2022

Visualizing Transport Key Performance Indicators Using the Open Trip Model Data Messaging Format

BACHELOR INDUSTRIAL ENGINEERING & MANAGEMENT – THESIS

BHINAWA PUTRA RAJA

Visualizing Transport Key Performance Indicators Using the Open Trip Model Data Messaging Format

16-01-2023

Author:

Bhinawa Putra Raja

BSc Industrial Engineering and Management

University of Twente

Supervised by:

Sebastian Piest (University of Twente)

Amin Asadi (University of Twente)

In collaboration with:

Saumyajit Parida (Emons Group)

Kevin Lemmens (Emons Group)

Bjorn Goossens (Bullit Digital)

PREFACE

This bachelor thesis “Visualizing Transport Key Performance Indicators Using the Open Trip Model Data Messaging Format” is written as the final graduation project for the degree BSc Industrial Engineering and Management at the University of Twente. The research is done with colaboration with The Emons Group and Bullit Digital. The goal of the research is to explore a way to utilize transport data using the Open Trip Model.

I would like to thank Emons representatives Saumyajit Parida and Kevin Lemmens and Bjorn Goossens from Bullit Digital for their willingness to provide useful information, support, and feedback throughout the duration of the thesis. Being able to collaborate with individuals from the industry was an inspiring experience. I would also like to give special thanks to my supervisors Sebastian Piest and Amin Asadi for being patient and helpful by giving me guidance and assistance whenever needed.

I dedicate my work to my family and friends who have always provided me with unconditional love, support, and motivation throughout my bachelor’s degree.

Thank you,

Bhinawa Putra Raja

Enschede, January 2023

MANAGEMENT SUMMARY

This bachelor thesis is a collaboration between The Emons Group and Bullit Digital. Emons is a logistics company that collaborated with Bullit Digital in the development of Officedog.

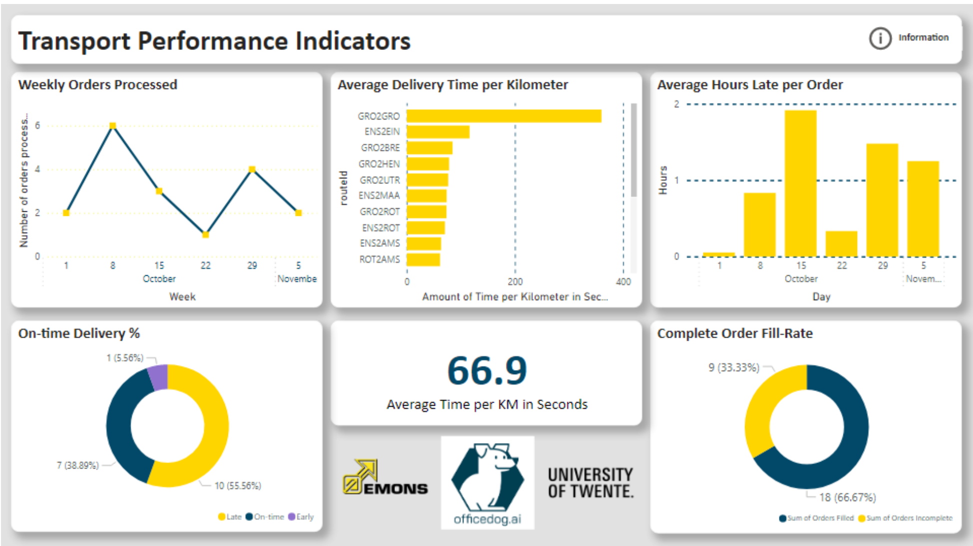
The idea of the thesis originated with the motivation to find ways of digitizing logistics operations. The Open Trip Model (OTM) is an open-source standardized data communication format that is used in the Officedog platform by Bullit Digital. Emons provides real-time data streams that are extracted from board computers installed in their trucks and is formatted in the OTM concepts in Officedog. The focus of the thesis is to find a way to utilize the data extracted from the board computers which are transformed into the OTM format.

We identify the core problem to be the lack of a tool that measures logistics performance using the data streams and unknown KPIs to measure using the extracted data from Emons. The outcome of this thesis delivers a tool that functions as an assistance for logistics decision making by showing the user general performance metrics of transport activity in form of KPIs.

The research process is done based on the Managerial Problem-Solving Method (MPSM) which involved 7 phases. It outlines the research to find out the problem, research methods, possible solutions, and evaluating solutions. The main research question of this research is: *How can Emons make use of real-time data streams to make logistical decisions?* This question is answered by formulating refined sub-questions that require literature study or experience surveys and solving the core problem. The answers provide insight on how the OTM can be used, what are the KPIs useful for measuring transport performance, how to prepare and model data, and how to build a dashboard with appropriate visuals.

A performance dashboard is developed in Microsoft Power BI that measures transport KPIs selected from findings in literature study and interview. The data is uploaded to Power BI using an Excel file provided by Officedog which uses the OTM format. Power Query Editor is used to model data in Power BI. KPIs from literature study are selected by conducting surveys and the Analytical Hierarchy Process (AHP). This research shows that Emons have a way to utilize their data streams via the OTM that is able to show their transport performance in form of relevant KPIs and Bullit Digital can implement the KPIs in Officedog to improve their overview dashboard functionality.

The dashboard measures 5 main KPIs: Weekly Orders Processed, Order Fill-Rate, Average Hours Late per Order, On-time Delivery %, and Average Delivery Time per Kilometer. The goal of the dashboard is to provide a general summary of transport performance and assist decision making in logistics operations management. The dashboard design was given an overall score of 3.7/5 (moderately high) judged by relevant stakeholders.



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LIST OF ABBREVIATIONS

IT	Information Technology
OTM	Open Trip Model
MPSM	Managerial Problem Solving Method
KPI	Key Performance Indicator
KQ	Knowledge Question
RQ	Research Question
API	Application Programming Interface
OTE	Overall Transport Effectiveness
AHP	Analytic Hierarchy Process
BSC	Balance Scorecard
QUIM	Quality in Use Integrated Management
MCDA	Multi-Criteria Decision Making Analysis
ERD	Entity Relationship Diagram
OTIF	On-Time in Full
BI	Business Intelligence

1. INTRODUCTION

Chapter 1 introduces the research to give background knowledge, problem context, research questions, and the approach. *Section 1.1* provides brief context of the companies that the research is collaborating with. *Section 1.2* provides early identification of the problem case in a structured manner. *Section 1.3* explains the problem-solving approach that is used for the rest of the research. *Section 1.4* provides a list of research questions that are answered in the research. *Section 1.5* describes the methods that are used to obtain answers for the research questions.

1.1 COMPANY CONTEXT

The Emons Group is a family-owned group of companies that was established in 1943. Emons serves the European logistics market and specializes in niche transport solutions such as transporting glass, double deck cargo trailers, and residual mushroom waste transport. The company has over 700 employees and is based in Milsbeek, The Netherlands. Emons strives to deliver added value to customers by means of logistics with an aim of reducing costs and being environmentally sustainable (emons.eu, 2022).

Bullit Digital is a Netherlands based company that develops Information Technology (IT) solutions such as apps, website, and web shops for businesses. They utilize IT innovations such big data and artificial intelligence (bullit.digital, 2020). Together with Emons, Bullit Digital developed the environment Officedog which is part of a collaboration research project ICCOS and ReAL.

1.2 DEFINING THE PROBLEM

1.2.1 PROBLEM CONTEXT BY INDUSTRY SURVEY

Transportation companies are constantly looking for ways to measure and improve their logistical performance. With more advanced digitization being integrated to operations and logistics, it is important for a company to keep up with new advancements to stay competitive. There are several components tied into a logistics operations and digitization can be implemented in multiple areas. Finding a way to incorporate this improvement should be explored in an increasingly digitized environment. According to a research study done by Evofenedex, shippers seem to be lagging behind the rest of the logistics sector in terms of digitization (Evofenedex, 2019). Hence, an improvement to this sector in terms if IT innovation could see the entire logistics industry move forward to a more digitally efficient function.

According to the industry survey by Evofenedex, most companies in the logistics industry acknowledges the importance of IT systems. So, the lack of IT implementation is not caused by the absence of awareness by logistics companies. Some of the major bottlenecks pointed out in the survey include: Setting up systems and training employees is time consuming, implementation causes problems, linking existing systems is complex, high costs (Evofenedex, 2019). Implementation issues and linking existing systems are issues that can be investigated to find a possible solution.

1.2.2 EMONS PROBLEM CASE AND OPEN TRIP MODEL

Emons as a transport company have access to real-time data gathered from board computers installed in their shipping transports. Currently, there is desire to increase utilization of this equipment and data. This specifically can be improved in terms of digitization. The low use of this rich source of data is caused by a lack of exposure to use cases of their existing board computers and its capabilities of gathering real-time data. Alongside providing a use case for their existing systems for collecting data, this research investigates ways to communicate this source of data into something that is generally more understandable and usable across different IT systems by using the Open Trip Model (OTM).

As mentioned in the industry survey, implementation issues are a big part of why the industry is held up in terms of digitization. The OTM is used in the research as a way to communicate flow of logistical data more efficiently. It does so by standardizing the data into a uniform format that can be easily interpreted and communicated across logistics IT systems. The aim of using OTM is to make implementation of IT systems simpler by having the same format of data communication across functions. Exploring the functionality of OTM is explored to correctly utilize real-time data.

1.2.3 PROBLEM CLUSTER AND CORE PROBLEM

Based on Emons' case regarding the low utilization of data from board computers installed in their transport, there is a clear desire to improve logistical performance. As the board computers collect event data, the measurement of transport performance of Emons' freight can be improved using them. This is set as the action problem that Emons are dealing with and the main outcome of the research.

Data that is gathered from these board computers need a way to translate itself and communicate the information in a way that can be easily analyzed and measured. Effectively, efficient decision making can be improved. This is currently lacking in terms of utilizing real-time data from transport's board computers due to the lack of extended understanding in the equipment installed in the transports. Alongside the general industry problem with regards to the complexity of implementing IT solutions, we explore the use of OTM to solve Emons and the industry's problem. The use of the OTM will be done in collaboration with Bullit Digital's Officedog platform. Since the understanding of OTM and the use of data from board computers is still at a perceived low level, there is a low utilization of the data collected. Measuring performance of Emons' transports requires knowing which types of data collected from the board computers can be used. The process also involves knowing what type of performance can be measured by the existing data collected. To solve the low utilization of data, there needs to be a way to process and use the data. This is investigated in the research.

In this research we develop a tool that can visualize transport information based on real-time data. The tool considers important Key Performance Indicators (KPI) that are measurable. Choosing the right KPIs to visualize in the tool dictates the effectiveness of the tool and therefore the use of real-time data. We establish the core problem to be: ***Lack of tool to view logistics performance based on real-time data.***

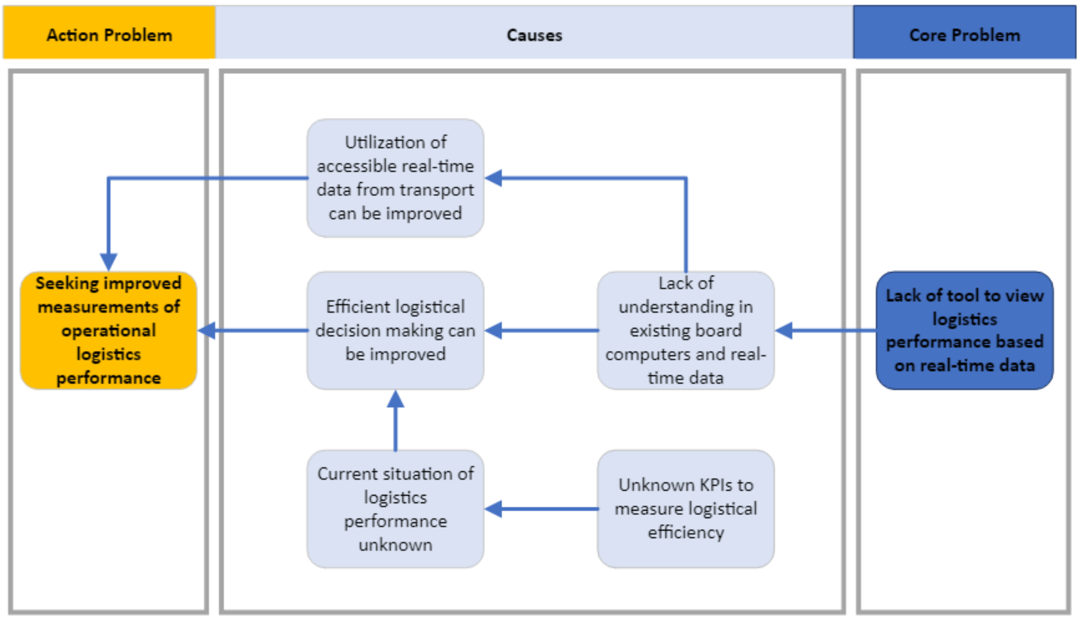


Figure 1 – Problem cluster

1.2.1 MEASUREMENT OF NORM AND REALITY

As described in the problem formulation, the current reality is that Emons utilizes the real-time data from the transports' board computers at a low level. Further details on what the current situation is will be investigated by research.

The norm can be expressed in research goals and what is intended to be delivered by the end of the research. Currently, the norm has no clear measurability factor. This can be solved by use of variables and indicators. From the core problem "lack of tool to view logistics performance based on real-time data", we can derive "lack of tool" as the variable. Though, the discrepancy between the reality (lack of) and norm (there is) can be expressed in further detail using indicators. The indicators to express the variables are:

- **Transport performance visualized in the tool**
  Based on the information gathered from real-time data, Emons should be able to measure their transport performance using the tool. Accurate information that depicts multiple transport's performance should be communicated through the tool via relevant KPIs.
- **Interpretability of the visualized data**
  The tool should be clear in the way it communicates real-time data. This is done using relevant graphs, charts, and tables. Clear motivation of the use of each visualization of data will support the reason of including them in the tool.
- **Usability of the tool**
  Navigating through the tool should be accessible and easy. The integration of data and OTM should be indicated in the tool.

1.3 PROBLEM SOLVING APPROACH

The problem-solving approach involves activities that take place in phase 2 of the Managerial Problem-Solving Method. This section describes the methodology of approach for the overall research and key points (research goals).

1.3.1 MPSM APPROACH

The Managerial Problem-Solving Method (MPSM) is a systematic problem-solving approach that consists of 7 phases (Heerkens, 2017). This method will be used over the course of the research sequentially through each phase. The 7 phases are defined and the corresponding research contents are as the following:

1. **Defining the problem**
   The problem is first identified by looking through the industry survey by Evofenedex and the case presented by Emons and Officedog. As the context is analyzed, defining the problem clearly is done by the problem cluster approach. By this approach we are able to identify the action problem and core problem. This process mainly comes from a cause-effect analysis that can set an early idea of the research approach.
2. **Formulating the approach**
   After the problem is identified clearly, the approach is drafted. The problem-solving approach is used to describe the activities and knowledge required (Heerkens, 2017). Key points of the research are set to guide the research process alongside the MPSM process.
3. **Analyzing the problem**
   Analyzing the problem includes looking back at the problem identification process and looking for potential new causes and missing details (Heerkens, 2017). Any knowledge problems that arise to

gather more information are investigated. This process aims to deeper the understanding of the problem-solving approach.

4. **Formulating (alternative) solutions**
   After gathering information and knowledge from knowledge problems and research questions, the formulation of the deliverable will take place. In this case, the tool will be developed based on criteria and decision-making processes determined during the previous phase. Any alternative solutions such as KPIs that are not used in the tool after some filtering process of choosing KPIs may be considered to formulate an alternative solution.
5. **Choosing the solution**
   After analyzing the developed tool and its effective use based on existing data available to use for testing, a final set of KPIs will be used in the tool.
6. **Implementing the solution**
   After the tool in finalized and is functional, the process of measuring transport performance is performed.
7. **Evaluating the solution**
   The functionality and effectiveness of the tool are analyzed based on preliminary research of what declares the visual measurement of KPIs effective. The validity of the solution runs into possible limitations as the implementation of the tool to Emons' real-time operations is hindered by time constraints.

1.3.2 KEY POINTS OF THE RESEARCH

Understanding OTM and application

In order to effectively use the Open Trip Model to communicate real-time data, we need to have a deeper understanding of its functionality and how to use it. We will conduct a study on the use of OTM to make sure the implementation process with regards to the tool is done correctly. This part of the research corresponds to *phase 2 of the MPSM* as we want to use OTM as an approach to solve the problem in a general industry point of view as well as developing the tool for Emons' case.

Assess current situation of data use in Emons

To improve the current situation of Emons' efficiency when using available data, we need to know what the current reality of the situation is. Being part of *phase 3 of the MPSM*, we analyze the problem in the context of Emons' case. When the current use of the data is identified, we will conduct research on how to add or improve the use of available real-time data.

Literature study on choosing effective KPIs

KPIs need to be chosen carefully when the goal is to measure and improve logistical performance. We will investigate what are the current KPIs that Emons are tracking and conduct literature study on what KPIs are suitable to measure logistics and supply chain efficiency. KPIs will also be chosen based on the limitations of the data that is available to us from the Emons data set.

Intended deliverables

When developing the tool, knowledge gathered from *phase 3 of the MPSM* will be implemented. This includes elements such as: KPI selection, OTM implementation, data-set filtering, visual diagram choices. Such elements are chosen for phase 4 of the MPSM: Formulating solutions. We then establish them as a solution in phase 5:

Choosing a solution. After it is clear which elements of the tool are to be integrated, phase 6 of the MPSM takes place as we implement the formulated solutions.

By the end of the research, a tool that visualizes real-time data streams using OTM will be functional. The tool will go through testing and any possible alternatives solutions are considered. Subsequently, this corresponds to phase 7 of the MPSM: Analyzing the solution. This tool, in form of a performance dashboard, gathers and communicates data in form of KPIs that is visualized clearly in order to help with efficient decision making for Emons' supply chain. The KPIs shown in the tool will be based on literature search as well as some managerial input from Emons.

Phase 4 of the MPSM also involves formulating alternatives solutions, hence we will also test the functionality of the tool (in phase 7 of the MPSM) to see if some things can be improved or if any issues arise. Should any points of improvement exist, we cycle back to phase 3 of the MPSM in order to analyze the issues and to find potential solutions. These findings would later be an alternative solution of phase 4.

As a general deliverable in the interest of the transport industry, we explore the usability of OTM and the possibility of its implementation across different functions. Any findings in terms of feasibility of OTM or its limitations with implementation will be noted.

1.4 RESEARCH QUESTIONS AND KNOWLEDGE PROBLEMS

As part 3 of the MPSM, we analyze the problems and identify what information and knowledge is required to solve the problem. These will be expressed in terms of research questions and knowledge problems. As we aim to solve Emons' case as well as provide a general finding for the industry regarding the implementation of OTM as an IT solution, we investigate questions that concerns each of the two parts.

