km value then to the emission. We summarized all emission as the total emission.

5.1   Evaluating Chargeable Weight

Following the process depicted in Figure 5.1, the first step was evaluating the chargeable weight. Since there were flaws in the raw input data, we had to design a methodology to manage these defects for further calculation. A priority list of weight value sources was introduced to decide which weight should be chosen as chargeable weight for each shipment. The list contained three sources, listed following priority-descending order: a) direct weight, b) average weight, and c) maximum weight. During the evaluation process, we verify the availability of each of them and select the weight value from the source with highest priority. The process was completed for every shipment until all of them were assigned an appropriate weight.

To give a better picture of the evaluation process, we present here how the weight values from each

source were obtained. First, the direct weight; it refers to the weight that was specified in the raw input data. If this field was not empty and contained valid value (larger than 1 and smaller than defined maximum), then it would be considered as chargeable weight for the shipment. In contrast, if the raw input data was invalid, we would turn to the average weight; the value was evaluated by looking up a list of averages by shipment detail. Each number in the list was calculated by averaging weight of shipments shipped within designated time period and via specified transportation, and linked with a search key containing shipment date and transport mode information. Finally, for the maximum weight, the value was predefined, and used when the other two values we mention above were not present.

The principle we describe above was applied to every shipment in the raw input data. Once the chargeable weight was completely evaluated, we then marked the source of every chargeable weight and proceeded to the next step: figuring out the shipping distance.

5.2   Evaluating Shipping Distance

To evaluate the shipping distance, we applied the same priority-list methodology as describe in the previous section. The list for shipping distance contained four sources, listed following priority-descending order: a) in-city distance, b) direct distance, c) average country distance, and d) maximum distance.

The distance values of direct distance and maximum distance were obtained following identical logic as in chargeable weight. The in-city distance refers to the distance we set for shipments that happened within single city. When the origin and destination are identical, the distance calculator application, developed within Group Sustainability, returns zero value. To account for such shipment, we defined the in-city distance for calculating the emission. As for average country distance it also came from a list that was constructed in a similar way as average weight, which the key difference was using the shipping distance of shipments occurred between same origin and destination countries to calculate average instead.

Again following the principle, we evaluated all the shipping distances with the source specified as well.

5.3   Selecting Emission Factor

There are various aspects that will affect the emission factor, and taking them into consideration can improve the correctness of factor selection and accuracy of the emission calculation. When choosing the emission factor for road freight, we had to consider a) shipment load, b) vehicle type, and c) fuel consumed. Due to the limitation of our raw input data, the only aspect we could utilize was shipment load. The possible values were Full Truck Load (FTL) and Less than Truck Load (LTL). If the shipment load was neither FTL nor LTL, we choose the emission factor for general road freight.

6 Implementation

After the completion of designing and setting number evaluating methods, we moved forward to implementation. Among the fixed procedures, additional strategies were introduced to further improve the usability and development efficiency. This chapter describes these strategies and ends with presenting the dashboard appearance.

6.1 Extracting Configuration

Based on the investigation and realization result in Section 4.1, we selected Qlik Sense as our development environment and implemented the layered design described in Section 4.3. Qlik Sense utilizes a SQL-like, data-oriented scripting language, thus the typical practices for object-oriented languages had to be adapted before applying to our application.

One of the major techniques we used when implementing was centralizing configuration file. We isolated system settings such as source file path and data time range from the script and kept them in a separated file. Whenever the application starts, it first reads all settings from this configuration file before proceeding further. The main advantage of such practice is that the application performance can be adjusted externally without diving into the script and background knowledge in programming. Since both technical developers and non-technical analysts are authorized to modify the applications, the feature benefits in testing and maintaining them. Within Group Sustainability, extracting configuration was already a common action among all dashboards, and it was applied to all three new road freight applications as well.

In addition to detaching the environmental parameters, we also separated the operational parameters from the code. By operational parameters we are referring to numbers that are being used while the applications are running. As an example, the maximum weight and maximum distance we mentioned in Chapter 5 are operation parameters and are declared independently; emission factors are also part of the group. Likewise, this action benefits in maintaining flexibility to emission-calculation-related settings and provides a direct and easy window for external users to peek in at how the applications work. Considering that emission calculation process may change from time to time, the preserved flexibility for these parameters is valuable in future emission report generation.

