MindFuel

Product-Service System implementation for truck fueling optimization business case

Master of Science Thesis in the Master Degree Program, Industrial Design Engineering

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CHALMERS UNIVERSITY OF TECHNOLOG
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Department of Product- and Production Development
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Abstract

The current project is triggered from a business opportunity in a new optimization area —truck refueling optimization—, coming from a big data analysis that exposed inefficient refueling in terms of unused fuel load which increases consumption. This unused fuel capacity comes mainly as a result of early refueling, i.e., too high fuel levels at the moment of refueling. Thus, *MindFuel*, the business case where this project is founded on, opens up for a new perspective of effective realisation, further considering driver behavior and involving stakeholders for the implementation of a product-service system. By exploring the reality of trucking and the state of the art of refueling related research, where little to no equivalents to the principles of MindFuel where found, a basis was set for a set of surveys and interviews with truck drivers, transport managers and other experts. In framing the concept design, it was valuable to check that some drivers showed certain skepticism for the foundational initial idea behind MindFuel, and thus there was a narrow window of willingness for time/effort dedication for the usage of a product that would implement it. Nonetheless, trip scenario simulations showed that when using average tank capacities there is actually a considerable margin for several refueling alternatives. A comprehensive problem area phase, gathering the most relevant challenges, led to a list of requirements that is valuable on its own as an outcome of the project, prescripting how a system like MindFuel should act in such a narrow action window, where the driver should not be disturbed nor demanded in excess, while still having a chance of getting results. An ideation process centered on requirement-compelling functions, as well as on an optimized multi platform interface led to a concept that provides multiple ways and choices to adapt the refuelling optimization to the diverse trucking industry: several tools and data available for the dispatcher, different fleet profiles, and individual driver preferences.

This report is written in English.

Keywords: *fueling, refueling, refueling optimization, fueling behavior, mindfuel, truck, fuel consumption, driver behavior.*

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Glossary & abbreviations

Fuel and MindFuel

FE: fuel efficiency

OA: optimization alternative/strategy for refueling, (OA1: eco, OA2: cargo, OA3: time).

FTLL: fuel tank level limit

FTL: fuel tank level

Logistics and weights

DTC: delivery timeframe compliance

Transport manager/planner, dispatcher: manages and allocates available carrying capacity.

Fleet manager: makes sure that transport capacity is available.

GVW: Gross vehicle weight *(check 'trucks' point under section 3.1.1)*

GCW: Gross combined weight *(check 'trucks' point under section 3.1.1)*

1 Introduction

This section introduces both the background and the trigger business case upon which the project has foundation. Some of the background information is sourced on this previous research, which was completed, reviewed and updated with current research.

1.1 Background

Volvo Group Telematics and Volvo Trucks have worked together to gain new insight in commercial truck usage, based on big data exploration. An analysis of fueling behavior of Dynafleet's (Volvo's Fleet Management Software) total population concluded that around a quarter of the fuel tank capacity could be optimized (Figure 1) on average. A business opportunity was found in the area of fuel optimization as a result of inefficient refilling practices, i.e., unused fuel load is carried due to early refilling and other behaviors. The resulting business case, namely MindFuel, opened up for implementation, further considering driver behavior in order to support new services within fuel advice.

Fuel efficiency, a priority in fleet management

The unpredictability of fuel prices in the recent times has made fuel efficiency one of the most important priorities in truck fleet management. Moreover, fuel expenditure has become the highest operational cost, supposing around 30% of total expenses (Antich, 2013). On the other hand, the dramatic increase of CO_2 emissions in the last years, growing 45% from 1990 to 2007 and expected to rise 40% more until 2030, encouraged the European Union to increase emissions reduction measures, setting the goal of reducing CO_2 emissions in transport by at least 60% (Staubach et al., 2013).

Consequently, consistent efforts have been taken to minimise and optimize fuel spend. Several strategies involving the revision of vehicle specifications and the development of more fuel-efficient components and vehicles have been conducted, leading to savings up to 5-10% (Bektas and Laporte, DEFRA, Demir et al., Nylund; cited in Staubach et al., 2013). What is more, latest investigations have been focusing on driving behavior in order to tackle this issue. In fact, practices such as reducing vehicle's idling time have demonstrated to be able to lead up to 19% savings (Illinois Green Fleets Organization, 2014). Nevertheless, the costs tied to the technology needed to support drivers while resting or waiting, difficult its implementation. Furthermore, recent studies show that although eco-driving behaviors can decrease fuel consumption up to 10-15% right after the training, the impact of the training decreases after 3 months down to 4-5%, ending up in differences in savings of around 2% in the long run for experienced drivers (Wåhlberg, 2007 and Zarkadoula et al., 2007). This considerable figure highlighted the need of finding alternatives able to lead to higher compliance rates.