1.4.1 EMONS CASE RELATED RESEARCH QUESTIONS

Main research question: How can Emons make use of real-time data streams to make logistical decisions?

The main goal of this research is to find a way to utilize real-time data for logistics decision making. Logistics decision making can start by observing trends and patterns throughout daily operations. For example, there is an observed trend of deliveries being late from Enschede to Amsterdam. The delay is then identified to be caused by the high number of roundabouts on that delivery route. Decision can be made to alter the route of this delivery.

Research (sub)question 1: Which types of data in the dataset are useful to measure transport performance?

The data gathered from board computers installed in Emons' trucks contain a lot of different information. Gathering this type of data would be too extensive to be monitored manually. The trucks can provide multiple kinds of data for every event that they execute. Filtering big data into information that are useful for visualizing the KPIs take place. A clear method of choosing which data to use is investigated.

Research (sub)question 2: What is the current use of the available data in relation to measuring logistics performance?

We observe what the current state of Emons is, regarding what they do with the available data. This makes improvement of the current reality possible and to have a clear norm. We identify what KPIs are being measured, what data infrastructure is in place, and what kind of decisions are made effectively.

Research (sub)question 3: What is the aim of the use of real-time data in relation to measuring logistics performance?

With the fully functional tool, we clearly establish how it can be useful to help with decision making in a logistics point of view. This includes a clear motivation for the choice of KPIs and visual diagrams.

1.4.2 OTM AND KNOWLEDGE PROBLEM QUESTIONS

Knowledge problem 1: What is the Open Trip Model (OTM) and what are its possible applications and limitations?

Since we are using the OTM to communicate the data generated, it is important that we fully understand the concept of OTM and how to use it. This knowledge is used directly when developing the data visualization tool. The application of OTM is also of interest as a general IT solution for the transport industry. Exploring the possibility and limitations of OTM application in different scenarios are also done.

Knowledge problem 2: How can measurement of transport operations performance be evaluated?

As the action problem is to improve and measure operational logistical performance, we investigate what exactly correlates efficient transport operations with the real-time data that is available to us. To correctly address what measures to use for evaluating performance, we establish indicators for evaluation.

Knowledge problem 3: What Key Performance Indicators (KPIs) are used to assess transport performance and how do we select which KPIs to use?

Based on theory and literature search, we look for suitable KPIs to use in order to express transport performance based on the data that we are able to gather. Then we investigate a way to pick out which KPIs to use by using a structured methodology.

Knowledge problem 4: How can KPIs be visualized in a tool that measures transport performance?

Visualizing data can be performed in many ways. Here we investigate the different forms of diagrams such as graphs and charts to understand how they can effectively express the KPIs that we have chosen.

1.5 RESEARCH DESIGN

1.5.1 TYPE OF RESEARCH

An exploratory study is conducted when answering research questions and knowledge problems. Exploration investigates areas that are new or vague to the researcher. It is also applicable when the researcher lacks a clear idea of the problems that may arise during the study. More insight and knowledge are gained when conducting an exploratory study. When conducting an exploratory study, qualitative techniques are mainly used (Cooper & Schindler, 2014). Two main techniques are used in our research: Secondary data analysis and experience surveys.

Secondary data analysis refers to the process of searching within secondary literature. Secondary literature are studies made by others for their own purposes. Data from secondary sources help decide what needs to be done and can be a rich source of hypotheses. It can also help with identifying which methodologies are successful or not. Use of primary data or original research, however, can be inefficient for decision making

(Cooper & Schindler, 2014). This method is used when seeking more knowledge or insight on certain topics that arise during the MPSM.

Experience surveys take place when people are interviewed about their ideas on important issues or subjects (Cooper & Schindler, 2014). This method is used to gain more insights on how Emons currently function and what their expectations are, especially regarding their use of data. Short interviews take place to investigate research questions that require descriptive and qualitative information.

1.5.2 RESEARCH SUBJECTS AND STAKEHOLDERS

The subjects of research mainly consist of data gathering methods, KPI selection, Data and KPI visualization, and dashboard modelling.

The stakeholders of this research consist of the researcher, research supervisors, Emons, and Bullit Digital.

1.5.3 DATA GATHERING METHOD

Secondary data analysis is done using databases for peer reviewed articles. The literature study gather data and knowledge from articles obtained from Scopus, Google Scholar, Web of Science, and past thesis papers from the University of Twente (UT) repository.

Experience surveys are done by presenting questions and/or discussions with Emons or Bullit Digital representatives.

Data gathering method for each research questions are indicated in *Table 1*.

Question	**Research type**	**Data gathering method**
How can Emons make use of real-time data streams to make logistical decisions?	Exploratory, qualitative	Main research question, literature study, surveys
How can performance in transport operations measurements be evaluated?	Exploratory, qualitative	Literature study
What is the Open Trip Model (OTM) and what are its possible applications and limitations?	Exploratory, qualitative	Literature study
Which types of data in the dataset are useful to measure transport performance?	Exploratory, qualitative	Literature study
What Key Performance Indicators (KPIs) are used to assess transport performance and how do we select which KPIs to use?	Exploratory, qualitative	Literature study
How can KPIs be visualized in a tool that measures transport performance?	Exploratory, qualitative	Literature study
What is the current use of the available data in relation to measuring logistics performance?	Descriptive, quantitative	Interview (experience surveys)

What is the aim of the use of real-time data in relation to measuring logistics performance?	Descriptive, qualitative	Interview (experience surveys)

Table 1 – Research questions, types, and methods

1.5.4 LIMITATIONS OF RESEARCH DESIGN

Limit of application to different functions

The development of the tool involves considerations taken from the approach of using the OTM. The goal of using OTM is to create a uniform format of processing data for it to function across different IT systems. The data processing method and tool use, however, may not be feasible to be applied in different functions of other organizations' IT systems. Format of data used by Emons and Bullit Digital that is used in this research could differ, therefore findings that are obtained from this research's case may not be directly applied to general IT system use.

The measurement of performance is based on Emons' and Bullit Digital's interests as well as limitations of the complexity of the research. Measuring performance of logistics operations could take form in many KPIs. Adding to KPIs found in literature study, the research explores the research stakeholders' interests directly on what KPIs they would like to see measured. The KPIs implemented in the tool is also limited to the type of data available. KPIs found from literature study that cannot be measured due to missing data types are not used. KPIs chosen in this research may also not be applicable to different organizations due to the potential differences of data types across different IT systems. Therefore, direct application of the research findings to general IT systems is not guaranteed.

Limit of time constraint

The research is limited to feasibility of obtaining results and delivering the desired deliverables within a time constraint of 10 weeks. Allocation of time is mostly spent on the development of the tool rather than the application of the tool itself. The main deliverable is a functioning tool that measures transport performance. The measurement of performance would preferably require an application of the tool to a real situation within Emons' logistics operations, but limited time available to make this possible was not guaranteed.

Complexity of the research findings and applying them to the development of the tool are tailored to the limited time constraint. The processing of data is based on the complexity of using certain types of data. Therefore, the KPIs chosen also depend on the complexity of the task. The process of developing the tool is kept at a moderate complexity level to ensure the research is complete and delivered on time.

1.5.5 VALIDITY AND RELIABILITY

A measurement tool is effective when the tool is an accurate indicator of what we are interested in measuring. When we evaluate the effectiveness of the tool, we consider the validity and reliability (Cooper & Schindler, 2014).

Validity is the extent to which a test measures what we want to measure. There are 2 major types of validity: external and internal. External validity is the research finding's ability to be generalized across persons, settings, and times. Internal validity refers to the ability of the research tool to measure what its intended to (Cooper & Schindler, 2014). External validity concerns of the functionality of the tool as well as OTM implementation is explored in the study of OTM concepts (KQ2). The extent of external validity is limited to time constraint due to the complexity of the issue. Internal validity of the tool is checked by multiple testing to see if any inaccurate measurements are evident. Measurements of KPIs in the tool is also analyzed whether they are showing correct and meaningful data. This is done in parallel to the development of the tool by continuously improving the tool.

Reliability is the ability of the measurement tool to supply consistent results (Cooper & Schindler, 2014). As we analyze multiple testing of the measurement tool with sets of data, reliability can be assured if the performance indicators are free of any random errors. This means the tool should be functional with regards to any change of conditions that is not in direct effect of the data set. Multiple testing of the tool help identify the reliability level.

2. THEORETICAL PERSPECTIVE AND PRIOR KNOWLEDGE DISCOVERY

In this section, each knowledge problem is addressed before proceeding to solution formulation. Answering knowledge problems correlate to *MPSM phase 3: Analyzing the problem*. *Section 2.1* describes the Open Trip Model basics, *Section 2.2* describes how to evaluate the measurement of transport performance, *Section 2.3* explores KPIs related to logistical and transport performance and the selection framework, *Section 2.4* identifies ways to visualize KPIs in form of a dashboard.

2.1 THE OPEN TRIP MODEL – KQ1

The Open Trip Model (OTM) is a simple, open-source, and easy-to-use data model that can be used to exchange real-time logistic trip data which provides a standardized digital vocabulary to describe and exchange information before, during, and after transport operations (OpenTripModel, 2022).

2.1.1 IMPORTANT CONCEPTS

Since transport is organized in a variety of ways within supply chains due to different business requirements and regulations, OTM was created with some design goals. These design goals include: The model is independent of how transport within a supply chain is organized, the model is independent of modality or transport type, the data is human and machine readable, the model is extensible (OpenTripModel, 2022).

OTM is built upon the concept of lifecycles. The lifecycle provides a context to the phase of an operation. It provides a description whether a certain data is “planned”, “projected”, “actual”, or “realized” events. These are the 4 default phases in OTM, but can be expanded if needed (OpenTripModel, 2022). The 4 phases are described as follows:

Lifecycle phase	**Description**
“planned”	The “planned” phase is pre-trip. Events in this phase are planned events. A planning of a logistic operation can be modeled as a series of “planned” events.
“projected”	The “projected” phase models projected (estimated) times. Given a series of “planned” events and associated “actual” events, “projected” events can be calculated.
“actual”	The “actual” phase is on-trip. This phase models the reality that is happening at real-time. Actual events usually originate from tracking devices or traffic information systems.
“realized”	The “realized” phase is post-trip. This phase can be used to view and analyze logistics operations. Events in this phase are recorded and archived events from the “actual” phase.

Table 2 – Lifecyle phases and their descriptions in OTM (OpenTripModel, 2022)

Different types of information are needed by each actor within a supply chain. However, there are a few information which are shared. OTM aims to describe and communicate this shared information. This information is called entities. The following entities are base entities which are abstract but can be more concrete with added metadata and references (OpenTripModel, 2022).

Type of information (Entities)	Description and examples
Location	A location entity models any sort of location. It can refer to an address and a geographical point or area. Ex: store, warehouse, consumer, buffer zone, loading spots, environmental zones.
Vehicle	A vehicle entity models any means which someone travels or something is carried or conveyed. Vehicles can be coupled, thus a combination of a truck and a trailer are modeled as two coupled vehicles. Ex: truck, trailer, train, airplane.
Route	A route entity describes how a vehicle geographically moves between two points.
Trip	A trip entity models the concept that goods will be transported between two or more locations. A trip may be linked to a route.
Shipment	A shipment entity models an arbitrary amount of good that are transported.
Actor	An actor entity represents organizations or persons that participate in a logistics process in OTM. Ex: person who receives a parcel, store that receives a truck full of goods.
Events	All dynamic behavior is modeled as event(s). Events describe a state change on an entity. For example: “startMovingEvent” is an event used to indicate a vehicle entity from standstill to moving state. Ex: “startLoading”, “startUnloading”, “coupleVehicle”.

Table 3 – Entities and their descriptions implemented in OTM (OpenTripModel, 2022)

Every entity exist in all lifecycle phases. Once an entity is defined in a lifecycle phase, it exists in all lifecycle phases with the same properties. Events differ between lifecycles as an event happens in one lifecycle phase. However, events can be related between different lifecycle phases (OpenTripModel, 2022).

OTM provides the ability to communicate physical location and routes. This is done using a method of describing location by geospatial information system known as “location referencing”. There are 3 types of location reference methods commonly used that are supported in OTM: absolute positioning, linear referencing, dynamic location referencing. Location referencing provides live traffic information to a transport navigation device (OpenTripModel, 2022).

2.1.2 OTM IMPLEMENTATIONS AND LIMITATIONS

OTM was developed by Simacan in order to initiate innovation in the market. It is a product of collaborative work between Albert Heijn and its transport service providers. OTM is used to exchance real-time logistic trip data on the web, making it easier for shippers, carriers, software vendors, and truck manufacturers to create a multi-brand application and services. As of now, OTM is widely used and implemented by multiple logistics service providers, shippers, and IT suppliers for different cases (OpenTripModel, 2022).

However, the OTM only considers the message format of data. It is built to make communication between logistics systems easier by creating a standard format but does not necessarily cover the data exchange process. The data exchange process includes variables such as the passing of information regarding what data has been changed. There are also no mechanism to fetch lists of data, which means that that even though two systems may have implemented the OTM, the connection between systems may not be straight forward.

In this research, the solution generation does not involve building a tool from scratch using OTM. Instead, an OTM Application Programming Interface (API) by Bullit Digital called Officedog will be used to develop a visualization dashboard. Therefore, the extent of the use of OTM is limited to the parameters set by the Officedog interface. The exploration of the possible use of OTM for improving transport measurement is an extension of the Officedog API and its functionalities.

2.2 MEASURING TRANSPORT PERFORMANCE MEASUREMENTS – KQ2

Before selecting KPIs for assessing transport performance, we need a set of indicators to refer to. The indicators provide a means to measure which KPIs are fit for our research goal. As the research aims to measure transport performance, we take on the Overall Transport Effectiveness (OTE) framework by Iankoulova (2012). The OTE framework is a hierarchy of metrics which evaluates how effectively transportation vehicles are utilized and how transportation tasks are executed compared to planning (Iankoulova, 2012). The framework definition fits the aim of our research in order to implement the framework into our KPI selection process.

OTE uses The Auditor General of Canada approach when applying design criteria for measurement systems (Franceschini et al., 2007). The measurements within the proposed framework are designed in such a way that they satisfy three broad criteria - meaningful, reliable, and practical (Iankoulova, 2012). Iankoulova uses the three criteria approach when designing the OTE framework. The criteria are also used when validating the measurements with stakeholders. The overview of the criteria is described in table n.

Criteria		**Description**
Meaningful	Understandable	The measure is clearly and consistently defined, well explained, measurable, with no ambiguity.
	Relevant	The measure relates to the objectives, is significant and useful to the users, and attributable to activities.
	Comparable	The measure allows comparison over time or with other organizations, activities or standards.
Reliable		The measure accurately represents what is being measured (valid, free from bias); the data required can be replicated (verifiable); data and analysis are free from error; not susceptible to manipulation; and balances (complements) other measurements.
Practical		The implementation of the measure is feasible financially, and timely data is available.

Table 4 – The Auditor General of Canada criteria for performance measures (Iankoulova, 2012)

Iankoulova suggests that the “Relevant” criterion is the most valuable, where the criterion is described to be the degree to which the “measure relates to the to the objectiives, is significant and useful to the users, and attributable to activities” (Franceschini et al., 2007). The value of each criterion are later evaluated and implemented in the KPI selection process.

2.3 KPI IDENTIFICATION AND SELECTION FOR TRANSPORT PERFORMANCE – KQ3

In *Section 2.3.1* the KPIs related to measuring logistics and transport performance are identified, then the selection process is based on the AHP framework described in *Section 2.3.2*.

2.3.1 KPI IDENTIFICATION BASED ON LITERATURE

KPI selection for measuring performance in the tool is based on literature review and experience surveys. The literature review take on a more general interest while the experience survey takes interests of Emons and

Bullit Digital representatives. The literature review is based on article findings by means of Systematic Literature Review in *Appendix A*.

As shown in *Figure 2*, metrics used to measure supply chain performance is divided into 3 groups of sustainability: social, economic, environmental. Under each of the 3 groups, KPIs measure different aspects of each metric. A list of individual metrics is used in an online survey and respondents were asked to provide information (positive or negative) about certain dimensions and sub-dimensions. Majority of the participants have roles in the logistics services sector and possess a managerial position in the company (Piotrowicz & Cuthberson, 2012).

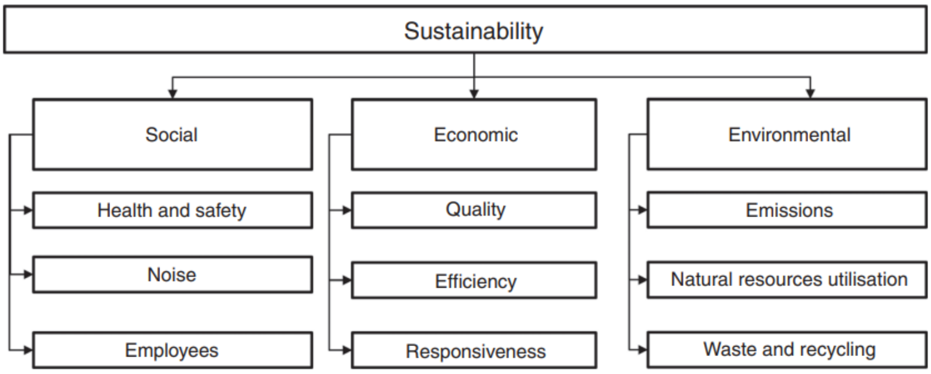


Figure 2 – Metrics dimensions and sub-dimensions (Piotrowicz & Cuthberson, 2012)

Of each sub-dimension, based on the respondents of the online survey, important KPIs to measure supply chain performance are identified in *Table 5*.

Social	**Economic**	**Environmental**
Health and safety: • Number of accidents (employees) • Work condition • Number of accidents (non-employees)	Quality: • On-time delivery • Customer satisfaction • Order fill rate • Product/service availability	Emissions: • Level of CO2 emission • Level of CO2 emission from transport processes • Level of CO2 emission from infrastructure
Noise: • Noise volume • Time of noise emission • Noise emission in urban areas	Efficiency: • Distribution costs • Total costs • Transport costs • Loading capacity utilization	Natural resources utilization: • Energy use • Water consumption • Energy consumption • Energy consumption per revenue
Employees: • Employees skills • Employees satisfaction • Percent of labor cost spent on training	Responsiveness: • Stock-outs • Product lateness • Lead time • Forecast accuracy	Waste and recycling: • Level of waste • Level of products recycled • Level of products reused

Table 5 – Important social, economic, environmental KPIs based on a survey (Piotrowicz & Cuthberson, 2012)

It is worth noting that based on the number of answers of the survey, the usage of social and environmental KPIs was lower compared to economic metrics (Piotrowicz & Cuthberson, 2012). There is an evident priority in measuring economic and business-related performance with regards to supply chain. Other metrics can still be deemed useful depending on the company's interest. However, not all the KPIs in the scope of supply chain can be directly applied to transport performance. It is important to keep this in mind in the KPI selection process.