6.2 Dashboard Appearance

The last step of the implementation was visualizing the emission calculation result. With respect to *NFR-2*, which indicated similarity to previous developed dashboards was required, we set up the new dashboard for road freight with identical items and charts.The dashboards for other transport modes

were treated as templates; based on these templates we swapped the original data with road freight data to generate corresponding graphs and analysis. Moreover, we added a new column to the landing page of the system, as shown in Figure. 6.1, to present the key values of road transportation emission.
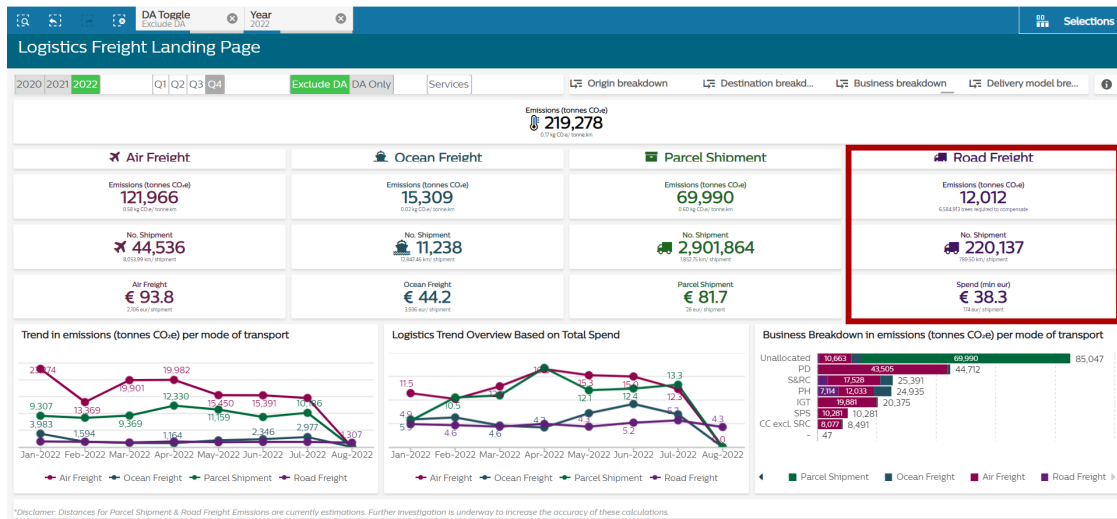

Figure 6.1: The new landing page which road freight column was added to the right, as indicated by the rectangle

While creating the user interface, we utilized a Qlik Sense feature: defining master items. The concept of master item is to set the commonly used analysis results or equations that are used in multiple conditions as inclusive objects. Whenever these objects are needed, instead of retyping the functions we can simply drag and drop the master items for deployment. Declaring measures and features as master items not only increases the implementation efficiency, but also connects all numbers that are evaluated via same equation together. When changes to the these analysis are required, we need only to edit the related master items instead of every appearance of them.

Taking the existing dashboard as reference, we completed the road freight dashboard interface. The result is shown in Figure. 6.2.
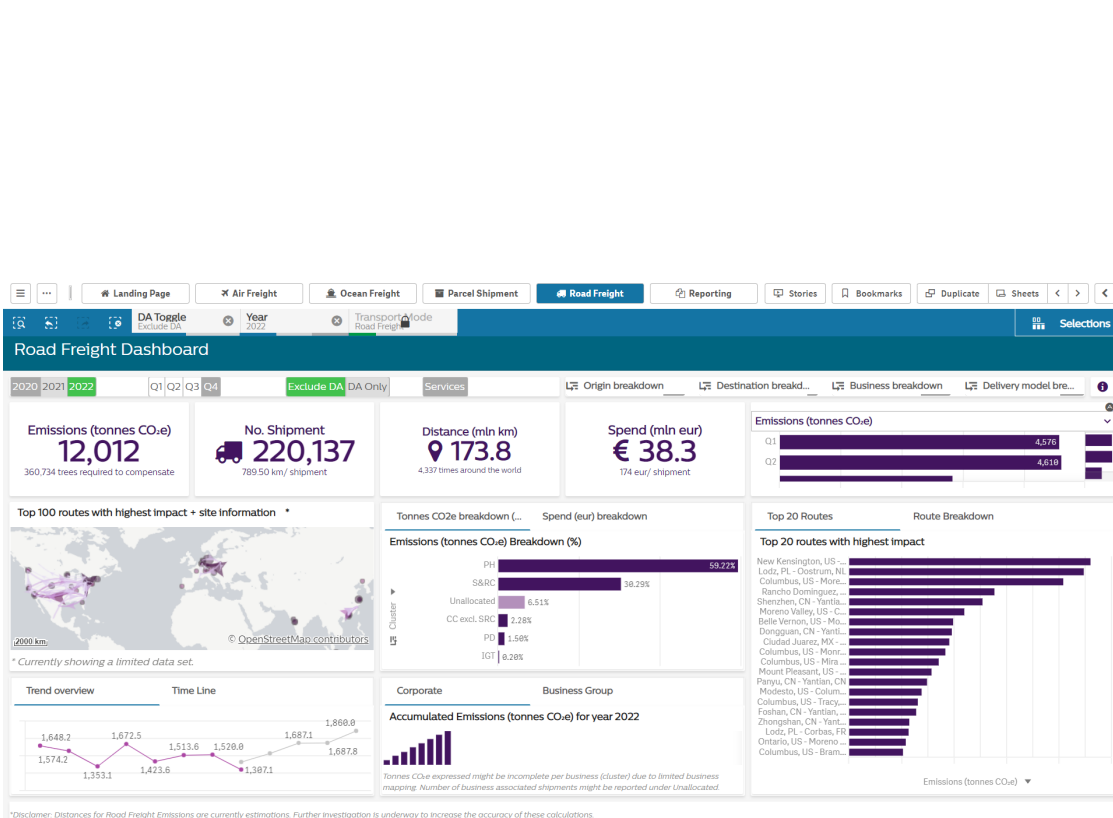
Figure 6.2: The road freight dashboard