Refueling optimization

In this context, the extensive data analysis carried by Volvo Telematics revealed that above the reserve 10% of the tank, another quarter of the tank fuel is unused on average (Figure 1, “Before”). This means not only unused extra weight is carried increasing fuel consumption, but also that refuelling is done more often than required, which negatively impacts on the productivity.

Three optimization alternatives

These insights led to 3 different *optimization alternatives* (OA, from now on) shown in figure 1. First, the partial “fill up” (later called “ECO” in the new concept), which consists in not filling more fuel than the used until the next refill plus the 10% reserve margin. The resulting decrease on average weight reduces fuel consumption and emissions. Second, The partial “fill up” + cargo (“CARGO” in the new concept”), which uses the same optimizable capacity to increase the amount of cargo. Finally, “fill up” till max. (“TIME” in the final concept) uses all the fuel tank, reducing the amount of stops to cover a certain distance. These alternatives are interchangeable and combinable depending on variables such as the gas station availability, delivery timeframes, fuel consumption or type of cargo.

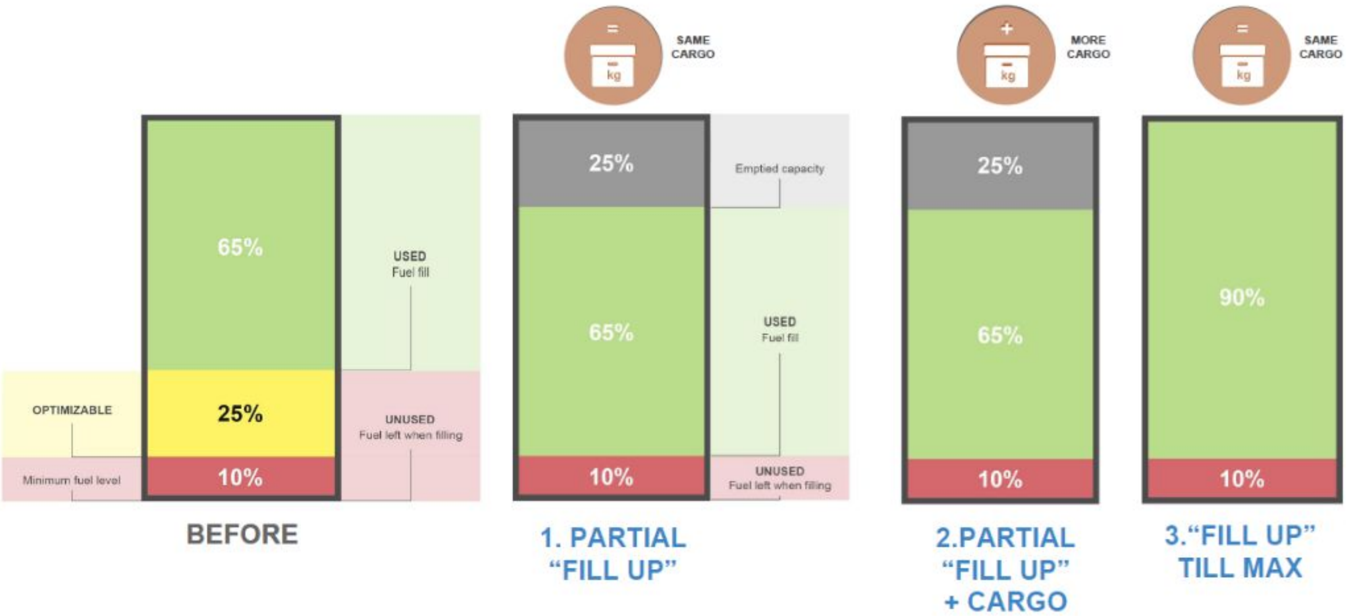


Figure 1: Fueling behavior of average Dynafleet population (“Before, left”) and fueling OAs (1., 2., and 3,).