Many companies use the Balanced Scorecard (BSC) method to analyze effectiveness and regulate activity. Although, its application to logistics is not adequate as the method was formed to evaluate a company's value using non-monetary indicators with traditional financial indicators. Therefore, an adaptation of the BSC in terms of logistical activities can be expressed by a complex of KPIs (Lukinskiy et al., 2013).

By analysis of contemporary logistics sources, there is not a universal viewpoint of a composition of KPIs that measure logistics activity effectiveness. But to sum up different approaches, KPIs that generally evaluate efficiency and effectiveness of logistics should include: total logistical costs, quality of logistical service, logistical cycles duration, productive capacity, return on investments in logistical infrastructure. This then narrows down to logistics specific indicators that are separated into effectiveness indicators and performance indicators (Lukinskiy et al., 2013). This is outlined in *Figure 3*. However, the scope of this perspective is too broad for our research.

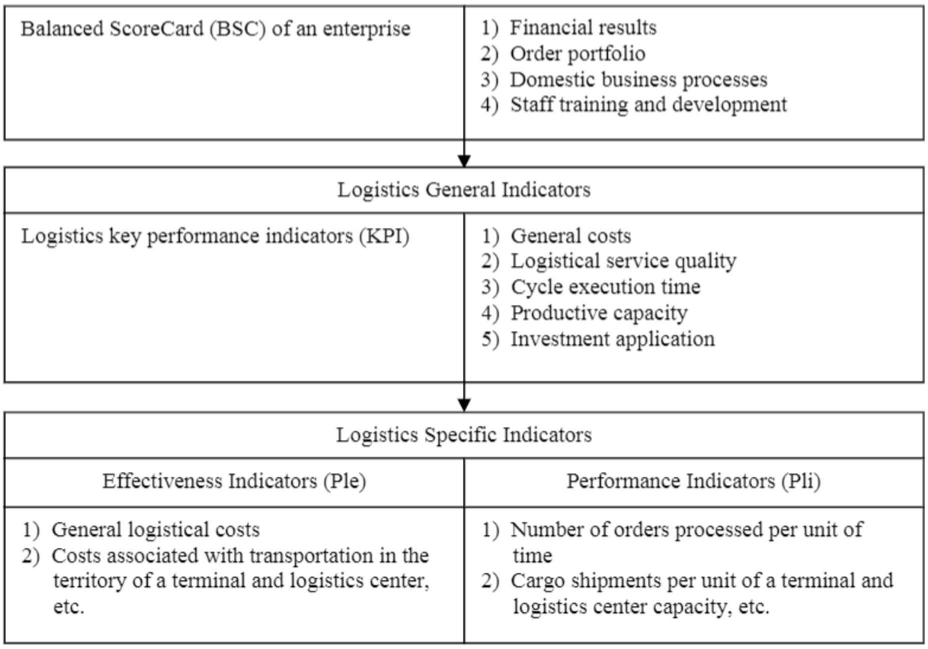


Figure 3 – Hierarchy of a company's logistical activity indicators (Lukinskiy et al., 2013)

A literature study that reviewed 57 peer-reviewed articles in a scientific journal called "Supply chain resilience and key performance indicators: A systematic literature review" identifies 10 non-financial KPIs that might be of interest in assessing supply chain performance (Karl, et al., 2018). The findings are listed in *Figure 4*.

Non-financial KPIs	Gunasekaran et al. (2001)	Chan (2003)	Gunasekaran et al. (2004)	Conceição & Quintão (2004)	Aragão et al. (2004)	Sellitto & Mendes (2006)	Huang & Keskar (2007)	Bhagwat & Sharma (2007)	Chae (2009)	Cai et al. (2009)	Ganga et al. (2011)	Cho et al. (2012)	Carvalho et al. (2012)	Sacomano Neto & Pires (2012)	Cedillo-Campos et al. (2014)	Avelar-Sosa et al. (2014)	Bai & Sarkis (2014)	Chelariu et al. (2014)	Gunasekaran et al. (2015)	Sjøbakk et al. (2015)	Anand & Grover (2015)	De Felice & Petrillo (2015)	Morini et al. (2015)	Katiyar et al. (2015)
Capacity utilization	✓		✓					✓				✓										✓		✓
Stock level	✓	✓						✓											✓	✓				
Quality of delivered goods	✓		✓	✓							✓	✓				✓				✓				✓
Order Lead Time	✓	✓	✓		✓			✓		✓		✓	✓	✓	✓					✓	✓	✓	✓	✓
Delivery Lead Time	✓		✓					✓				✓		✓										✓
On-time delivery of goods			✓	✓	✓	✓				✓						✓		✓						✓
Supplier delivery efficiency		✓	✓				✓		✓			✓					✓	✓						
Supplier rejection rate		✓					✓										✓							
Consumer Satisfaction		✓		✓	✓	✓				✓		✓		✓		✓		✓	✓			✓		✓
Damage return rate		✓																						✓

Figure 4 – Non-financial KPIs from a supply chain perspective (Karl, et al. 2018)

A research by Iankoulova (2012) conducted a study on cooperation between logistics companies, for reducing empty kilometers. In the study, the author identifies KPIs commonly used in logistics companies with a focus on transportation activities. The findings of the research are described in the following.

According to results of a survey, with 71 transportation companies participating, conducted by the National Private Truck Council in the USA (2004), a set of KPIs were indicated as important for performance measurement. These KPIs measure: percent of on-time delivery (83.9%), percent of empty kilometers (26.6), annual driver turnover rates (11%), average miles per gallon (6.1%) (Petty, 2005).

Common logistics KPIs that focus on transport activities are identified by Griffis et al. (2007). The KPIs are listed in *Figure 5*.

1. On-Time Delivery Percentage
2. Days Order Late
3. Complete Order Fill Rate
4. Items Picked per Person per Hour
5. Average Line Item Fill Rate
6. Weeks of Supply
7. Percent of empty kilometers
8. Annual driver turnover rates
9. Average miles per gallon
10. Cost per kilometer
11. Average Backorder Fill Time
12. Percent Error Pick Rate
13. Perfect Order measurement

Figure 5 – List of sample logistics KPIs with focus on transport activities (Griffis, S.E., et al., 2007)

Identifying supply chain performance KPIs in a broad sense will produce an excessive number of indicators. To narrow down the selection of KPIs, it is wise to specifically focus on measurements of transport related activities in the supply chain, as it is our focal point in the research as described in the problem context and definition. Therefore, a selection process take place to dictate which KPIs are included in the tool.

2.3.2 KPI SELECTION USING AHP PROCESS

According to Parmenter (2015), there are often confusions between indicators are misuse of them for their measurements. Parmenter describes KPIs as non-financial indicators that evaluates how well the overall process is performing, corresponds to critical success factors, and indicates what actions can improve the performance drastically. These KPIs are kept to a number up to 10 measures and at a frequency of the hour, day, and weeks (Parmenter, 2015). From the previous identified KPIs that measure logistics and supply chain KPIs, we choose to measure a maximum of 10 non-financial KPIs in the scope of transport activities. Narrowing down the scope of logistics into transport activities is a choice made due to limitations of time constraint, complexity, and data availability.

The final KPI selection is done using the Multi-criteria Decision Making Analysis (MCDA), which is the theory of the use of computational methods that incorporate several criteria and order of preference in evaluating and selecting the best option among many alternatives based on the desired outcome (Ozsahin et al, 2021). Methods of MCDA involve a process of determining criteria, weighting them, scoring KPIs based on the weighted criteria, and determine final KPIs based on their overall scores (Ambergen, 2021). The MCDA method used in this research is the Analytic Hierarchy Process (AHP). AHP was developed by Thomas L. Saaty and is based on mathematics and psychology. Instead of recommending the best alternative, AHP encourages decision makers to find a solution that better suits their goal and perception of the problem (Ozsahin et al, 2021). Since this research is limited to the existing data collected in the dataset as well as a 10-week time constraint, alternative solutions are too complex for the scope of the current research. The AHP is suitable as we aim to find KPIs based on the given data already available and the goal of the research.

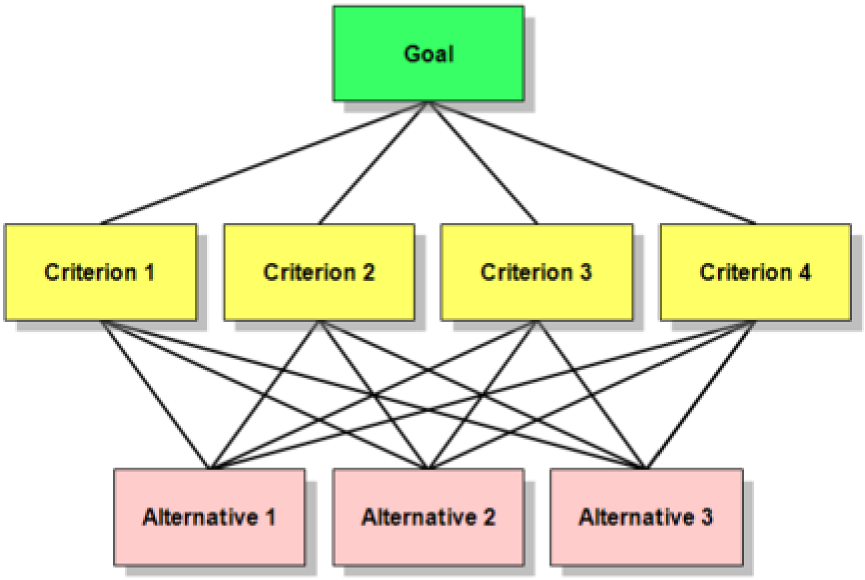


Figure 6 – Simple AHP hierarchy

The hierarchy structure of AHP is shown in *Figure 6.* The top of the hierarchy is the objective, the second level are how the 4 criteria contribute to the objective, the third level are how each of the alternatives contribute to each criterion.

The AHP method is generally implemented in four following stages described by Podgórski (2015):

1. Decomposition of a decision problem and a construction of a hierarchical model of criteria and decision variants affecting the solution of the problem.
2. Pairwise comparison of the criteria and generating the vector of weights for individual criteria.

3. Pairwise comparison of decision variants in relation to individual criteria and generating the local weight vectors for those variants in relation to those criteria.
4. Determination of the vector of global preference of decision variants, arranged in relation to the contribution of variants in achieving the objective of the ultimate decision problem.

The pairwise comparison of criteria is done by a numeric scale from 1-9 which are explained in the *table n* below. When comparing, whole numbers above 1 means the criterion is of more importance, while fractions are reciprocals of the whole numbers and mean they are less important.

Value	Description
1	Equal
2	Between equal and moderate
3	Moderate
4	Between moderate and strong
5	Strong
6	Between strong and very strong
7	Very strong
8	Between very strong and extreme
9	Extreme

Table 6 – Pairwise rating scale for AHP comparison (Ambergen, 2021)

A mathematical process based on pairwise comparison of criteria is done in the KPI selection process. The comparison process is used to create weights for the criteria. The consistency of the weights of the criteria are evaluated and accepted within a 10% confidence ratio. Then scores of each KPI based on every criterion are weighed to give an aggregate score. The criteria are based on the theoretical framework of *Section 2.2.*

2.4 KPI VISUALIZATION FOR DASHBOARD IMPLEMENTATION – KQ4

Dashboards are visual representations of data that can be in form of graphical visualizations as well as textual visualization. Humans are generally better in interpreting graphical visualization than textual (Few, 2006). This section investigates the approach to dashboard building and the various ways to interpret data (KPIs) to communicate its measurements efficiently.

2.4.1 SYSTEMATIC DASHBOARD BUILDING APPROACH

To visualize data in form of a dashboard, a systematic approach, shown in *Figure 7*, to develop the dashboard by Ambergen (2021) is followed. The approach involves 4 steps:

1. Data gathering
2. Data modelling
3. Dashboard design
4. Maintainability

First, data gathering is simply collecting the data to calculate the KPIs. Second step, data modelling, is described as the process of cleaning, preparing, and modeling the data that is gathered before it is used. Thirdly, the KPIs calculated in the third step will be visualized in form of graphs and charts. Lastly, the maintainability aspect means that the dashboard should be maintainable and be used outside of the research and in real-world practice (Ambergen, 2021).

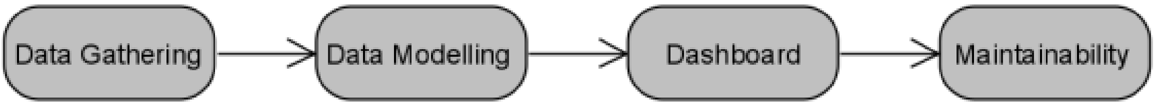
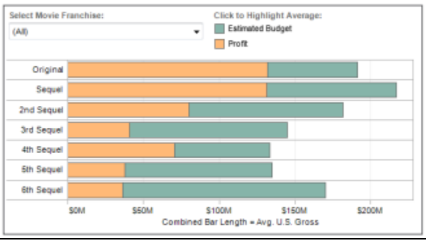
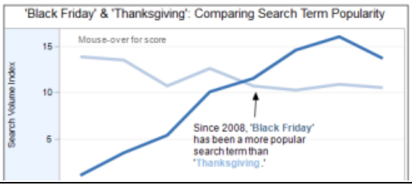
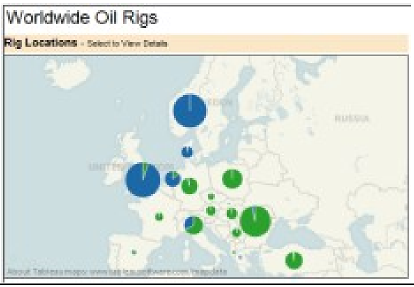
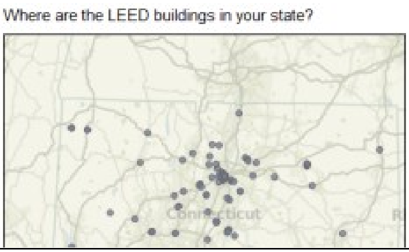
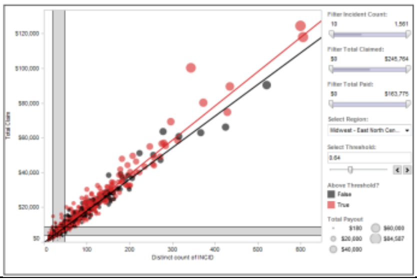
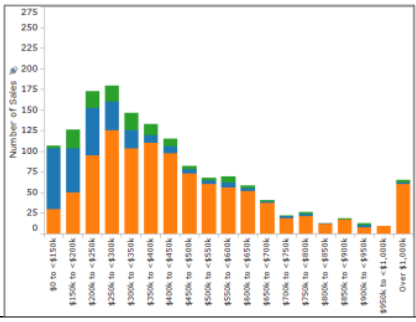
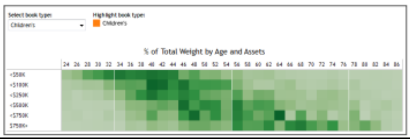


Figure 7 – Systematic Dashboard Building Approach (Ambergen, 2021)

2.4.2 CHARTS FOR VISUALIZATION

There are various kinds of charts that can express data in different ways. To prevent misrepresentation in the visualization of KPIs, we identify and describe the common charts. The theoretical framework for charts are taken from an article by Hardin et al. (2012).

Chart type	Example	Description
Bar		Bar charts are the most common ways to visualize data. It compares information quickly by revealing highs and lows at a glance. Especially effective when dealing with numerical data that splits into different categories to seek trends.
Line		Line charts connect individual numeric data points. It provides a simple way to visualize a sequence of values. Primarily used to display trends over a period of time.
Pie		Pie charts are used to show relative proportions of information. It is commonly mis-used. Bars or stacked bars are more effective when showing comparisons. Pie charts often misses key points and the viewer has to work too hard.
Map		Maps are used when using location type (geocoded) data.

Scatter plot		Scatter plots are useful when giving a sense of trends, concentrations, and outliers that direct the viewer to a point of focus. Mainly used to investigate the relationship between different variables.
Gantt		Gantt charts are used to illustrate the start and finish dates of a project in form of a schedule. Most used in project management. Can be used to understand how other things such as people or machines are in use over time.
Bubble		Bubbles are used as a technique to accentuate data on scatter plots or maps. It is used because the varying size of the circles provide meaning about the data. It can also vary by color.
Histogram		Histograms are used to understand how data are distributed across groups.
Bullet		A bullet graph is a variation of a bar chart. It is used to evaluate performance of a metric against a goal. (Ex. Actual spending vs. budget).
Heat map		Heat maps are used to show relationship between two factors. It compares data effectively across two categories using color to see where the intersection of the categories is strongest and weakest.
Highlight table		Highlight tables are an extension of heat maps. It shows how data intersects using color with added numbers to provide detail.

Program	201	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Medicaid	1	10	27	106	151	179	199	228	248	272	301
Medicare	-75	-92	-100	-107	-112	-119	-131	-139	-147	-151	-161
Interest	-7	-16	3	30	48	63	83	103	131	157	193
Security	104	80	110	144	159	163	173	184	185	193	201
Non Sec.	-69	-23	9	35	57	76	89	104	115	124	129
Other	198	209	194	276	351	392	413	440	455	483	521
Soc Sec	0	1	3	6	7	8	9	7	5	5	6
Revenue	-56	76	99	211	250	302	353	414	447	442	466
Deficit	209	95	148	272	410	460	483	513	545	640	725
Nat Debt	486	434	560	797	1067	1312	1615	1950	2320	2755	3244

Table 7 – Chart types and descriptions of use (Hardin et al., 2012)

2.4.3 DATA VISUALIZATION VALIDATION

The dashboard is designed in accordance with the Quality in Use Integrated Management Framework (QUIM) (Seffah et al., 2006). A research done by Iankoulova (2012) identified 5 relevant factors for dashboard design from the QUIM framework. The factors are explained in *Table 8*.

Factor	Description
Efficiency	The capacity of the dashboard to enable users to expend appropriate amounts of resources in relation to the effectiveness achieved in a specific context of use.
Satisfaction	The subjective response from users about their feelings when using the dashboard (i.e., is the user satisfied or happy with the system).
Learnability	The ease with which the features required for achieving particular goals can be mastered. It is the capacity of the dashboard to enable users to feel that they can productively use the dashboard right away, and then they quickly learn other new (for them) functionalities.
Usefulness	The capacity of the dashboard to enable users to solve real problems in an acceptable way. Implies that the dashboard have practical utility, which in part reflects how closely the product supports the user's own task model.
Effectiveness	The capacity of the dashboard to enable users to achieve tasks with accuracy and completeness.