7 Validation and Verification

Within this chapter we discuss the steps we took to validate and verify the dashboard. By validation we ensured the system meets the stakeholders' requests; this gave us a guarantee that the system has the ability to present specifications and limitations defined earlier. Furthermore, to check if the final deliverable was developed correctly, we also conducted several verification sections to justify the process. After going through validation and verification, we concluded that the dashboard is well-founded and satisfies Philips' needs.

7.1 Validation

Validation is "the assurance that a product, service, or system meets the needs of the customer and other identified stakeholders. It often involves acceptance and suitability with external customers [8]." With respect to the definition, we had to examine whether the dashboard meets the functional and non-functional requirements specified in Chapter 3.

We started with validating the functional requirements. Since the features and performance measurements were clearly defined in these requirements, the validation for them was easy and straightforward. The process was conducted in a bi-weekly demo session; within each session we first highlighted which new features were added, and demonstrated lively to the stakeholders in Group Sustainability. At the end of the demonstration, we would collect feedback from the audience and continue with discussion on whether the current implementation matched the expectation claimed. Each functional requirement was realized and validated one by one following the recurring procedure described.

In comparison with functional requirements, the fulfillment of non-functional requirements could not be verified directly. To validate user-related non-functional requirements, we held a review and feedback session with all stakeholders within Philips as participants after integrating the new system with the existing dashboard. The group was composed of about 20 participants, in which part of them belongs to Group Sustainability. The session lasted one week, and the group was allowed to manipulate the dashboard freely. We asked the members to provide feedback based on their experience with the system, and matched these feedback to the requirements to judge whether they were satisfied. After modifying the interface based on the feedback, we concluded the user-related non-functional requirements were validated.

Finally, to validate the design-related non-functional requirements, we invited our Qlik Sense architect and senior developer to review the process model. This was the last step of project validation, and we stated the dashboard was properly validated.

7.2 Verification

The definition of verification is "the evaluation of whether or not a product, service, or system complies with a regulation, requirement, specification, or imposed condition [8]." Within the project scope, one of the most significant limiting condition was specified in Section 2.3: the report is SOX compliant. To verify if the dashboard-generated report is SOX compliant, an inspection toward input and output data was required.

The verification was completed by auditing whether the data was distorted during our process. Considering the most important feature of the dashboard is presenting the total emission, we selected fields closely-related to emission calculation and finance-related fields for verification. The fields are a) number of shipments, b) chargeable weight, and c) shipment cost. We summed up the value in each selected field, and compared the results with the raw input data. With a five percent tolerance, which was suggested by the domain expert, we sent our report to Philips' auditing group and verified the dashboard as being SOX compliant.

8 Existing System Refinement

During the road freight dashboard development process, we were also investigating the problems within our operating dashboards. We discovered a series of improvement points and worked on refinement, as described in Section 4.2. This chapter presents the refinement process implemented.

8.1 Refining Process

The first step of refinement was integrating the data into fewer sources. Our data provider was able to provide road and ocean shipments, reducing our shipment data source to three parties rather than four. Next, we reviewed our reference data and combined information into files based on role played in the system and how data were utilized. For example, parameters related to system setting were grouped into a configuration file. This step solved the scattered reference data issue mentioned in Section 4.2. All the data integration steps were verified by following a similar process described in Section 7.2.