All in all, MindFuel provides value and reduces environmental impact by either optimizing fuel refill to enable more cargo, saving fuel weight to optimize fuel consumption, and/or time. The business case concluded that the OAs had potential to led up to an increase of 0.77% in savings (due to reduction of consumption and fueling events) and 0.93% in income (due to the increased cargo volume), according to the base case. However, those numbers came from a concrete fleet analysis, with a specific value of cargo (in that case, dry bulk). Therefore, it was concluded that further investigation should be done, comparing different fleet and cargo types.

1.2 User and context

In the current trucking and logistics context, many factors are essential to the current concept implementation, like drivers needing to stop driving every 4 ½ hours, refueling, or coordinating this with vital needs. Moreover, drivers must justify their work activities in the tachograph, and face issues like parking scarcity, or dealing with payment variables (more common in the US).

In a more technical level, understanding truck categories, combination types and permitted weights is essential to see how cargo can be optimized. On another subject, drivers only stop in stations that fit a truck of their size and that have a pump of the supplier their fleet has an agreement with. Cargo, route and shipment types are also varied, ranging from, e.g., specialized refrigerated semitrailers to long combination bulk cargo trucks. There are also considerable differences and variety in the routes, load/unload schedules and means of loading and unloading. Last but not least, the concept product proposed in this project is set in the fleet management systems framework, meaning it depends on a set of information that is recorded, coded, and selectively sent via wireless technology to allow services like Dynafleet work. These are ruled by standards that are quite popular among the industry for matters like efficient driving, additional tachograph justification, or advanced functionality linked to fuel efficiency and machine learning.

1.3 Project stakeholders

Executive user, truck driver

The primary user, truck drivers, directly affect the optimization of fueling in their practices. In this case, the selected segment is long hauling (long trips) drivers driving within Sweden, as their bigger fuel tanks present larger optimization margins when compared to distribution vehicles. Moreover, the drivers would benefit from the implementation of MindFuel in terms of fuel stops reduction and potential motivation resulting from a direct contribution to reduction of emissions.

Co-user and customer, fleet manager

Furthermore, fleet manager/dispatchers will also be directly involved, both in the planning of the overall refuelling strategy as well as in the truck-trip allocation. Depending on the optimization alternative chosen, fleet owners/dispatchers can benefit from enabling more cargo in the trucks, reduce consumption and fueling stops as well as contributing to the reduction of emissions.

Service provider: Volvo Group Telematics, Volvo Trucks

Volvo would benefit by delivering a highly personalised service, offering a customizable service that comprehends users and thus a high quality customer experience. What is more, the business case is in line with Volvo’s brand identity and core values (safety, quality and environment).

1.4 Value proposition of trigger case

The current section provides an overview of the value proposition that had been presented in the initial MindFuel's business case, prior to this project.

1.4.1 General value proposition

The value proposition explained below is broken down in the following categories: fuel and Diesel Exhaust Fluid consumption, cost of capital, overweight fine reduction, enable more cargo, fuel stops reduction, tank design change opportunities, lifetime of the truck and reduction of emissions. Note that the impact of all of this factors will highly depend on the selected OA for each particular case.

Fuel and Diesel Exhaust Fluid consumption

Due to the reduction of the optimizable unused fuel, the truck transports less average weight (figure 2). This fact is particularly interesting for the optimization alternatives partial "fill up" and "fill up" till max since it significantly affects the bottom line, leading to a reduction of 0,5% and 0,25% in the total Dynafleet population case respectively.

Cost of capital

Having the data from Dynafleet total population as a basis, the current fueling behavior shows that fleet owners are not using 35% of the capital invested in fueling up the truck. Since there is a way to optimize 25% of the tank, the fleet owner gets an opportunity to use 25% of the capital, in this case, around 3 000 SEK per truck per refill cycle.

Overweight fine reduction

On average, 19,8% of trucks in Sweden get one overweight fine per year for transporting an extra load of 1000 kg, supposing an average fine of 6000 kr (according to transportstyrelsen). Since 2000 kr is the base penalty and an additional fine of 400 kr per each extra 100 kg is applied, a reduction of optimizable unused fuel transported leads to a reduced average fine. This strategy is applicable in the partial "fill up" and "fill up" till max alternatives.