Table 8 – QUIM factors used in the design of the dashboard (Iankoulova, 2012)

The operationalization of the design factors are expressed in QUIM criteria for measurability purposes. The criteria are expressed in *Table 9*.

Criteria	Description
Minimal action	Capability of the dashboard to help users achieve their task in a minimal number of steps.
User guidance	Whether the user interface provides context sensitive help and meaningful feedback when errors occur.
Navigability	Whether the user can move around in the dashboard in an efficient way
Minimal memory load	Whether the user is required to keep minimal amount of information in mind in order to achieve a task.
Feedback	Responsiveness of the dashboard to user inputs or events in a meaningful way
Likeability	User perception, feelings, and opinion of the product.
Consistency	Degree of uniformity among elements of the user interface and whether they offer meaningful metaphors to users.
Accuracy	Capability to provide correct results or effects.

Table 9 – Criteria for the operationalization of design factors (Iankoulova, 2012)

A given criteria could be an operationalization of one or more factors. *Figure 8* shows how each factor relates to the criteria. The goal is to achieve a high-level compliance to the factors regarding the design of the dashboard (Iankoulova, 2012).

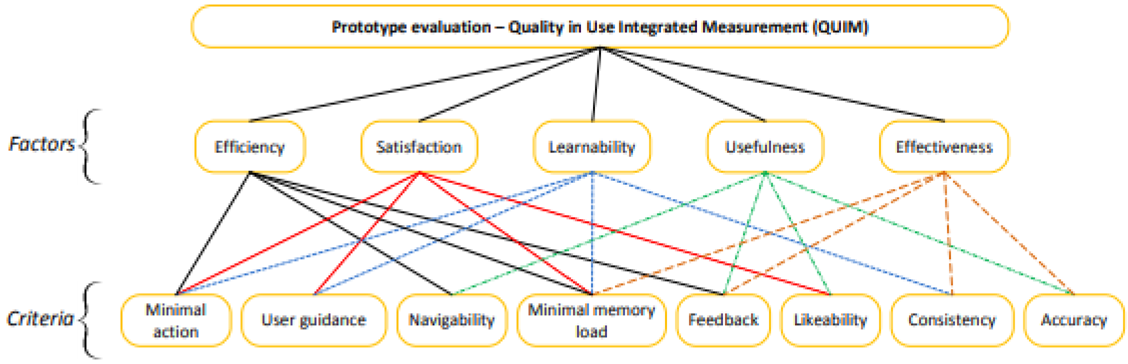


Figure 8 – Map between the factors and the criteria used in the design of the dashboard

After the design of the dashboard is finalized and the dashboard is fully functional, the QUIM framework is used to assess the validity. Input and feedback from stakeholders are based on answers received from survey questions related to the framework.

2.5 CONCLUDING KNOWLEDGE PROBLEMS

As all the knowledge questions are now answered, the new information gained from theory of literature are applied to the development of the solution. Concepts of the OTM is explored and the tool is developed based on data formats used in the OTM. A way to measure the effectiveness of transport performance measurements is identified by using the OTE framework by Iankoulova (2012). This framework provides a means to systematically measure the KPIs in the process of selection. A broad range of KPIs are also identified to assess logistics and transport performance. The KPIs are narrowed down to transport activity indicators which are later refined further into a maximum of 10 final chosen KPIs to implement in the tool. The selection of KPIs to implement involves the AHP process of multi-criteria decision making that incorporates the OTE framework. Developing the tool in form of a dashboard is outlined by a systematic dashboard building approach by Ambergen (2021). Ways to visualize KPIs are also explored, and the appropriate visual to present each KPIs are chosen. The functioning dashboard is validated using the QUIM framework for dashboard design. A survey that asks questions based on QUIM factors and criteria assesses the performance of the dashboard.

3. CURRENT SITUATION ANALYSIS

This section seek to answer the (sub)research questions to establish the current situation of Emons and Bullit Digital as well as the desired outcome of the research. This section is a part of phase 3 of the *MPSM: Analyzing the problem.*

3.1 ANALYZING DATA AVAILABLE IMPORTED FROM EMONS INTO OFFICEDOG API – RQ1

Since the research is limited to the use of OTM through Bullit Digital's Officedog, we analyze the data available taken from Emons through Officedog. The Officedog interface is intended to be used as a database. First, we explore the different data tables to identify the available data types. By connecting to the Officedog OTM database, we are able to generate the existing Entity Relationship Diagram (ERD) to show the different data tables, data types, and their relationships. The ERD, list of data tables, and data types are shown in *Appendix n.*

Currently, multiple tables can be found on the Officedog database. Different types of data that is collected from Emons' transports and imported into tables in the OTM format are found, but not all the tables (missing columns and completely empty tables) are filled with data. Some of the data tables that has existing tables are the Actors, Vehicles, and Events. The data imported into Officedog is also not continuous, making real-time measurements of KPIs by continuously extracting data from Officedog not feasible. Using Officedog as a primary database also is a complex task, as missing data would have to be uploaded into the environment beforehand.

3.2 CURRENT USE OF REAL-TIME DATA AND AMBITIONS – RQ2 & RQ3

3.2.1 EMONS INTERVIEW

To assess the current use of data in Emons, an interview is carried out with 2 business analysts from Emons. A general interview is held with themes that correlate with questions of research sub-question 2 and 3. Current use of data obtained from board computers and existing IT systems are questioned. While ambitions of the company regarding the use of data is also discussed. The information obtained from the interview is deemed not confidential and Emons representatives are aware of the use of information (bachelor's thesis).

Interviewee 1 mentions that the board computers that are installed in the transport vehicles of Emons continuously collects data and is imported to Emons' current database systems. There are existing Business Intelligence (BI) systems that can store and analyze data. Currently the company is working with the Microsoft environment and using platforms such as Azure and Power BI. Analyzing performance is currently being done in form of visualizing data which is done using several visual dashboards on Power BI. Data in several dashboards are updated at frequencies depending on the type of information needed. For general purposes, Emons updates performance measures on a weekly basis.

Interviewee 2 mentions that Emons are continuously trying to find ways to incorporate data and business intelligence into their management. They are actively measuring many different KPIs of transport performance as well as different functions in their operations. In the interview, we discussed ideas of which KPIs can be worth implementing in a performance dashboard as a result of this research. Some of the ambitions include measuring empty kilometers, driver productivity rates, delays per region. The KPI selection in this research is done in a more structured way. Ideas and suggestions from the Emons representatives are considered in the KPI selection process and many are also mentioned in literature study KPIs.

3.2.2 OFFICEDOG API

Currently, the Officedog API has an overview dashboard that displays a limited number of KPIs. There are 3 indicators displayed as shown in *Figure 9.* The On Time in Full chart (OTIF) visualizes the proportion of orders completed on time compared to orders that are incomplete and/or late. The active transport orders graph shows the number of daily transport orders for a span of 11 days. Lastly, the vehicle counter shows the number of vehicles that are in the database.

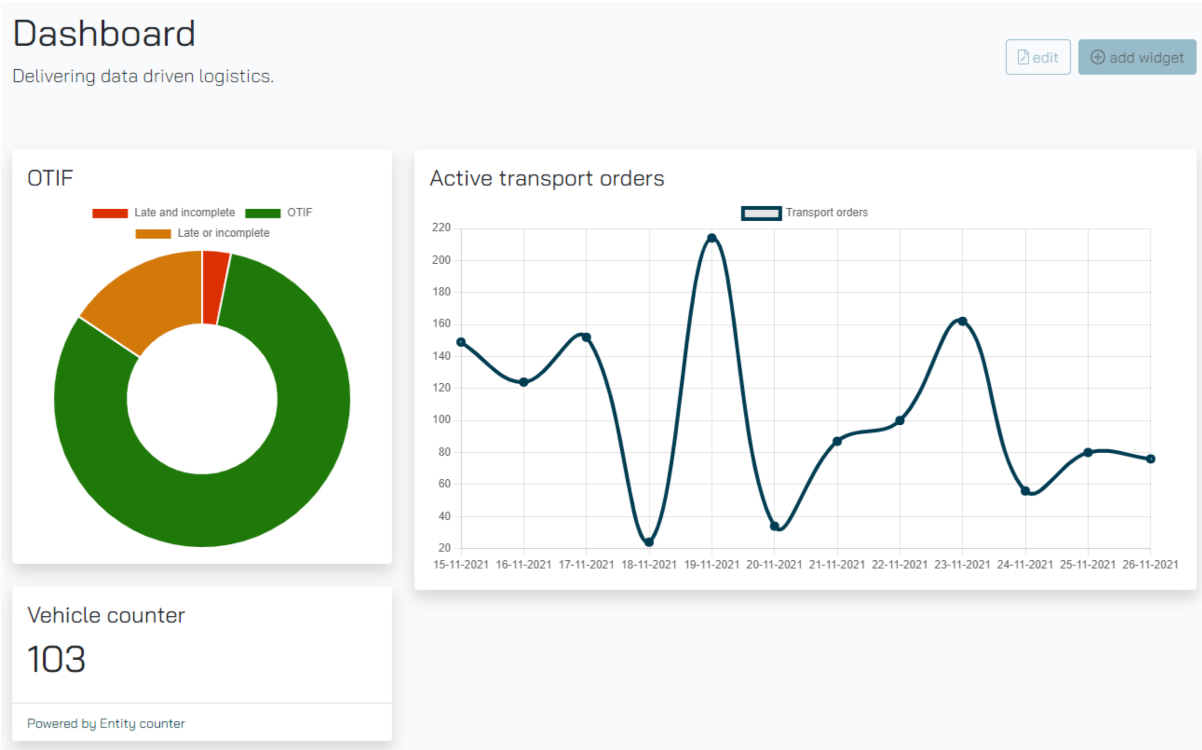


Figure 9 – Current Officedog dashboard (Bullit Digital, 2022)

A representative from Bullit Digital mentions that both the OTIF and Active transport orders charts are mock-ups and not based on real-time data streams of Emons transports. The vehicle counter visualized in the current dashboard is an ongoing continuous entity counter. While the vehicle counter is functional, the other KPIs visualized are currently not continuously updated or display real information. The goal is to have a working dashboard that updates information as long as the stream of data is continuously populating the database and transformed into the OTM format.

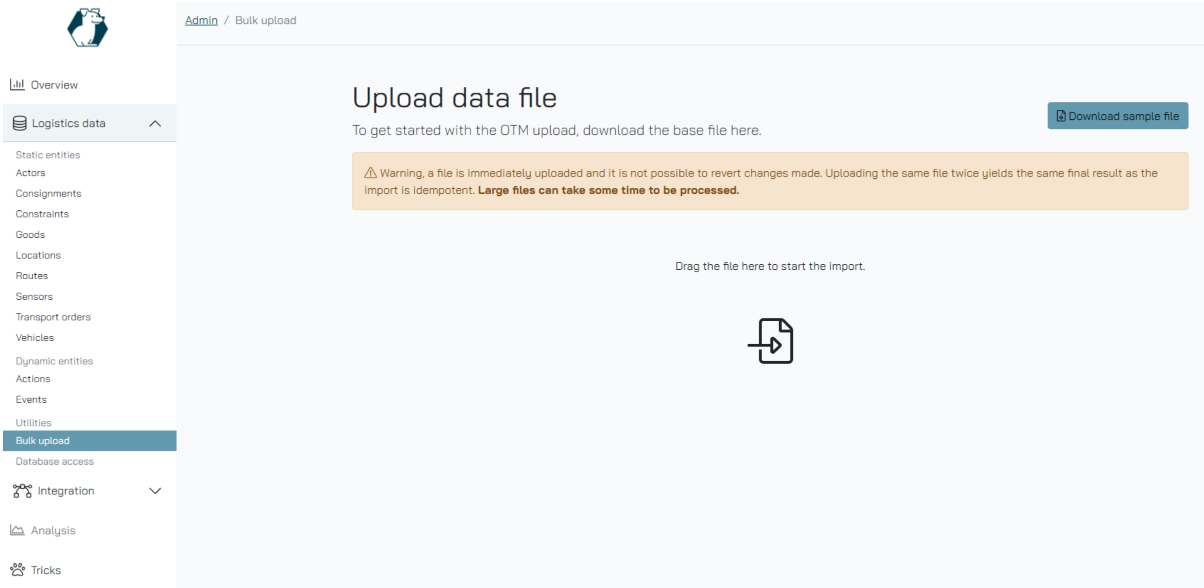


Figure 10 – Other Officedog API functionalities (Bullit Digital, 2022)

Figure 10 shows (on the left) all the data tables that can be filled using the OTM format. There are static entities as well as dynamic entities. The "Bulk upload" function in Officedog allows the user to upload an excel file that is downloadable from the API. The excel file is a base file that contains tables of static and dynamic entities that can be filled and then uploaded to the Officedog API in order to transform them into the OTM format. This then will be uploaded into the Officedog database. An example of an empty table "Events" of a base excel file is shown in *Figure 11.*

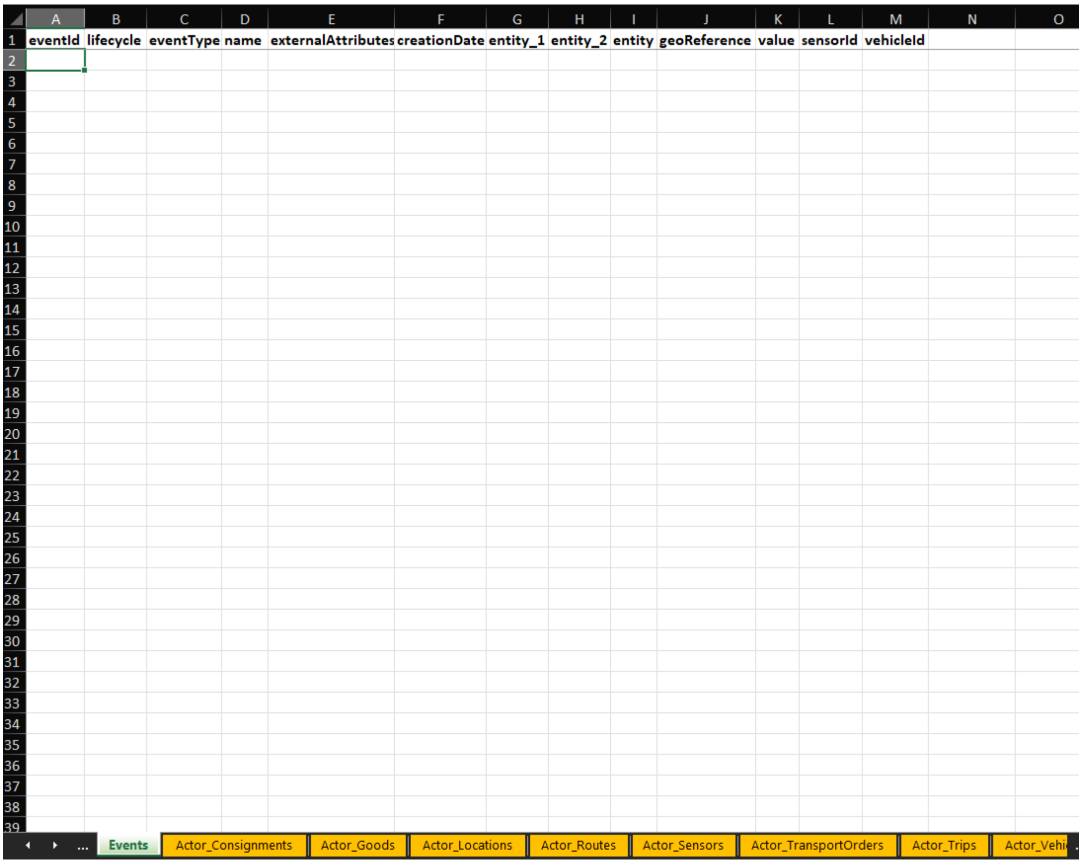


Figure 11 – Example of (empty) "Events" table in bulk upload base excel file (Bullit Digital, 2022)

3.3 CONCLUDING CURRENT SITUATION ANALYSIS

To conclude, a full analysis on the current situation of Emons and Officedog help establish what can be used to develop the solution as well as the desirable outcomes of the research. Analyzing the Officedog interface discovers the possibilities and limitations of working using the OTM. Since the data from Emons that is used in Officedog is not entirely complete and able to measure various KPIs, this is set to be a limitation. A different approach to implementing data and transforming them into visualized KPIs is explored in the next sections. Current situation analysis of Emons' use of data sets out a good basis for what can be applied to the tool. Their mention of the use of Power BI suggests that a dashboard developed using this software is the most familiar to work with. Suggestions of possible KPIs to measure also help give an idea of what KPIs can be included in the KPI selection process.

4. SOLUTION FORMULATION AND CHOOSING THE SOLUTION

After going through 3 phases of the MPSM, now we elaborate MPSM step 4: Formulating (alternative) solutions and MPSM step 5: Choosing the solution. In this section, the formulation of a solution is explained based on the core problem stated and a choice is made.

4.1 DASHBOARD SOLUTION CHOICE

In the first section, a core problem was formulated to be "Lack of tool to view logistics performance based on real-time data". The idea of the tool is to serve as a medium to assess the real-time data obtained from the database using the OTM. Preceding the core problem, the cause was formulated to be a low utilization of the data obtained from transports. As we observed from the research question, this is not entirely the case. Real-time data from Emons is actively being processed using the company's BI systems. So, it should be made clear that the aim of this research is to create a tool to assess logistics data using the OTM format.

There are multiple ways to assess logistics (transport) data. A one-time analysis of the data by reporting observations is possible, but it is time consuming and does not support the goal of the research to develop a tool that can be updated in real-time. Search algorithms and data mining is also possible but can be complex to implement due to the likely use of coding, which is beyond the research complexity limit. A balance scorecard solution can be used to assess historical data, but it is mainly utilized when the goal is to make strategic decisions for long term ambitions. A visualization dashboard is suitable as it can measure current-state performance continuously from a database and can be simple to implement using existing BI applications.

There are several ways to develop a measurement dashboard. Some of the market leaders for BI applications include Microsoft Power BI, Tableau, Oracle, and Qilk. Since the interview with Emons representatives indicated the use of Microsoft services is their current and future ambitions, the development of the tool is done using Microsoft Power BI. Power BI also provides its functionality for free which other applications may not, which makes Power BI more feasible for this research.

4.4 APPROACH FOR POPULATING DATA

The goal of the research is to use the OTM data messaging format. Due to the complexity limitations of the research, no direct OTM data formatting is done manually. Instead, all OTM concepts of data communication format will be utilized through the Officedog platform. This essentially means that all the data goes is communicated using the Officedog OTM format.