Next, we defined a set of naming conventions with clear explanation that acted as a new standard for the system. By following the instruction and definition given in this document, a novel user could easily understand the dashboard context without paying much effort. In addition, developers and auditors could also track down the calculation process and compare it to defined standards referring to the same table. We started with converting the outdated terms into new formats at the input's end to ensure the field names were fixed even before the cleaning and calculation starts.

After unifying the naming conventions, we then worked on merging duplicated calculations. We picked out the steps that were shared in common by each subsystem across different freight types and remove redundant copies, and guided the data to flow into a single pipeline. Although the total processing time remained the same, the structure complication was reduced and maintenance became much easier; it was no longer needed to perform repeated tasks whenever a change to the system was required.

The last step of refinement was proposing a new user interface. In the latest layout we emphasized the key elements such as total emission and freight weights, and reduced the size or removed the minor charts and tables. We expected the renovated design would allow the users to spot the most important and the most desirable information at first glance.

9   Conclusion

In the project "From Data to Insights to Drive Sustainable Change in Philips' Global Road Freight CO2e Emissions", we designed and implemented applications for calculating the road shipment emissions from Philips' logistics process. These applications acted as part of the logistics emission reporting system and were integrated together with existing applications for other modes of transport. The outcome of the project was validated and verified by different parties, and now working fluently on a daily basis.

Besides the road freight applications, the newly designed architecture was also used to reform other applications; specifically speaking, the structure of ocean freight applications were replaced and adapted to the most recent model. This action resolved the problems we discovered in the previous version, and improved the maintainability and modularity of our emission reporting system. The refinement was verified by the Philips' stakeholders, and looking forward to having the latest structure applied to all modes of transport.

As a conclusion, we recommend adapting the design we proposed in the report as new process for Philips' logistics emission reporting system. It defined a set of standard variables, removed redundant steps in earlier design, elevated the level of abstraction, and provided a highly-modularized scheme that was easy to extend and maintain. By following such a practice, the emission dashboard could be converted to a single-source, one-threaded system instead of the current multiple pipeline format which all applications were irrelevant.

Finally, we would also recommend integrating all data into one grand database for all purpose of use. The action not only benefits in guarding data privacy and safety, but also provides a chance to standardize the data format as well as improve the data quality.

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A   Stakeholder Analysis

This appendix describes the primary stakeholders for the project. The main stakeholders were from two different institutes, namely the Eindhoven University of Technology(TU/e) and Royal Philips N.V. The following sections present the analysis of stakeholders from both institutes separately.

A.1   Stakeholders within Royal Philips N.V.

The project drew a cross-department interest within Philips since multiple departments must be involved to attain the emission reduction goal. The main stakeholders of this project in Philips are listed below:

1. Philips Sustainability Group

2. Philips Integrated Supply Chain Group

3. Philips Integrated Warehouse Distribution Group

4. Philips Executive Board

5. Philips Business Group

6. Philips Marketing Group

The corresponding roles and interest of each stakeholders in the list above are described in Table A.1.

A.2   Stakeholders within TU/e

The EngD software technology program director, the project academic supervisor, and the project trainee are listed as individual stakeholders within TU/e in Table A.2.

Table A.1: The Royal Philips stakeholders

Stakeholder	Role	Interest in Project
Philips Sustainability Group	• Domain expert • Application evaluator • Application maintainer	• Automate emission report generation process • Generate precise emission report • Provide insight in how to reduce CO2e emissions of road shipments
Philips Integrated Supply Chain Group	• Application end user • Integrate shipment data owner	• Refine shipment process base on application analysis
Philips Integrated Warehouse Distribution Group	• Integrated shipment data provider	• Improve data collection process base on application requirements
Philips Executive Board	• Application end user	• Examine company CO2e emissions • Track road shipment CO2e emissions as well as plane and ship shipments • Design policies to reduce company CO2e emissions
Philips Business Group	• Application end user • Application evaluator	• Analyze CO2e emissions for different products • Develop environmentally friendly new products
Philips Marketing Group	• Application end user • Application evaluator	• Design marketing strategy and promotion idea base on emission reduction improvement

Table A.2: The TU/e stakeholders

Stakeholder	Role	Interest in Project
EngD Software Technology Program Director	• Trainee's EngD program director	• Quality of the project result • Success of the project • Future relationship with Royal Philips
Project Academic Supervisor	• Trainee's adviser	• Quality of the project result • Timeliness of the project • Academic ethic of the project result • Quality of the project report
Project Trainee	• Project developer • Project report author	• Graduation • Success of the project • Satisfaction of Royal Philips • Knowledge and experience gained throughout the project

About the Author

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