Enable more cargo

Emptying the optimizable unused fuel capacity leads to the opportunity of adding the proportional weight in cargo, thus making this approach a potential source of income. The optimization alternative partial "fill up" + cargo follows this logic (figure 3).

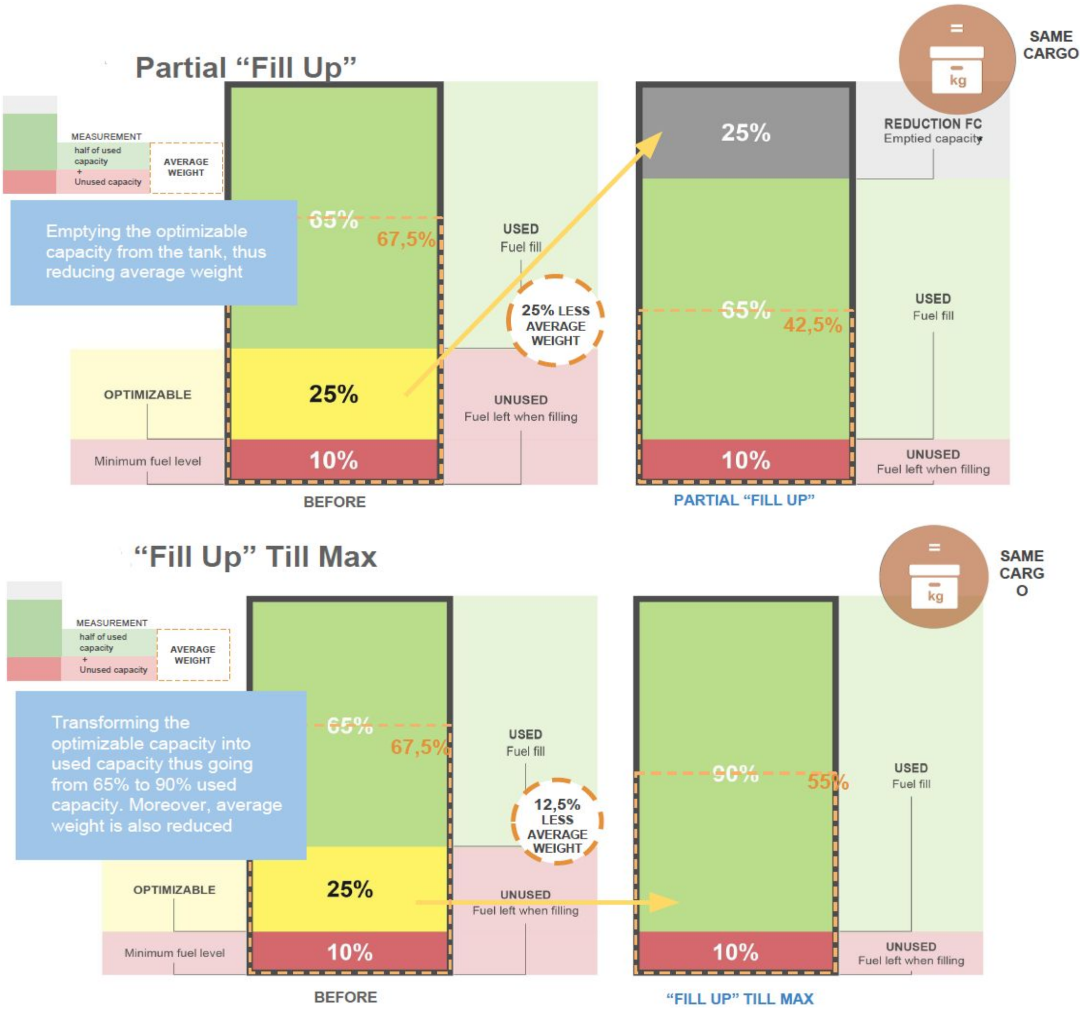


Figure 2: trigger case: reduction in consumption on partial “fill up” and “fill up” till max.