As observed earlier, not all the tables in the Officedog database is filled. There are data needed which are not available in the database to visualize the KPIs. Data that contain information regarding consignments between customers and Emons are likely not available due to confidentiality issues. Meaning that the KPIs that are intended to be implemented in the dashboard does not have the required data, as most the KPIs measure performance surrounding the delivery of orders to customers. To handle this limitation, mock delivery order data are created to fill up tables of the Officedog database. This is done by using the bulk upload function shown in *Section 3.2.2.* The needed tables are filled via the excel file template and uploaded to the Officedog platform. This file will then be transformed into the OTM format and exists in the Officedog database ready for dashboard connection.

However, this approach encountered limitations during connection testing to the Officedog database. The connection to Power BI is limited by Officedog as it surpasses the limit of actions allowed. As a precaution, we acknowledge that problems with connecting to the Officedog database and uploading data would cause delays in the development of the tool. This is due to the likely buffer of time between communicating with the Officedog representative. Therefore, a new approach to populating data utilizes the bulk upload functionality from Officedog that provides a downloadable Excel file. This Excel file will act as a database where the mock data will now be uploaded to. The connection to Power BI will then be straight from Excel locally and not from the Officedog database. The workflow of populating data is shown in *Figure 12.*

Although the integration of data into the dashboard is no longer real-time based, the idea of real-time format of event data can still be applied. In the implementation of this research, the data is populated manually in the Excel file then acts as a local database. This then connects to the Power BI dashboard and refreshes the added data as the Excel file is manually updated or edited. This concept is applicable to the database that Officedog runs on. Instead of the manually populated Excel file, in the context of the Officedog database, the data is uploaded from the board computers into the database in real-time. The data modelling and visualization process in the dashboard would possess the same concepts as the data tables from the Excel file directly correlates to the Officedog data tables. Therefore, the literal implementation of the dashboard in this research is not real-time, but the theoretical idea of the implementation continues to utilize real-time approach.

After the data is made available, tested, and functional (visualization is working), validation using real data could be a possibility of future work.

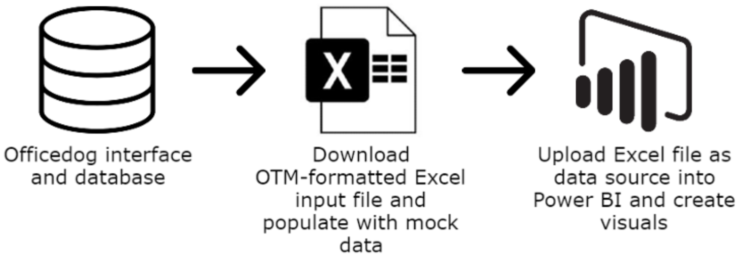


Figure 12 – Data population workflow

4.3 KPI SELECTION

4.3.1 KPI SCORING

A survey was done by the researcher, 2 Emons representatives, a representative from Bullit Digital, and the research supervisor. The Emons representatives provide scoring with valuable opinions from people of the industry. The Bullit Digital and research supervisor perspective are most useful in terms of opinions for practicality. A template of the survey can be found in *Appendix C*. All the scores given to the literature KPIs and any other proposed KPIs are aggregated and then scored by criteria weighing using the AHP method.

For simplicity and elimination of human calculation error, the AHP calculation is done via an online tool: AHP Priority Calculator by Goepel (2022). The pairwise comparison of criteria and the resulting weights are shown in *Appendix D*. The aggregated scores from each survey are then weighed for the final selection of KPIs in *Table n.*

KPI (source)	Understandable	Relevant	Comparable	Reliable	Practical	Weighted Score
Number of accidents (Piotrowicz & Cuthberson, 2012)	4.25	4.25	4.5	4.25	3.25	3.75625
On-time delivery % (Griffis et al., 2007)	4.75	4.75	5	3.75	3.25	3.96175
Complete order fill rate (Griffis et al.,	5	4.75	4.75	4	4	4.34575

2007)						
Number of shipments per terminal territory (Lukinsky at al., 2013)	4.25	3.25	4	4	4	3.79
Days order late (Griffis et al., 2007)	4.5	4.5	5	4	3.75	4.12125
Empty kilometers % (Griffis et al., 2007)	3.75	4.75	4.75	3.75	2.75	3.5975
Driver turnover rate (Griffis et al., 2007)	3.25	4.25	4.75	3	2	3.00425
CO2 emissions from transport processes (Piotrowicz & Cuthberson, 2012)	3.25	3.75	4.5	3	2.75	3.20975
Delivery lead time (Karl et al., 2018)	4.25	4.25	4.75	4	3.75	4.0065
Number of orders processed per unit of time (Lukinsky at al., 2013)	4.75	4	4.75	4.75	4.75	4.51
Orders late per terminal territory (Lukinsky at al., 2013)	3.75	3.25	3.75	3.5	3.5	3.45275
Damage return rate (Karl et al., 2018)	4	3.75	3.5	3.5	3	3.357
Average miles per gallon (or KMs per liter) (Griffis et al., 2007)	4.25	3.75	4.75	4	3.5	3.74375
Cost per kilometer (Griffis et al., 2007)	2.5	5	4.5	2.5	2.25	3.21825

Table 10 – Final KPI weighted scores

The green shaded rows are the top 5 scoring KPIs which are implemented in the dashboard and the yellow shaded columns are the proceeding 5 highest scoring KPIs that may be implemented should there be any problems with the first top 5.

4.3.2 FINAL KPIS DESCRIPTIONS

1. Number of orders processed per unit of time (Lukinsky at al., 2013)

This KPI aims to measure productivity by counting the numbers of orders placed that are being processed over a certain period. Measuring this KPI requires "processed" to be defined. For example, there are 10 orders placed in a week. We want to measure the number of orders processed in this week. We then define processed as the event that the order is on its way to the customer. After the week has been realized, we identify 5 orders are on its way to the customer or completed. We can then say that there are 5 orders processed this week.

2. Complete order fill rate (Griffis et al., 2007)

This indicator measures the number of orders fulfilled out of all the orders placed. Fill rate *F* is calculated by *Equation 2*:

$$F = \frac{N}{T} \times 100\%$$

Equation 1 – Complete order fill rate formula (Griffis et al., 2007)

Where *N* is the number of orders delivered to the customers and is completed, and *T* is the total number of orders placed in the system. For example, we acknowledge that there are 10 orders delivered to the customer and 15 total orders placed in the system. We calculate:

$$\frac{10\ orders\ completed}{15\ orders\ placed} \times 100\% = 66.67\%\ orders\ filled$$

Example 1 – Complete order fill rate example calculation

3. Days order late (Griffis et al., 2007)

Days order late refers to the number of days a particular order is delivered to the customer later than the expected or planned time of delivery. The average days that orders are late can be a better measure of an overall performance of transport. Average days order late L_{avg} for a period can be calculated by *Equation 3*:

$$L_{avg} = \frac{\sum_{i=1}^{n} D_i}{T}$$

Equation 2 – Average days order late formula (Griffis et al., 2007)

Where D_i is the number of days the order is late (or early) by calculating the number of days subtracted from a fulfilled order date by the expected delivery date, and *T* is the total number of orders fulfilled. For example, we analyze 3 orders that have been delivered to the customer. Order 1 was delivered 2 days late, Order 2 was delivered 1 day early, and Order 3 was delivered on the expected day of delivery. We calculate:

$$\frac{(2\ days) + (-1\ days) + (0\ days)}{3\ total\ deliveries} = 0.33\ average\ days\ late\ per\ order$$

Example 2 – Days order late example calculation

4. Delivery lead time (Karl et al., 2018)

Delivery lead time can be measured as the time between when an order is placed and when the order is delivered to the customer. Average delivery time of orders to the consumer (per kilometer) can also be a measure of delivery lead time in a more transport focused sense. T_{avg} measures how much time on average it takes to execute an order per kilometer to give the distance of orders less of an influence. This is shown in *Equation 4*:

$$T_{avg} = \frac{\sum_{i=1}^{n} T_i}{\sum_{i=1}^{n} L_i}$$

Equation 3 – Delivery time per kilometer formula (Sergeeva et al., 2019)

Where T_i is the time it takes to complete order i and L_i is the length of the route for order i (Sergeeva et al., 2019). For example, we observe 3 completed orders. Order 1 was completed in a total time of 1 hour, Order 2 was completed in 2 hours, and Order 3 was completed in 3 hours. Order 1 was delivered at a total distance of 50 kilometers, Order 2 was delivered at a distance of 100 kilometers, and Order 3 was delivered at a distance of 150 kilometers. We calculate:

$$\frac{(1\ hour) + (2\ hours) + (3\ hours)}{(50\ km) + (100\ km) + (150\ km)} = 0.02\ hours\ delivery\ time\ per\ kilometer$$

Example 3 – Delivery time per kilometer example calculation

5. On-time delivery % (Griffis et al., 2007)

On-time delivery rate measures the ratio of numbers of orders fulfilled within an acceptable timeframe from the expected delivery date over the total of numbers fulfilled. On-time delivery rate *O* shows the responsiveness performance and is calculated by *Equation 5*:

$$O = \frac{N}{T} \times 100\%$$

Equation 4 – On-time delivery % formula (Griffis et al., 2007)

Where *N* is the number of orders fulfilled on-time and *T* is the total number of orders fulfilled. It is important to note that the allowable timeframe in which an order is considered on-time must be addressed prior to measurement of the indicator. For example, we observe 3 delivered orders. We define the on-time date to be date 0. Order 1 was delivered on date +3, Order 2 was delivered on date +1, and Order 3 was delivered on date -2. If the allowable timeframe is +/- 1 day then we can establish that Order 1 is late, Order 2 is on-time, and Order 3 is early. For this scenario we classify early orders as on-time. We then calculate:

$$\frac{2\ orders\ on\ time}{3\ orders\ delivered} \times 100\% = 66.67\%\ of\ orders\ are\ on\ time$$

Example 4 – On-time delivery % example calculation

If we want to classify early orders separately, then the formula of *Equation 4* remains the same with variable *N* being orders delivered early.

4.3.3 CONCLUDING KPI SELECTION

After the selection process via survey of the KPIs found from literature study, we choose to implement 5 KPIs into the dashboard with ways to measure them clearly shown in the previous section. The KPIs identified from literature study can be considered as theory of how to measure performance of transport activities. The next step is applying the theory into practice and measuring the KPIs using data. KPIs that score outside the top 5 are considered as possible future works or alternative solutions for the MPSM methodology.

5. SOLUTION IMPLEMENTATION

The next step in the MPSM is Phase 6: Implementing the solution. Here we implement the theory from literature review and the conceptualized solutions from the previous phase. The solution implementation follows the Systematic Dashboard Building Approach by Ambergen (2021). This approach involves 4 steps: data gathering, data modelling, dashboard, and maintainability.

5.1 CREATING SCENARIOS (DATA GATHERING)

As per limitations of the data from the Officedog API, the approach to gather data for dashboard building is altered into data generation. Using the OTM format shown in the bulk upload excel file provided by Officedog as seen in *Figure 11*, scenarios are made up to populate data tables that are needed to visualize the KPIs chosen.

The scenarios consist of delivery trips going from a warehouse to a customer directly. There are 3 warehouses, with locations in Enschede, Rotterdam, and Groningen. The deliveries are made to 9 different customers located in Amsterdam, Maastricht, Rotterdam, Eindhoven, Hengelo, Groningen, Utrecht, Almere, and Breda. All the mock orders are made by customers of Glass Company Ltd. and the deliveries are carried out by Emons. The scenarios are made so that each warehouse receives an order from each of the 9 customers, meaning that there will be 27 orders in total.

After conceptualizing the scenario, the next step is to populate the excel file from Officedog that uses OTM communication format. The first step was to identify which tables are going to be useful and remove the unnecessary tables to prevent cluster when modelling data. The excel file has many different sheets that act as tables. The main tables are shown in *Appendix B.2*. The tables that are chosen to be populated by the conceptualized scenarios are tables: Actors, Consignments, Locations, Routes, TransportOrders, Trips, Vehicles, and Actions. Populated tables of the excel file are shown in *Appendix E.*

5.1.1 SCENARIO IMPLEMENTATION LIMITATIONS

1. **OTM trip simplified to a load-move-handover**
   In the Actions table of the excel file, a column called actionType has several different inputs namely stop, load, unload, handover, move, attachTransportEquipment, and detachTransportEquipment. To simplify the conceptualized trips into a more manageable workload, each trip only require 3 actionType to complete an order. First and order will have to be loaded, then the carrier will start to move towards the destination, then finally the order is delivered to the customer by handOver.

2. **Each trip only goes through each actionType once**
   To lessen the complexity of the trips, each delivery made go through each actionType once. This means that an order is completed when it goes through each actionType once in the same order to avoid issues in data modelling.

3. **Actions go through simplified lifecycle of requested to realized**
   The lifecycle is a big part of the OTM format of data communication. Lifecycle consists of types: requested, planned, projected, actual, and realized. Each lifecycle is explained in *Section 2.1.1.* For simplification, the orders require lifecycle requested and realized. In this scenario, the requested lifecycle applies to when an order is made by the customer and is ready for loading. Realized lifecycle applies to when an actionType is completed.

4. **Simplified trips of only delivering filled trucks, no return journeys**

Trips that populate the data tables only track data of deliveries of filled trucks to customers and no return journeys are going to be made. This is the case to simplify data modelling as the KPIs do not necessarily require empty state trips (e.g. Empty KMs).

5. **Trips only consist of one route, from warehouse to customer, no intermediate stops**
   The trips made to deliver start from the warehouse and straight to the customer classified in a single route. To simplify the process of delivery, no intermediary stops (e.g. rest or traffic) are recorded. This leaves each delivery with only 1 move actionType recorded.

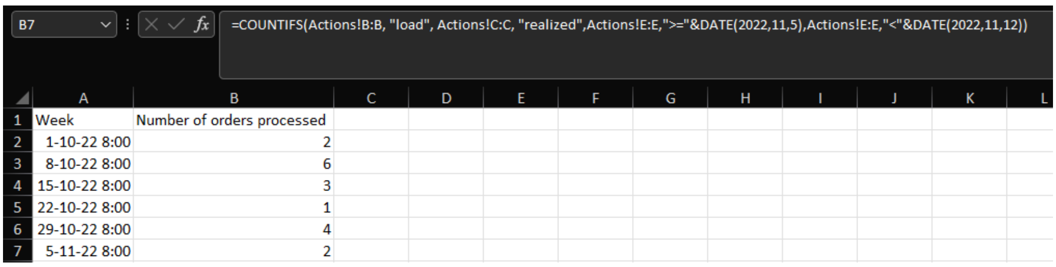
6. **Data population method may not be fully accurate**
   The data format of OTM is used by filling in the columns of data tables in the Excel input file. Because the data is completely made up and is manually inputted, the method of how data is inserted into the file may not be entirely accurate. This includes concerns such as the unique primary keys being present multiple times within one table, or data from other tables not being properly referred to create relationships. This may cause a lower level of validity of the proper use of the OTM messaging format and must be taken in mind.

5.4 MODELLING THE KPIS (DATA MODELLING)

Modelling the data is done based on each KPIs needs and carried out in Microsoft Power BI Power Query Editor or using Excel functions. The Power Query function is used to add custom column and new measure queries in Power BI modelling. To initiate the connection, Power BI is launched and the option to get data from an Excel file is chosen. The input file provided by Officedog with populated data tables is connected. Modelling each KPI is discussed below.

1. **Numbers of orders processed per unit of time**
   This KPI essentially shows the sum of orders that have been processed. To properly measure the KPI, the term “processed” needs to be defined. In this case, we define “processed” as the stage where an order is loaded onto a vehicle. And the total number of orders placed would be a count of all the unique orders which have requested a load actionType. The unit of time will be set as weekly as the delivery data is randomly populated within a 1-month frame. The KPI now specifically measures Weekly Orders Processed.

   As troubles were faced when attempting to implement the measurements in Power Query, this KPI was measured using Excel functions instead to reduce complexity of the task. The Excel function COUNTIFS is used to count scenarios with given conditions such as actionType, lifecycle, and the date. This KPI is measured using the Actions table of the input data. An example of the Excel formula is shown in *Figure 13* below.



B7

=COUNTIFS(Actions!B:B, "load", Actions!C:C, "realized",Actions!E:E,">="&DATE(2022,11,5),Actions!E:E,"<"&DATE(2022,11,12))

	A	B
1	Week	Number of orders processed
2	1-10-22 8:00	2
3	8-10-22 8:00	6
4	15-10-22 8:00	3
5	22-10-22 8:00	1
6	29-10-22 8:00	4
7	5-11-22 8:00	2

Figure 13 – Number of orders processed per unit of time Excel formula

2. **Complete order fill rate**

This KPI showcases the proportion of orders fully completed compared to all the orders that has been placed. To measure the KPI, orders completed and orders placed need to be defined by the existing data. In this case, complete orders are classified by orderId with actionType “handOver” with a “realized” lifecycle. And total orders placed are classified by orderId with actionType “load” and “requested” lifecycle. These data are obtained from the Actions data table. Due to complexity issues with recognizing unique actionId, this KPI is calculated in Excel. An example of one of the COUNTIF formula is shown in *Figure 14* below.

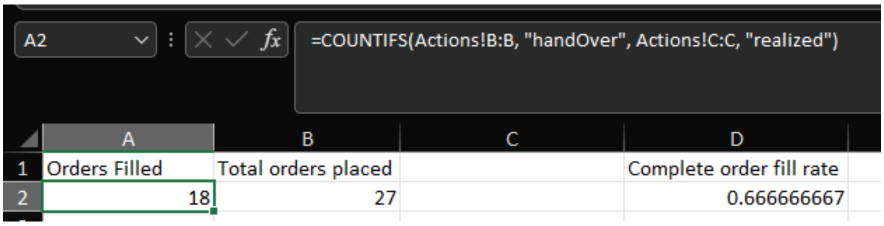


Figure 14 – Complete order fill rate Example formula

3. **Days order late**

This KPI aims to measure delivery lateness of orders. Instead of days order late, in this scenario we will use hours as the deliveries are made within The Netherlands and journeys are mostly under 4 hours. In order to know if orders are late or not, we need to define the projected on-time duration of each trip. To do this, for every routeId that has actionType “move” and lifecycle “realized”, we add the projected duration of a trip of that route to the startTime of that row (e.g. adding 2 hours to the moment a trip from Enschede to Amsterdam starts to set the projected on-time timing of delivery). A column called onTime is created using Power Query with some of the formulas shown in *Figure 15* below.