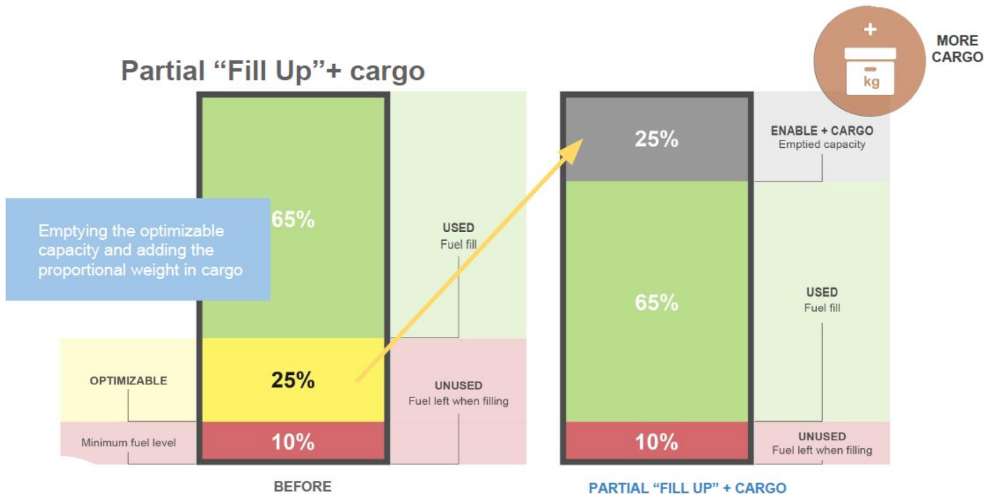


Figure 3: trigger case: enabling more cargo by emptying the optimizable unused fuel.

Reduction of fuel stops

The fuel tank representation on the left (figure 4) shows the current average Dynafleet population behavior, where every time trucks are fueled with 585 L of diesel. With optimizing strategy "Fill Up" till max. 810 L of diesel can be fueled up every time the truck goes to a gas station. Increase of an amount of fuel per fueling event leads to lower amount of events in total.

Lifetime of a truck

A more efficient utilisation of the truck, with a reduction of the weight transported supposes less impact on the component wear and therefore , an extended lifetime of the vehicle.

Reduction of CO2 emissions

Especially when applying the optimization alternative partial "fill up", consumption and hence brings CO2 emissions are reduced, as shown in figure 5.

Tank design change opportunities

Knowing the fuel consumption of each truck and being able to forecast the consumption of the different types of trips allows to determine how much fuel is needed and how much is disposable in the tank of each vehicle. This information opens up opportunities for providing more accurate customer assistance for choosing the adequate fuel tank.

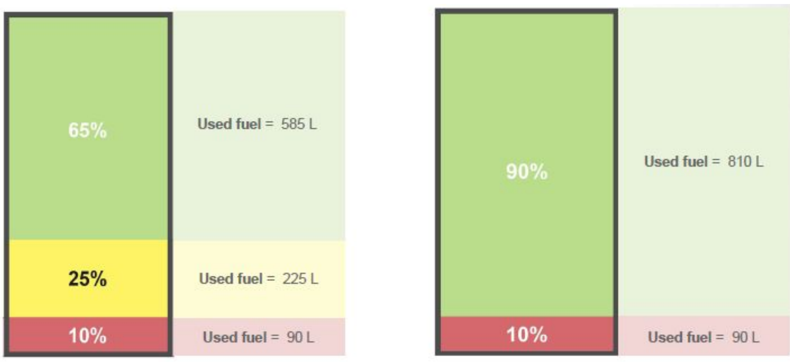


Figure 4: Fuel stops reduction due to increased used fuel capacity; "before" (left) versus "fill up till max." alternative (right).

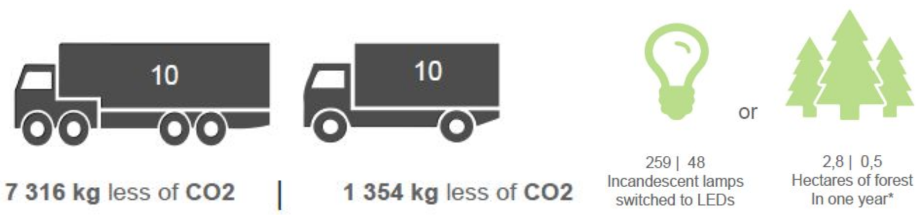


Figure 5: Annual emissions reduction applying partial "fill up" for an average truck fuel tank of 900 L).