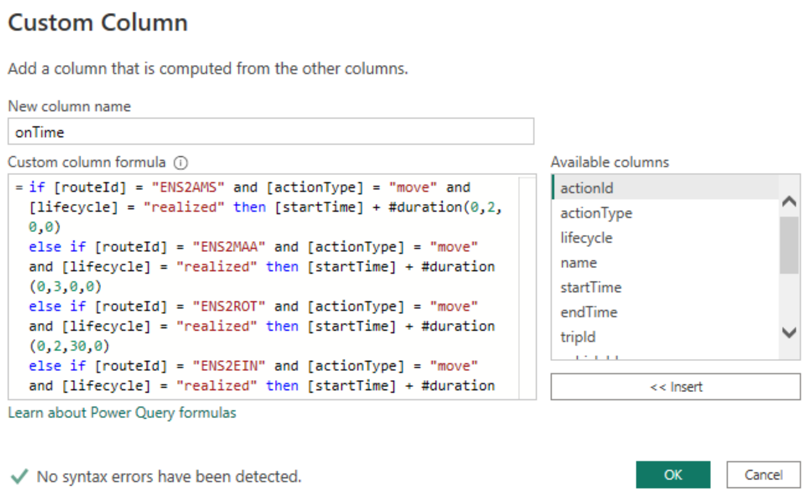


Figure 15 – onTime column added through Power Query

Then, a new column is made to calculate the hoursLate that an order is completed. This simply takes the difference in time between the column endTime and onTime of completed orders (based on actionType “move” and lifecycle “realized). A positive value of the hoursLate column means that the order is late by that amount of time from the projected ideal on-time timing, and a negative value means that it is early.

4. **Delivery lead time**

This KPI measures the time it takes to deliver an order. Although, delivery of different routes covers different distances. So, it would be appropriate to measure lead time in a uniform way that can be measured against each other. The average time taken to deliver an order per kilometer addresses this issue. This creates the same measurement of every kilometer of each route, making it comparable.

To carry out this measurement, a distance column had to be created for each routeId. Since automatic location tracking and constant update of georeferencing data is too complex for this research, manual distance measurement of each route had to be done. This means for each route, a static distance value is set (e.g. Enschede to Amsterdam is a 170km drive). The distance data is taken by a rough estimate from Google Maps directions function. Then, a measure of how long the delivery was completed in was made. A new column called “Time taken to deliver” simply calculated the difference in time between a trip’s endTime and startTime based on actionType “move” and lifecycle “realized as shown in *Figure 16* below.

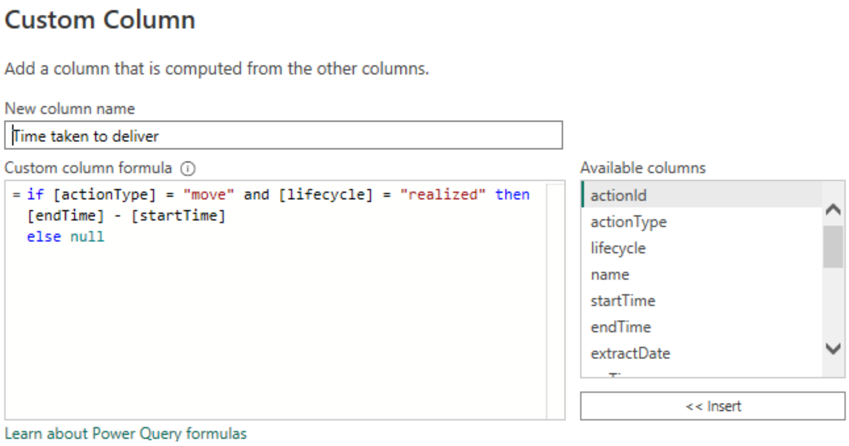


Figure 16 – Time taken to deliver column calculation in Power Query

Then, to finally showcase the measure of time taken to deliver an order per kilometer, the Time taken to deliver is divided by the total distance covered during the delivery. A new column calculating this measure is made and shown in *Figure 17* below. This calculation is based on the KPI formula in *Equation 3.*

Figure 17 – Time taken to deliver per KM calculation in Power Query

5. **On-time delivery %**

   This KPI measures the proportion of orders that are delivered to the customers on time versus the orders that are delivered late. To carry out this measurement, the on-time timeframe was already defined in the previous steps, but we still need to define what classifies a delivered order is on time or not. To do this, we set a timeframe with lower and upper bounds that applies to all orders. We chose the lower bound to be 15 minutes before the projected onTime time, and 45 minutes after the projected onTime time. An example of this condition is created as shown in *Figure 18* below.

Figure 18 – Creating an upper bound for on time classification of delivery in Power Query

If an order is completed before the lower bound, then the order will be classified as "Early", if it is within the time frame then it is classified as "On-time", if it is over the upper bound then it is classified as "Late". A new column called deliveryStatus carries out this classification as shown in *Figure 19* below.

Figure 19 – deliveryStatus for delivery early/on-time/late in Power Query

5.3 MODELLING THE DASHBOARD (DASHBOARD)

The dashboard is developed in Microsoft Power BI and the data is obtained from the Officedog Excel input file containing mock data in the OTM format. Power BI recognized the different data tables and have generated new columns and queries created in Power Query Editor. Selecting types of graphs and visuals can be found in the Visualizations tab and data is obtained from the Fields tab. Refer to *Figure 20* below.

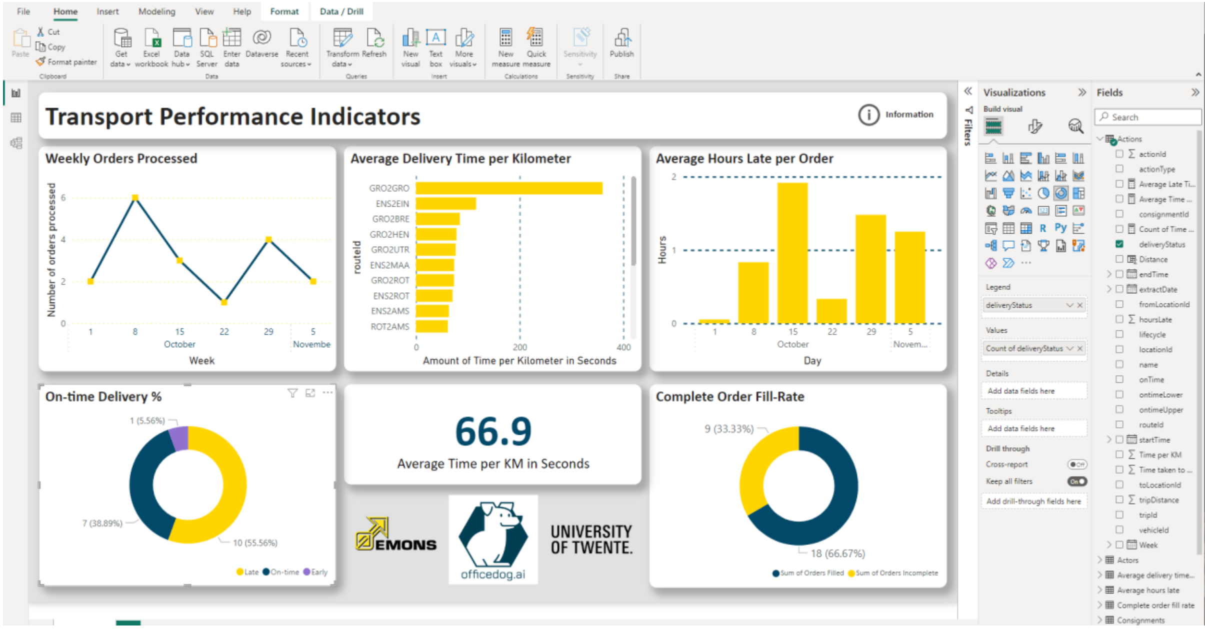


Figure 20 – The Microsoft Power BI dashboard and program showing visualization of On-time Delivery %

1. **Weekly Orders Processed**
   To visualize Weekly Orders Processed, we need to observe trends across different groups. The trends that we need to see is the sum number of orders processed. The different groups are the weeks that the orders are processed. The goal of this visualized KPI is to show the user how active the transports are every week. A bar chart or line chart can visualize this effectively. The line graph is used to show the change in number of orders processed per week better compared to a bar graph. An option of incorporating both bar and line is possible, but a cluster of figures within one measurement might over complicate the readability of the KPI. The y-axis measures the sum number of orders processed and the x-axis groups the orders into weeks.

2. **Complete Order Fill-Rate**
   Visualizing complete order fill-rate aims to show the user the proportion of current status of all orders. Out of all the total orders placed, this shows how many are completed compared to ones that are yet to be completed. This can be effectively shown by a simple pie/donut chart. It simply counts the sum number of orders delivered to the customer and the sum number of orders not delivered to the customer.

3. **Average Hours Late per Order**
   To visualize the average hours orders are late, it would be efficient to group orders per weekly to prevent too many measures being cluttered into one visual. Therefore, each completed order are grouped based on the week the order was delivered to the customer. The amount of hours late of all orders within a week is then averaged to give the average hours late per order. A bar chart effectively shows trends across different groups. The y-axis measures the average hours late per order and the x-axis splits orders into weekly groups. The higher the bar is, the higher the amount of hours late that an order is on that week on average. Shorter bars indicate that week on average faces less delays.

4. **Average Delivery Time per Kilometer**
   To measure delivery lead time in a more comparable manner, we measure the average delivery time per kilometer. This creates a uniform format of measuring lead time across different delivery distances. To visualize this, we incorporate 2 different visuals. First, we want to compare the lead time performance for

all the different routes of delivery. This means that the data is classified into groups of specific routes, making a bar chart effective for visualizing this indicator. The y-axis is the different routes delivery occur in, and the x-axis measures the average time it takes to deliver an order per kilometer in seconds. The other visual is a simple value card that measures the average time per kilometer a delivery is completed in seconds. This value averages all the orders completed without grouping to observe how the transports are performing as a whole average. Although, with a few interactions from the user in the dashboard, this value can show different cases. This will be elaborated in *Section 5.4.*

5. **On-time Delivery %**
   This KPI measures the proportion of orders delivered early, on-time, or late. As the KPI visualizes proportions, a pie/donut chart is effective. The chart simply counts the sum number of orders delivered early, on-time, and late. This gives the user an idea of how the transports are able to deliver within the allowable time frame.

5.4 DASHBOARD FUNCTIONALITY AND MAINTAINABILITY

The dashboard has a set of static and dynamic visuals created in Power BI. The static visuals, Weekly Orders Processed and Complete Order Fill-Rate, will not change according to user inputs in the dashboard. Static KPIs were created due to limitations mentioned in *Section 5.2.* The rest of the KPIs are dynamic visuals, which can change and show measurements of different scenarios. For example, in *Figure 21* below, a simple click on the proportion of deliveries late on the On-time Delivery % KPI changes the other dynamic KPIs. It shows the different delivery routes that were delivered late, the average time per kilometer of delivery for all late orders, and the average hours late per order of all late deliveries.

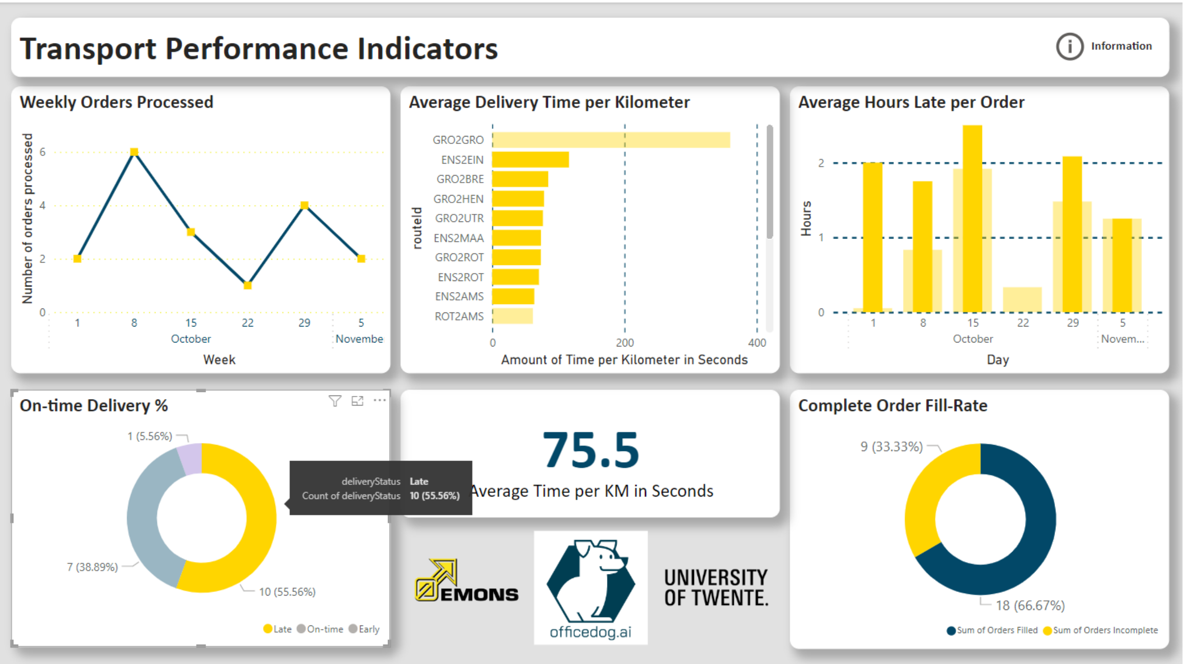


Figure 21 – Example of interaction with dynamic KPI visuals

The maintainability of the dashboard is limited based on the limitations mentioned in scenario implementation limitations in *Section 5.1.1.* One of the main limitations for dashboard maintainability is the way the data was implemented into the Excel input file. For one instance, the Actions table might see different actions being recorded with the same actionId. This makes it difficult to refer to different actionTypes of the same order.

Primary Key concept in the Excel file during implementation was difficult to manage as opposed to obtaining existing data from a database (e.g. SQL). This means that the associations between tables may not be fully functional or valid. The effect of this in the dashboard, is that if new data is added into the input file, it needs to be implemented in the same way as how the rest of the data was implemented. This makes implementation of real data likely not possible. An example of how the dashboard is limited, is how the visuals in the dashboard uses functions within the same actionId, meaning majority of them using the actionType “move” and lifecycle “realized” as shown in some of the queries shown in *Section 5.2.* Another limitation worth mentioning is the manual implementation of weekly orders grouping, on-time timeframes, and route distance. These values need to be implemented by changing or adding the query in Power BI Power Query and not by simply adding to the Excel inputfile. Making maintainability a complex task.

6. EVALUATION

The last phase of the MPSM is phase 7: Evaluating the solution. In this phase we assess the solution systematically. Issues that can be found during this phase usually routes the research back to the earlier phases of the MPSM, but due to time constraints, this phase mainly evaluates the solution.

6.1 QUIM SCORING

The dashboard, as a solution, will be assessed based on the QUIM framework for dashboard design by Iankoulova (2012) mentioned previously in *Section 2.4.3.* This assessment serves validation purposes of the research outcome. The QUIM framework assesses based on 5 factors that are influenced by 8 criteria. Each factor is measured by 4 of the 8 criteria. We conduct a survey, shown in *Appendix F,* that asks 8 questions that correspond to the criteria in *Table 9.* The criteria relate to each factor as shown in *Figure* 8 and are weighed equally. Answers from 5 respondents consisting of industry representatives from Emons, research supervisors, and a representative from Bullit Digital will be aggregated into one score for each criterion. The aggregated scores are then calculated into scores for the 5 main factors of the QUIM framework. The calculation and scoring tables is shown in *Appendix F.*

The final scores for each factor are as below:

- Efficiency: 3.8/5
- Satisfaction: 3.8/5
- Learnability: 3.8/5
- Usefulness: 3.7/5
- Effectiveness: 3.5/5

Assuming that the scores are aggregated out of a possible 5, we scale 1 as low, 2 as moderately low, 3 as moderate, 4 as moderately high, 5 as high. For each criterion, the dashboard design is evaluated at a moderately high level. More specifically, the feedback received indicate that the dashboard is designed well, but lower scores on usefulness and effectiveness show that functional aspects of the dashboard may need some improvements. Some extra feedbacks were received regarding what would be a possible future improvement for the dashboard. Being able to see more detailed data based on exclusion filtering is one of the further steps the dashboard can take.

6.2 REFLECTION TO NORM

Based on *Section 1.2.1*, the norm is to have a working tool to view logistics performance based on real-time data. Indicators were established to observe whether the solution has successfully fulfilled the norm. The first norm is to have transport performance visualized in the tool. This was described as the tool being able to measure transport performance via relevant KPIs gathered from real-time data. The developed dashboard is functional and displays performance via KPIs relevant to stakeholders. Although, the goal to use real-time data is limited due to complexity of the task. Secondly, the tool should clearly communicate data using relevant charts and there needs to be clear motivation of each visualization. The developed tool uses charts that are motivated by knowledge obtained from literature study to ensure that every KPI is interpreted well. Lastly, the usability of the tool indicates that the dashboard should be accessible and easy to use. Based on the evaluation of the dashboard design, the design of the dashboard scores moderately high on efficiency, satisfaction, and learnability. Indicating that the dashboard is fairly accessible.

6.3 LIMITATIONS

Limitations must be considered when assessing the outcomes of the evaluation process. Mainly, respondents are not able to observe the back-end development of the dashboard and the raw data itself, making validation limited. It limits the ability to assess whether the dashboard is showing accurate measurements in form of KPIs based on the data used, or if the KPI implementation process is done in the right way. The effectiveness assessment of the dashboard is also limited due to the lack of feedback to indicate whether the dashboard show helpful KPIs that can help with decision making. This is due to the QUIM framework used being largely focused on the design elements of the dashboard.

7. CONCLUSION AND FUTURE WORK

In this chapter we conclude by summarizing what has been done in the research in *Section 7.1*. We also look into possible future works that can be explored that were hindered by limitations of complexity or time constraint in *Section 7.2*.

7.1 CONCLUSION

The main goal of this research was to solve the core problem of developing a tool that is capable of visualizing logistics performance using the OTM data messaging format. The outcome of this research also aims to provide insight on one of the ways to digitize transport activities. As mentioned in the problem context in *Section 1.2.1*, digitization of logistics operations through IT innovations can be complex. Although some of the research findings and solution implementation was hindered by different kinds of limitations and complexities, the ability to develop a performance dashboard using concepts of the OTM format prove that digitization of logistics operations is possible in this manner and possibly in many other ways. The use of the OTM format, however, has the intention to create a uniform format to communicate data across logistics IT systems. Meaning that the successful implementation of OTM should theoretically solve the issue of complex communication across different IT systems. The feasibility of how OTM can be used to communicate across different IT systems is not discovered in this research, as it is beyond the scope of this research.