1.4.2 Initial use variables and alternatives

Having the previous background as framework, initial use cases had been developed. The most relevant variables for defining the use cases had been defined, and are described below:

1. Truck tank size and route length: these define the base refill optimization possibilities.
2. Type of cargo: weight vs volume sensitive. It defines the possibility of adding more cargo (weight sensitive) or not (volume sensitive).
3. Number of drivers per truck: a constant driver assigned to one truck or several. The more drivers, the more complex it is influence the behavior within a truck. This is particularly true for OA1 and OA2, since the driver is additionally required to not fill the tank till the top.
4. Typical load quantity: only if the truck is usually fully loaded in a weight sensitive cargo case, then more cargo (extra cargo) can be added with OA2.
5. Deadline for delivery: strict (narrow windows) or less strict (several hours of range). It defines the criticality of OA3, “fill up” till max., the most time-saving option.
6. Fuel consumption: depends on the total weight, engine, model and brand of truck among others. Driving behavior also influences consumption greatly.
7. Possibility to find gas stations: higher or lower, and their location. It influences which alternative may be more reasonable (e.g. OA1 requires more stops frequency than OA3).

These variables had been classified as determinant and additive depending if the variable excludes or includes the selected OA, or adds or reduces value in case of choosing that alternative. This categorisation served to define which OA is more suitable for each situation.

1.5 Purpose

This section lists the initial goals of the project. Bear in mind this project is technology and business case triggered; thus, it does not focus on solving existing drivers’ needs.

- Identify driver behavior and preferences that correlate to inefficient refueling actions and related challenges/opportunities for the implementation of MindFuel.
- Understand how stakeholders and surrounding systems affect each other and MindFuel: the implementability within Volvo Trucks fuel related services and the reality of fleets when arranging trips, the possible competition, and transport management systems.
- Discover driver motivations and concerns and how they can be implemented in the Product-Service System for user engagement or at least acceptance of the service.
- Develop a conceptual design proposal for the implementation of MindFuel, taking into account the insights gathered from the statements mentioned above.

2 Process & methods

The general design strategy employed for this project entailed a quite simple design process described by Cross (2008). It comprehends explorative, generative and evaluative phases, including frequent iteration between the last two, as well as communication, which spread particularly through the latest stages (figure 6 for process and methods overview).

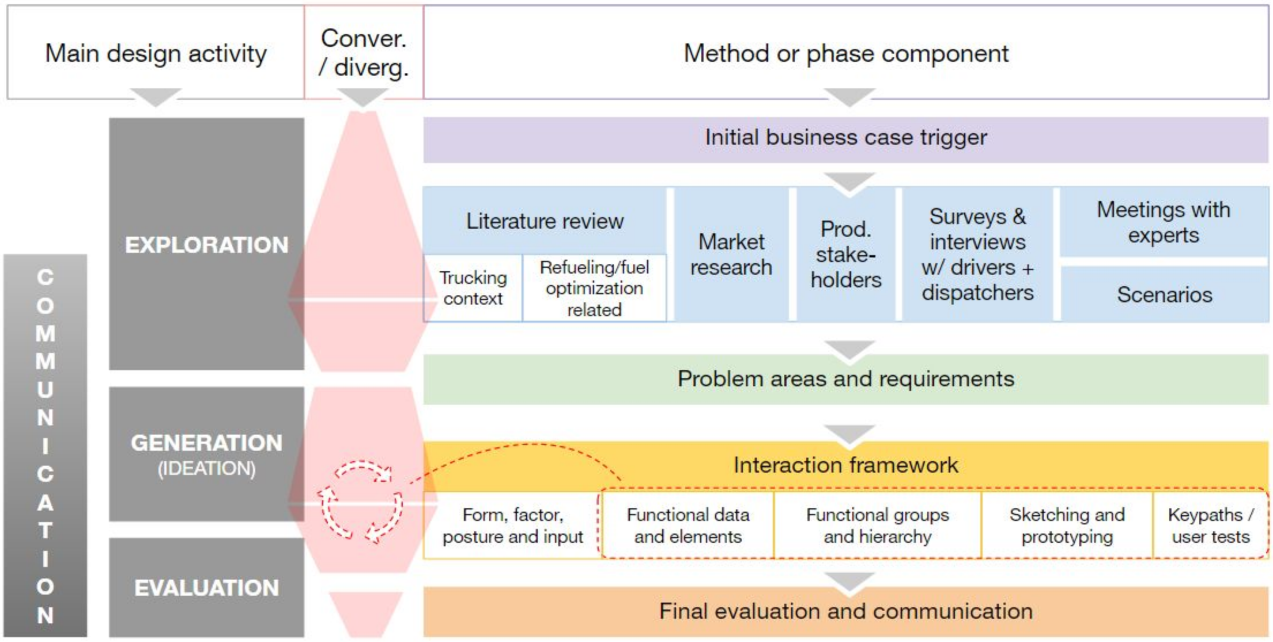


Figure 6: employed design process overview; design activities and methods.