The Emons problem case of this research was that there is perceived low utilization of board computers providing real-time data streams. One of the goals of this research is to provide a solution to how these streams of real-time data can be used. Due to complexity in the implementation stage of the research, the use of real-time data, especially live location data, cannot be used. Although, at a broader point of view, the conceptualization of how the solution is implemented could make use of real-time data streams. Data types such as Action, Location, Start Time, and End Time is used in the implementation of the solution. Even though the research uses mock data, the idea of what can be done using these data types can possibly be used when dealing with real-time data streams. Meaning that the dashboard solution can act as a rough example of what is possible using data extracted from the board computers via the OTM format. Should Emons consider utilizing real-time data streams through the OTM data formatting, the product of this research provides an example of what can be done.

The main deliverable of this research is a functioning tool that can utilize data streams through the OTM format. This tool came up in form of a performance dashboard. The dashboard was developed to solve the core problem of providing a tool to view logistics performance to help with decision making. Norms were set for the dashboard to have 3 elements as per *Section 1.2.1*: Transport performance visualized in the tool, Interpretability of visualized data, Usability of tool. The validity of the developed dashboard is showcased by the assessment survey sent to research supervisors, Emons representatives, and a representative from Bullit Digital. After obtaining responses, the dashboard achieved a moderately high score based on the QUIM framework for dashboard design. Although, some improvements can be made based on critical feedback of the functionality of the dashboard for detailed decision making. Observing specific and more detailed data in the dashboard is said to be lacking.

The main research question of this research is: How can Emons make use of real-time data streams to make logistical decisions? This is followed by other research sub-questions and knowledge questions that are answered by surveys, interviews, and literature study. As the research sub-questions and knowledge questions bring more insights to create a solution for the core problem, the main research question can be answered. Emons can make use of real-time data streams by extracting event, action, location data from their board computers into a data storage that communicates the data in OTM format which can be used to develop tools such as a dashboard that visualizes the data in form of measurable KPIs. The answer to the main research question is the outcome of this research and is an example of one of the ways Emons can utilize their streams of data. Not only is this solution applicable to Emons, ideas of the implementation of the OTM to create a dashboard can be of interest to other logistics operations in general. Officedog can also benefit from this research by incorporating the KPIs into their existing API. This research theoretically and practically shows that various transport performance KPIs can be measured using their existing OTM data structure, meaning implementation into Officedog is likely possible to improve their current overview dashboard.

Outcomes of the research:

- Explored concepts of the OTM
- Implemented a solution based on the OTM ideas of data communication and formatting
- Developed a transport performance dashboard visualizing:
    - Weekly Orders Processed
    - Average Delivery Time per Kilometer
    - Average Hours Late per Order
    - Complete Order Fill-Rate
    - On-time Delivery %

7.2 FUTURE WORK

Limitations and complexities of this research are acknowledged and can be a possible look into what can be explored in future research. First, the concepts of OTM are explored and surface level knowledge of the OTM data communication format is applied. Although, one of the main problems that logistics operations have with regards to implementing IT solutions is the complexity of being able to apply IT solutions across different types of data systems. The OTM aims to solve this issue by creating a standardized format of data communication, but how communication between different IT systems can be achieved is not explored in this research. Being able to identify the issues of complexity of this problem can lead to a solution that provides information or an example on how the OTM can act as a bridge to communicate data across varying IT systems.

Secondly, the development of the dashboard was done via Microsoft Power BI and a template OTM-formatted Excel file as a data source provided by the Officedog API. This means that the dashboard is a standalone product that functions solely from the Excel input file. Further research can be done to work with Bullit Digital to implement the dashboard into the Officedog API. Doing this means that the data would be extracted from the OTM database connected to the Officedog API instead of a separate Excel file. The current state of the dashboard functionality in Officedog isn't fully functional and KPIs are completely static. The same dynamic KPIs could potentially be implemented in Officedog with adjustments in the implementation stage of this research to suit to needs of the Officedog platform.

Similar to the previous possible future work, creating a dashboard capable of using real streams of data would be something worth looking into. By being able to develop a dashboard that is able to update itself as data is continuously added, the validity of the result of the research can be enhanced. Ideally, this direction would incorporate fully accurate use of the OTM instead of a simplified version which can be observed in this research. A fully functional and maintainable dashboard can then be validated by real-life scenario data instead of creating mock ones. This requires further research beyond the current complexities and limitations.

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9. APPENDICES

APPENDIX A – SYSTEMATIC LITERATURE REVIEW

1. The knowledge problem

What Key Performance Indicators (KPIs) are used to assess logistical performance?

As the main goal of this research is to develop a tool (in form of a dashboard) that visualizes near-real-time data in forms of KPIs to support logistics performance measurement and decision making, we investigate what KPIs are the most effective in doing so. Besides interviewing Emons representatives regarding their preferences in terms of KPI selection, we conduct a scientific literature review to find out which KPIs can be included in the tool. We will look into two main aspect of the research question:

- What KPIs measure logistics performance?
- How to choose KPIs to measure logistics performance?

2. Search terms and strategy

The search terms that are going to be used in the search for literature to answer the research question are: KPI, logistic, transport, performance.

Databases such as Scopus and Web of Science will be used to find literature that are peer-reviewed. Articles from the University of Twente thesis database will also be used when it is of interest or recommended by supervisors.

3. Inclusion and exclusion criteria

In order to narrow down the list of articles, inclusion and exclusion criteria are identified. Elements in the inclusion criteria are specifications for the article to possess. Exclusion criteria are elements that can make the article dismissible.

Inclusion criteria	**Reasoning**
Includes terms: Key Performance Indicator, KPI, logistic, dashboard, transport, optimization, efficiency, supply chain, decision making, performance	These are terms and keywords that are relevant to the research question and research topic in general. At least one or more of these keywords should be included in the chosen article.
Subject area: Engineering, business management, decision sciences (Scopus)	Gathering results from subject areas of interest based on the research topic.
Exclusion criteria	
Subject area: Any subject area that was not limited to the ones mentioned in the inclusion criteria	Narrowing down results to only those within the subject area of interest.
Language: Non-English languages	Only considering English written articles for comprehension reasons.

4. Search results

The search process follows the following steps:

1. Search the search terms in the scope of "title, abstract and keywords"
2. Narrow down results to inclusion and exclusion criteria

3. Reading titles and abstracts manually to choose which articles to review
4. Check full document availability of article
5. Check for referenced documents for possible articles of interest
6. Read contents of the articles if needed information is evident

Search terms	Database	Scope	Results
“KPI” AND “logistic” AND “performance” AND “transport”	Scopus	Title, abstract and keywords	16
“KPI” AND “logistic” AND “performance” AND “transport”	Web of Science	Title, abstract and keywords	7

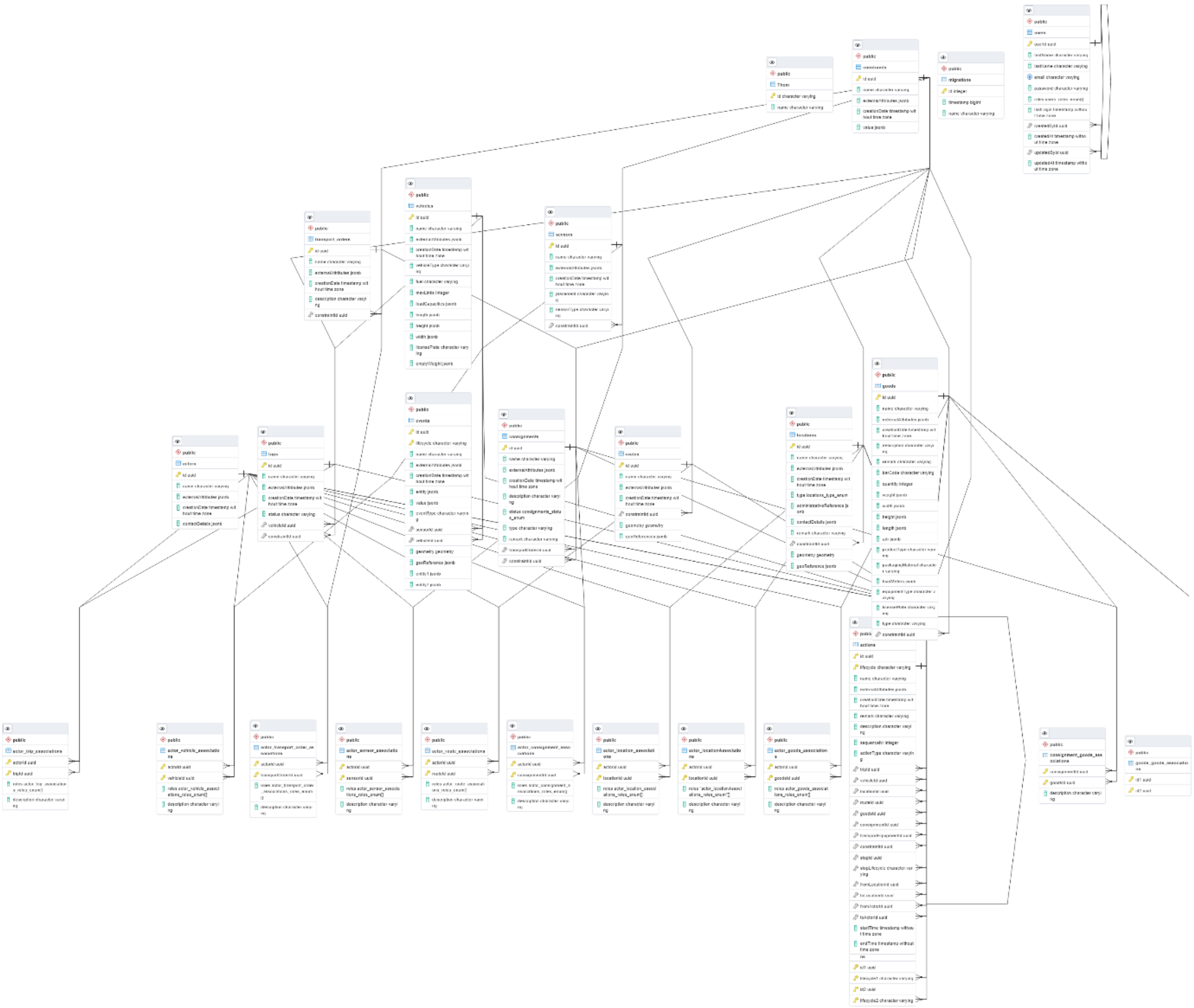
No.	Author (year)	Title	Database	Availability
1	Kovács, G., Kot, S. (2017)	Software development for performance measurement evaluation of road transport activity	Scopus	No
2	Wojciech, P., Cuthbertson, R. (2015)	Performance measurement and metrics in supply chains: an exploratory study	Scopus	Yes
3	Vasiljeva, T., Minx, M. (2018)	The impact of selected road freight transport management measures for the society and environment	Scopus	No
4	Lukinskiy, V.S., Pimonenko, M.M.m Paajanen, M., Shulzhenko, T.G. (2013)	Development of methodology and tools for comparative assessment of operational efficiency of KPI-based logistical infrastructure facilities	Scopus	Yes
5	Majercak, P., Cug, J., Hoa, H.T.T. (2016)	Improving Vietnam Logistics Service Chain Quality by Applying Appropriate Key Performance Indicators KPIs	Web of Science	No
6	Torbacki, W., Kijewska, K. (2019)	Identifying Key Performance Indicators to be used in Logistics 4.0 and Industry 4.0 for the needs of sustainable municipal logistics by means of the DEMATEL method	Web of Science	Yes
7	Karl, A.A., Micheluzzi, J., Leite, L.R., Pereira, C.R. (2018)	Supply chain resilience and key performance indicators: A systematic literature review	Scopus	Yes
8	Iankulova, I. (2012)	Business Intelligence for horizontal Cooperation: Measuring the Performance of a Transportation Network Sharing Cooperation Between Logistics Companies.	UT theses	Yes

Article	Key findings
2	KPIs with regards to Social, Economic,

	Environmental sustainability. Most important economic KPIs: on time delivery, customer satisfaction, total costs, transport costs. Social: employee skills, employee satisfaction. Environmental: CO2 emissions from transport, energy use.
4	Using the Balanced Scorecard as a key tool for analyzing and regulating a company's activity. Figure 2: framework of hierarchy of a company's logistical activity indicators. Logistics specific indicators: Effectiveness (General logistical costs, costs associated with transport per territory of a terminal and logistics center). Performance (Number of orders processed per unit of time, cargo shipments per unit of terminal and logistics center capacity).
7	Table 3: Provides a list of non-financial KPIs from a supply chain perspective
8	Provides commonly used KPIs that are focused on transportation activities.

APPENDIX B – OFFICEDOG DATA TABLES

B.1 COMPLETE ENTITY RELATIONSHIP DIAGRAM OF OFFICEDOG DATA TABLES



B.2 MAIN DATA TABLES WITHOUT RELATIONSHIPS

events	
id	[PK] uuid
lifecycle	[PK] uuid
name	character varying
externalAttributes	jsonb
creationDate	timestamp without time zone
entity	jsonb
value	jsonb
eventType	character varying
sensorId	uuid
vehicleId	uuid
geometry	geometry
geoReference	jsonb
entity1	jsonb
entity2	jsonb

goods	
id	[PK] uuid
name	character varying
externalAttributes	jsonb
creationDate	timestamp without time zone
description	character varying
remark	character varying
barCode	character varying
quantity	integer
weight	jsonb
width	jsonb
height	jsonb
length	jsonb
adr	jsonb
productType	character varying
packagingMaterial	character varying
loadMeters	jsonb
equipmentType	character varying
licensePlate	character varying
type	character varying
contraintId	uuid

vehicles	
id	[PK] uuid
name	character varying
externalAttributes	jsonb
creationDate	timestamp without time zone
vehicleType	character varying
fuel	character varying
maxLinks	integer
loadCapacities	jsonb
length	jsonb
height	jsonb
width	jsonb
licensePlate	character varying
emptyWeight	jsonb

actors	
id	[PK] uuid
name	character varying
externalAttributes	jsonb
creationDate	timestamp without time zone
contactDetails	jsonb

sensors	
id	[PK] uuid
name	character varying
externalAttributes	jsonb
creationDate	timestamp without time zone
placement	character varying
sensorType	character varying
constraintId	uuid

actions	
id	[PK] uuid
lifecycle	[PK] character varying
name	character varying
externalAttributes	jsonb
creationDate	timestamp without time zone
remark	character varying
description	character varying
sequenceNr	integer
actionType	character varying
tripId	uuid
vehicleId	uuid
locationId	uuid
routeId	uuid
goodsId	uuid
cosignmentId	uuid
transportEquipmentId	uuid
constraintId	uuid
stopId	uuid
stopLifecycle	character varying
fromLocationId	uuid
toLocationId	uuid
fromActorId	uuid
toActorId	uuid
startTime	timestamp without time zone
endTime	timestamp without time zone

spatial_ref_sys	
srid	[PK] uuid
auth_name	character varying
auth_srid	integer
srtext	character varying
proj4text	character varying

transport_orders	
id	[PK] uuid
name	character varying
externalAttributes	jsonb
creationDate	timestamp without time zone
description	character varying
constraintId	uuid

constraints	
id	[PK] uuid
name	character varying
externalAttributes	jsonb
creationDate	timestamp without time zone
value	jsonb

routes	
id	[PK] uuid
name	character varying
externalAttributes	jsonb
creationDate	timestamp without time zone
constraintId	uuid
geometry	geometry
geoReferences	jsonb

cosignments	
id	[PK] uuid
name	character varying
externalAttributes	jsonb
creationDate	timestamp without time zone
description	character varying
status	cosignments_status_enum
type	character varying
remark	character varying
transportOrderId	uuid
constraintId	uuid

trips	
id	[PK] uuid
name	character varying
externalAttributes	jsonb
creationDate	timestamp without time zone
status	character varying
vehicleId	uuid
constraintId	uuid

locations	
id	[PK] uuid
name	character varying
externalAttributes	jsonb
creationDate	timestamp without time zone
type	locations_type_enum
administrativeReference	jsonb
contactDetails	jsonb
remark	Type
constraintId	uuid
geometry	geometry
geoReference	jsonb

KPI Selection and Evaluation Survey for Stakeholder

Criteria

The following are the criteria for making the evaluation of the KPIs measurable. Each criteria is described briefly.

Criteria	Description
Understandable	The KPI is clear and measurable
Relevant	The KPI is significant and useful
Comparable	The KPI allows comparison over time, activities, or standards
Reliable	The KPI can be proven its accuracy by means of validation and verification
Practical	The KPI can be implemented, complexity of measurement feasible (10 week project time constraint) and data is available

Scoring scheme

The following is the scoring scheme for each KPI based on every criterion. Scores should be given in whole numbers between (and including) 1-5 for all criterions of each KPI. The numbers correspond to the description stated in the table below.

Score	1	2	3	4	5
Description	Poor	Insufficient	Neutral	Sufficient	Good

KPIs

The following are the KPIs obtained from literature study. The goal is to have between 5-10 KPIs measured and visualized in a performance dashboard. Final selection of KPIs will go through aggregating the score by weighted criteria. Please note that the data tables are based on the Open Trip Model database, Officedog, by Bullit Digital. The list of tables can be found in the Appendix.