Different actions and methods comprised the explorative phase, which mainly correspond to the 'Problem exploration' section in this report. First, a general revision and exploration of the initial triggering case was done, in order to set a solid and reviewed foundation. Then, a more specific literature review was conducted, mainly online, including engineering publications within refueling optimization and related topics. In parallel, a detailed trucking context understanding was attained, focusing on drivers and refueling, consulting a wider range of sources, from logistic agencies or reports, to official legislations, regulations, or even trucker forums and articles.

In this same stage, an online market research was also done for products that were considered relevant or worth knowing about for the current implementation, including eco-driving related interfaces, fleet and fuel management systems, fuel cards (not included here due to its eventual lesser relevance), and Volvo related services like Dynafleet or others that were clarified later on by experts (Fuel Advice, Fuel and Efficiency, Driver development…). This information required specific source types for each case. In addition, a basic research of the stakeholders within the logistic structures was required so the roles taking part in MindFuel could be clarified. This included early online search based in the consensus of various source types and later confirmation of experts through the different interviews and meetings.

The questionnaires (see appendix 9.4) and interviews with drivers and dispatchers were essential for this project. In designing these questionnaires several iterations were done together with Volvo workers as context findings were turning up. Moreover, these were refined after a first test survey. The questionnaires were composed of multiple choice answers, optional additional answers, valuation scale answers and open questions when relevant. These were printed and conducted explaining and guiding respondents when required. The questionnaires and interviews were carried out in Gothenburg at Stigs Center refueling location; Stena Terminal, a ship container loading terminal; and Halléns Transport AB offices, intermodal and drayage transportation company. A total of 2 fleet managers and 10 truck drivers answered the surveys.

Nonetheless, during the project it was early noticed that the relevant findings were qualitative and not about statistics, so surveys were also audio-recorded and merged in a process that would have been constantly adapted to the limited circumstances of each encounter, including language barriers and terminology adaptation or explaining the basic idea behind the concept. The method for the interviews was based on having the questionnaires as a base script and deepening in topics that appeared relevant through the conversation, or issues the interviewee would bring up related to mentioned topics. Meetings with experts (Volvo Trucks engineering and Fuel services) were also recorded, transcribed and conducted in a similar fashion, aiming to pragmatically refine the scope of the project for its implementability within the industry and the current company.

Additionally, trip scenarios were also simulated in spreadsheets in order to grasp the magnitude of different variables in assumable simulated situations and have a better global understanding, for each of the alternatives and known trip profiles or patterns. This simulation was generated ad hoc for the project and it is explained in the scenarios section (3.3.6), so there is no formal method beyond what one could call a variable-driven scenario simulation.

All this research was gathered into different categories of problem areas (section 3.4, fully available in appendix 9.5) was employed as an overall detailed checklist to come to a comprehensive requirements and wishes list. The requirement list was used as a means of converging a substantial part of the insights that the explorative core brought, beyond just being an evaluative checklist as it may be in other cases.

Entering the ideation phase, it worth mentioning that opposedly to more typical Industrial Design Engineering, a number of differentiable pre-concepts to choose from were not generated at any stage. A reason for this was the general implementation framework of the project, which had been leaning more and more towards a non physical, specific app-based product as the implementability and usefulness of technologies were narrowing down due to company indications (Dynafleet context, for example) and the simplicity (attain gains with very little) and low margin optimization that characterized the initial business case. Another reason was the acceptability of key stakeholders (dispatchers, drivers), who ended up being rather constraining towards specific functionality.

For all these reasons, the interaction design framework described by Cooper (2014) was found appropriate in order to design a multiple platform graphical user interface suited for each use within the different roles in the logistics company. The main steps shaping this process described next are the ones that Cooper (2014) lists in figure 7.