Please fill in the table below:

KPI	Understandable	Relevant	Comparable	Reliable	Practical
Number of accidents					
On-time delivery %					
Complete order fill rate					
Number of shipments per terminal territory					
Days order late					

Empty kilometers %					
Driver turnover rate					
CO_2 emissions from transport processes					
Delivery lead time					
Number of orders processed per unit of time					
Orders late per terminal territory					
Damage return rate					
Average miles per gallon (or KMs per liter)					
Cost per kilometer					
Other KPI(s) unmentioned and worth measuring:					

APPENDIX D – KPI SELECTION USING AHP WEIGHTING

Criteria pairwise comparison scores

	Understandable	Relevant	Comparable	Reliable	Practical
Understandable	**1**	**1/4**	**2**	**2**	**1/4**
Relevant	**4**	**1**	**5**	**6**	**1/3**
Comparable	**1/2**	**1/5**	**1**	**3**	**1/7**
Reliable	**1/2**	**1/6**	**1/3**	**1**	**1/6**
Practical	**4**	**3**	**7**	**6**	**1**

Priority weights

	Cat	Priority	Rank	(+)	(-)
1	Understandable	10.2%	3	2.8%	2.8%
2	Relevant	28.8%	2	9.1%	9.1%
3	Comparable	7.5%	4	3.5%	3.5%
4	Reliable	4.8%	5	1.9%	1.9%
5	Practical	48.7%	1	20.4%	20.4%

Number of comparisons = 10
Consistency Ratio CR = 6.4%

KPI Scores

KPI	Understandable	Relevant	Comparable	Reliable	Practical	Weighted Score
Number of accidents	4.25	4.25	4.5	4.25	3.25	3.75625
On-time delivery %	4.75	4.75	5	3.75	3.25	3.96175
Complete order fill rate	5	4.75	4.75	4	4	4.34575
Number of shipments per terminal territory	4.25	3.25	4	4	4	3.79
Days order late	4.5	4.5	5	4	3.75	4.12125
Empty kilometers %	3.75	4.75	4.75	3.75	2.75	3.5975
Driver turnover rate	3.25	4.25	4.75	3	2	3.00425
CO2 emissions from transport processes	3.25	3.75	4.5	3	2.75	3.20975
Delivery lead time	4.25	4.25	4.75	4	3.75	4.0065
Number of orders processed per unit	4.75	4	4.75	4.75	4.75	4.51

of time						
Orders late per terminal territory	3.75	3.25	3.75	3.5	3.5	3.45275
Damage return rate	4	3.75	3.5	3.5	3	3.357
Average miles per gallon (or KMs per liter)	4.25	3.75	4.75	4	3.5	3.74375
Cost per kilometer	2.5	5	4.5	2.5	2.25	3.21825

***Green: Top 1-5; Yellow: Top 6-10**

APPENDIX E – POPULATED EXCEL TABLES

actorId	name	externalAttributes	creationDate	phone	contactName	email	iban	vatCode	gln
EMO	Emons BV								
GCL	Glass Company Ltd.								
CUS1	Customer1								
CUS2	Customer2								
CUS3	Customer3								
CUS4	Customer4								
CUS5	Customer5								
CUS6	Customer6								
CUS7	Customer7								
CUS8	Customer8								
CUS9	Customer9								

	A	B	C	D	E	F
1	consignmentId	name	consignmentStatus	externalAttributes	creationDate	description
2	COS1		requested			
3	COS2		requested			
4	COS3		requested			
5	COS4		requested			
6	COS5		requested			
7	COS6		requested			
8	COS7		requested			
9	COS8		requested			
10	COS9		requested			
11	COS10		requested			
12	COS11		requested			
13	COS12		requested			
14	COS13		requested			
15	COS14		requested			
16	COS15		requested			
17	COS16		requested			
18	COS17		requested			
19	COS18		requested			
20	COS19		requested			
21	COS20		requested			
22	COS21		requested			
23	COS22		requested			
24	COS23		requested			
25	COS24		requested			
26	COS25		requested			
27	COS26		requested			
28	COS27		requested			
29	COS1		accepted			
30	COS2		accepted			
31	COS3		accepted			
32	COS4		accepted			
33	COS7		accepted			
34	COS8		accepted			
35	COS9		accepted			
36	COS10		accepted			

Actors | Consignments | Locations | Routes | TransportOrders | Trips | Vehicles | Actions | Enums | Orders processed per time | Complete o ...

	A	B	C	D	E	F	G	
1	locationId	name	locationType	addressCity	addressCountry	administrativeName	administrativeStreet	administrat
2	W1ENS	Glass Company Warehouse 1	warehouse	Enschede	NL			
3	W2ROT	Glass Company Warehouse 2	warehouse	Rotterdam	NL			
4	W3GRO	Glass Company Warehouse 3	warehouse	Groningen	NL			
5	C1AMS	Customer 1	customer	Amsterdam	NL			
6	C2MAA	Customer 2	customer	Maastricht	NL			
7	C3ROT	Customer 3	customer	Rotterdam	NL			
8	C4EIN	Customer 4	customer	Eindhoven	NL			
9	C5HEN	Customer 5	customer	Hengelo	NL			
10	C6GRO	Customer 6	customer	Groningen	NL			
11	C7UTR	Customer 7	customer	Utrecht	NL			
12	C8ALM	Customer 8	customer	Almere	NL			
13	C9BRE	Customer 9	customer	Breda	NL			
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								

Actors | Consignments | Locations | Routes | TransportOrders | Trips | Vehicles | Actions | Enums | Orders processed per time | Complete o ...

routeId	name	externalAttributes	creationDate	constraintId
ENS2AMS		170		
ENS2MAA		244		
ENS2ROT		204		
ENS2EIN		186		
ENS2HEN		10		
ENS2GRO		148		
ENS2UTR		156		
ENS2ALM		153		
ENS2BRE		210		
ROT2AMS		78		
ROT2MAA		203		
ROT2ROT		5		
ROT2EIN		116		
ROT2HEN		192		
ROT2GRO		245		
ROT2UTR		62		
ROT2ALM		100		
ROT2BRE		53		
GRO2AMS		180		
GRO2MAA		335		
GRO2ROT		245		
GRO2EIN		260		
GRO2HEN		138		
GRO2GRO		5		
GRO2UTR		188		
GRO2ALM		154		
GRO2BRE		255		

Actors | Consignments | Locations | Routes | TransportOrders | Trips | Vehicles | Actions | Enums | Orders processed per time | Complete o ...

transportOrderId	name	externalAttributes	creationDate	description
ORD1				
ORD2				
ORD3				
ORD4				
ORD5				
ORD6				
ORD7				
ORD8				
ORD9				
ORD10				
ORD11				
ORD12				
ORD13				
ORD14				
ORD15				
ORD16				
ORD17				
ORD18				
ORD19				
ORD20				
ORD21				
ORD22				
ORD23				
ORD24				
ORD25				
ORD26				
ORD27				

Actors | Consignments | Locations | Routes | TransportOrders | Trips | Vehicles | Actions | Enums | Orders processed per time | Complete o ...

	tripId	name	tripStatus	externalAttributes	creationDate	vehicleId	constraintId
1	tripId	name	tripStatus	externalAttributes	creationDate	vehicleId	constraintId
17	W2C7		requested	62		V016	
18	W2C8		requested	100		V017	
19	W2C9		requested	53		V018	
20	W3C1		requested	180		V019	
21	W3C2		requested	335		V020	
22	W3C3		requested	245		V021	
23	W3C4		requested	260		V022	
24	W3C5		requested	138		V023	
25	W3C6		requested	5		V024	
26	W3C7		requested	188		V025	
27	W3C8		requested	154		V026	
28	W3C9		requested	255		V027	
29	W1C1		accepted	170		V001	
30	W1C2		accepted	244		V002	
31	W1C3		accepted	204		V003	
32	W1C4		accepted	186		V004	
33	W1C7		accepted	156		V007	
34	W1C8		accepted	153		V008	
35	W1C9		accepted	210		V009	
36	W2C1		accepted	78		V010	
37	W2C5		accepted	192		V014	
38	W2C6		accepted	245		V015	
39	W2C7		accepted	62		V016	
40	W3C1		accepted	180		V019	
41	W3C3		accepted	245		V021	
42	W3C5		accepted	138		V023	
43	W3C6		accepted	5		V024	
44	W3C7		accepted	188		V025	
45	W3C8		accepted	154		V026	
46	W3C9		accepted	255		V027	

Actors | Consignments | Locations | Routes | TransportOrders | Trips | Vehicles | Actions | Enums | Orders processed per time | Complete o ...

	vehicleId	name	externalAttributes	creationDate	vehicleType	fuel	maxLinks	loadCapacities	length	height	width	licensePlate	emptyWeigh
2	V001	Truck Carrier 1											
3	V002	Truck Carrier 2											
4	V003	Truck Carrier 3											
5	V004	Truck Carrier 4											
6	V005	Truck Carrier 5											
7	V006	Truck Carrier 6											
8	V007	Truck Carrier 7											
9	V008	Truck Carrier 8											
10	V009	Truck Carrier 9											
11	V010	Truck Carrier 10											
12	V011	Truck Carrier 11											
13	V012	Truck Carrier 12											
14	V013	Truck Carrier 13											
15	V014	Truck Carrier 14											
16	V015	Truck Carrier 15											
17	V016	Truck Carrier 16											
18	V017	Truck Carrier 17											
19	V018	Truck Carrier 18											
20	V019	Truck Carrier 19											
21	V020	Truck Carrier 20											
22	V021	Truck Carrier 21											
23	V022	Truck Carrier 22											
24	V023	Truck Carrier 23											
25	V024	Truck Carrier 24											
26	V025	Truck Carrier 25											
27	V026	Truck Carrier 26											
28	V027	Truck Carrier 27											
29	V028	Truck Carrier 28											
30	V029	Truck Carrier 29											
31	V030	Truck Carrier 30											

Actors | Consignments | Locations | Routes | TransportOrders | Trips | Vehicles | Actions | Enums | Orders processed per time | Complete o ...

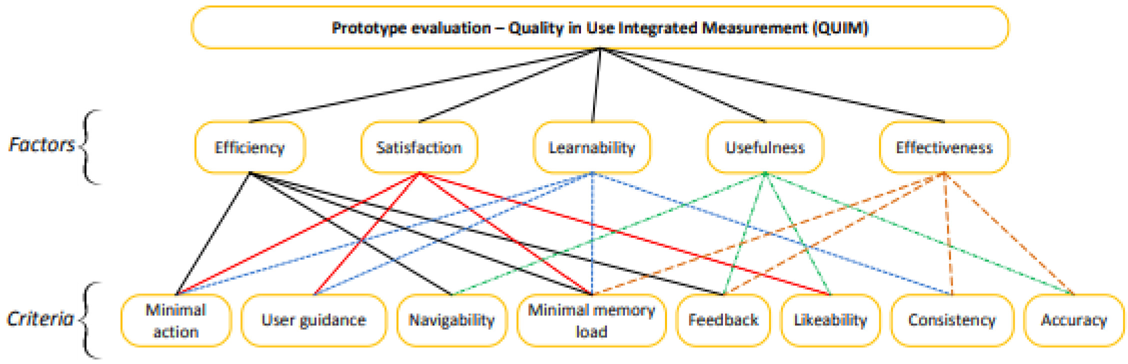
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	**actionId**	**actionType**	**lifecycle**	**name**	**startTime**	**endTime**	**sequenceNr**	**tripId**	**vehicleId**	**locationId**	**routeId**	**goodsId**	**consignmentId**	**fromLocationId**	**toLocationI**
86	4	move	realized	Order from W1 (ENS) to CUS4 (EIN)	15-10-22 16:59	15-10-22 22:59		W1C4	V004	W1ENS	ENS2EIN		COS4	W1ENS	C4EIN
87	7	move	realized	Order from W1 (ENS) to CUS7 (UTR)	15-10-22 10:56	15-10-22 13:26		W1C7	V007	W1ENS	ENS2UTR		COS7	W1ENS	C7UTR
88	8	move	realized	Order from W1 (ENS) to CUS8 (ALM)	8-10-22 15:46	8-10-22 17:56		W1C8	V008	W1ENS	ENS2ALM		COS8	W1ENS	C8ALM
89	9	move	realized	Order from W1 (ENS) to CUS9 (BRE)	11-10-22 12:31	11-10-22 15:31		W1C9	V009	W1ENS	ENS2BRE		COS9	W1ENS	C9BRE
90	10	move	realized	Order from W2 (ROT) to CUS1 (AMS)	28-10-22 11:29	28-10-22 12:49		W2C1	V010	W2ROT	ROT2AMS		COS10	W2ROT	C1AMS
91	14	move	realized	Order from W2 (ROT) to CUS5 (HEN)	29-10-22 17:30	29-10-22 20:30		W2C5	V014	W2ROT	ROT2HEN		COS14	W2ROT	C5HEN
92	15	move	realized	Order from W2 (ROT) to CUS6 (GRO)	11-10-22 8:55	11-10-22 12:00		W2C6	V015	W2ROT	ROT2GRO		COS15	W2ROT	C6GRO
93	16	move	realized	Order from W2 (ROT) to CUS7 (UTR)	12-10-22 15:32	12-10-22 16:32		W2C7	V016	W2ROT	ROT2UTR		COS16	W2ROT	C7UTR
94	19	move	realized	Order from W3 (GRO) to CUS1 (AMS)	20-10-22 8:45	20-10-22 11:45		W3C1	V019	W3GRO	GRO2AMS		COS19	W3GRO	C1AMS
95	21	move	realized	Order from W3 (GRO) to CUS3 (ROT)	8-10-22 9:55	8-10-22 14:55		W3C3	V021	W3GRO	GRO2ROT		COS21	W3GRO	C3ROT
96	23	move	realized	Order from W3 (GRO) to CUS5 (HEN)	13-10-22 13:56	13-10-22 16:56		W3C5	V023	W3GRO	GRO2HEN		COS23	W3GRO	C5HEN
97	24	move	realized	Order from W3 (GRO) to CUS6 (GRO)	5-10-22 14:23	5-10-22 14:53		W3C6	V024	W3GRO	GRO2GRO		COS24	W3GRO	C6GRO
98	25	move	realized	Order from W3 (GRO) to CUS7 (UTR)	4-10-22 15:29	4-10-22 19:29		W3C7	V025	W3GRO	GRO2UTR		COS25	W3GRO	C7UTR
99	26	move	realized	Order from W3 (GRO) to CUS8 (ALM)	1-11-22 17:35	1-11-22 19:00		W3C8	V026	W3GRO	GRO2ALM		COS26	W3GRO	C8ALM
100	27	move	realized	Order from W3 (GRO) to CUS9 (BRE)	1-11-22 14:54	1-11-22 20:54		W3C9	V027	W3GRO	GRO2BRE		COS27	W3GRO	C9BRE
101	1	handOver	realized	Order from W1 (ENS) to CUS1 (AMS)	5-11-22 17:34	5-11-22 17:34		W1C1	V001	C1AMS	ENS2AMS		COS1	W1ENS	C1AMS
102	2	handOver	realized	Order from W1 (ENS) to CUS2 (MAA)	29-10-22 16:14	29-10-22 16:14		W1C2	V002	C2MAA	ENS2MAA		COS2	W1ENS	C2MAA
103	3	handOver	realized	Order from W1 (ENS) to CUS3 (ROT)	6-11-22 20:22	6-11-22 20:22		W1C3	V003	C3ROT	ENS2ROT		COS3	W1ENS	C3ROT
104	4	handOver	realized	Order from W1 (ENS) to CUS4 (EIN)	15-10-22 22:59	15-10-22 22:59		W1C4	V004	C4EIN	ENS2EIN		COS4	W1ENS	C4EIN
105	7	handOver	realized	Order from W1 (ENS) to CUS7 (UTR)	15-10-22 13:26	15-10-22 13:26		W1C7	V007	C7UTR	ENS2UTR		COS7	W1ENS	C7UTR
106	8	handOver	realized	Order from W1 (ENS) to CUS8 (ALM)	8-10-22 17:56	8-10-22 17:56		W1C8	V008	C8ALM	ENS2ALM		COS8	W1ENS	C8ALM
107	9	handOver	realized	Order from W1 (ENS) to CUS9 (BRE)	11-10-22 15:31	11-10-22 15:31		W1C9	V009	C9BRE	ENS2BRE		COS9	W1ENS	C9BRE
108	10	handOver	realized	Order from W2 (ROT) to CUS1 (AMS)	28-10-22 12:49	28-10-22 12:49		W2C1	V010	C1AMS	ROT2AMS		COS10	W2ROT	C1AMS
109	14	handOver	realized	Order from W2 (ROT) to CUS5 (HEN)	29-10-22 20:30	29-10-22 20:30		W2C5	V014	C5HEN	ROT2HEN		COS14	W2ROT	C5HEN
110	15	handOver	realized	Order from W2 (ROT) to CUS6 (GRO)	11-10-22 12:35	11-10-22 12:35		W2C6	V015	C6GRO	ROT2GRO		COS15	W2ROT	C6GRO
111	16	handOver	realized	Order from W2 (ROT) to CUS7 (UTR)	12-10-22 16:32	12-10-22 16:32		W2C7	V016	C7UTR	ROT2UTR		COS16	W2ROT	C7UTR
112	19	handOver	realized	Order from W3 (GRO) to CUS1 (AMS)	20-10-22 11:45	20-10-22 11:45		W3C1	V019	C1AMS	GRO2AMS		COS19	W3GRO	C1AMS
113	21	handOver	realized	Order from W3 (GRO) to CUS3 (ROT)	8-10-22 14:55	8-10-22 14:55		W3C3	V021	C3ROT	GRO2ROT		COS21	W3GRO	C3ROT
114	23	handOver	realized	Order from W3 (GRO) to CUS5 (HEN)	13-10-22 16:56	13-10-22 16:56		W3C5	V023	C5HEN	GRO2HEN		COS23	W3GRO	C5HEN
115	24	handOver	realized	Order from W3 (GRO) to CUS6 (GRO)	5-10-22 14:53	5-10-22 14:53		W3C6	V024	C6GRO	GRO2GRO		COS24	W3GRO	C6GRO
116	25	handOver	realized	Order from W3 (GRO) to CUS7 (UTR)	4-10-22 19:29	4-10-22 19:29		W3C7	V025	C7UTR	GRO2UTR		COS25	W3GRO	C7UTR
117	26	handOver	realized	Order from W3 (GRO) to CUS8 (ALM)	1-11-22 21:35	1-11-22 21:35		W3C8	V026	C8ALM	GRO2ALM		COS26	W3GRO	C8ALM
118	27	handOver	realized	Order from W3 (GRO) to CUS9 (BRE)	1-11-22 20:54	1-11-22 20:54		W3C9	V027	C9BRE	GRO2BRE		COS27	W3GRO	C9BRE
119															
120															

Actors | Consignments | Locations | Routes | TransportOrders | Trips | Vehicles | Actions | Enums | Orders processed per time | Complete o ...

APPENDIX F – ASSESSMENT SURVEY

Assessment survey questions are answered on a scale from 1-5, 1 being strongly disagree and 5 being strongly agree. The questions and the average scores obtained from responses are as below:

1. The dashboard achieves its function in a minimal number of steps (minimal action)
   Score: 4
2. The user interface provides help or feedback in case of an error or inconvenience (user guidance)
   Score: 2.7
3. User is able to move around the dashboard efficiently (navigability)
   Score: 4.3
4. User is only required minimal information in mind to achieve a task in the dashboard (minimal memory load)
   Score: 4.3
5. The dashboard is responsive to user inputs (feedback)
   Score: 2.5
6. The dashboard is visually appealing (likeability)
   Score: 4
7. Elements of the dashboard convey consistent information of the same theme (consistency)
   Score: 3.3
8. The information provided by the dashboard appear to show meaningful results (accuracy)
   Score: 4
9. General feedback and/or concerns regarding the dashboard (Free answer)
   - Nice, compact
   - Lack of exception filtering for detailed data analysis



Factor	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Final Score
Efficiency	4	4.3	4.3	2.5	**3.8**
Satisfaction	4	2.7	4.3	4	**3.8**
Learnability	4	2.7	4.3	3.3	**3.8**
Usefulness	4.3	2.5	4	4	**3.7**
Effectiveness	4.3	2.5	3.3	4	**3.5**

*Criteria hold equal weight (25%)