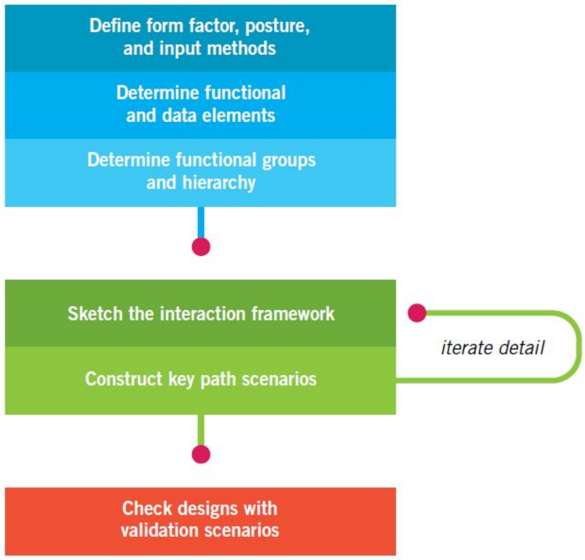


Figure 7: interaction design framework definition process (Cooper, 2014).

Thus, the form was first defined according to the platforms specified in the requirements (smartphone and onboard screen for drivers and desktop for dispatchers). The postures were discussed after, meaning whether more sovereign (continued use, full dedication) or transient (side-assistant, screen sharing, less frequent use) attributes were desirable, as well as which trade-offs had to be considered in this sense (see section 4.1.1).

Functional elements, data elements and functions were subsequently defined following the conclusions from the exploration (requirements), as Cooper (2014), suggests "concrete manifestations of the functional and data requirements [...] identified earlier". He defines data elements as the fundamental objects of interactive products preferably fitting within users mental models. Cooper (2014) also defines functional elements as the "operations that can be done to the data elements and their representations in the interface" (management of data elements). In this process a little divergence would occur again by designing around functions (elements, hierarchies, grouping, relationships between different data and elements…), having an emphasis on understanding and solving questions like how to minimize user input and effort, or how different optimization alternatives would actually operate (see section 4.1.3).

This content was gradually merged towards the generation of sketches and prototypes, in constant small iterative steps, even after vector prototypes were being generated (what Cooper would call pixel level refinement). One of the critical tools to make sure the most important interaction was covered, was the use of keypaths which consider central scenarios generated by a logic narrative of the product use around which interaction would happen (Cooper, 2014). As an initial external evaluation, brief user tests were performed. Finally, in this report relevant features of the design are checked against requirements and wishes.

3 Problem exploration

The current chapter provides an overview of the problem exploration research conducted in the project. The problem exploration phase is broken down in five categories: literature review, market analysis, user studies and fieldwork, problem areas and requirements.

3.1 Literature review

The literature review conducted in this project aimed to set the main research areas that would help to set the general framework for further investigation. It is divided is seven subsections: first an introductory passage on relevant information about trucking, continuing with fuel consumption and the impact of truck weight, refueling, routing and planning in truck fleets, fuel theft, motivations of truck drivers and finally, Human-Machine Interaction displays in truck driving. The first and following point, 3.1.1, aims to provide a general picture about trucking and related topics.

3.1.1 Relevant general info about trucking

Hour regulations and tachograph

The EC regulation No 561/2006 (2006) provides a common set of European Union rules for maximum driving times: 9 h daily —10 h optional exemption twice a week—, 56 h weekly, and 90 h fortnightly. Minimum daily rest is 11 h, —9 h optional exemption thrice a week—. Daily rest can be split into 3 hours rest followed by 9 hour rest to make a total of 12 hours daily rest. This regulation also sets a weekly rest of 45 continuous hours—9 h optional exemption every second week—. Minimum driving breaks are set for 45 min —splittable into 15 + 30, and must be taken not later than after 4 ½ hours of driving.

Council Regulation (EU) No 165/2014 (2014) sets the basis for the tachograph to enforce driving time and resting regulations for professional drivers both to prevent fatigue, and guarantee fair competition and safety. Since 2006, digital tachographs —compulsory in vehicles over 3,5 t— provide more secure and accurate data: distance, speed, driving times and rest periods. The system includes a printer for road side inspections and the driver has a card to ensure inspections remain simple. Drivers must operate the four switch mechanisms in the tachograph enabling the system to distinguish between driving time, breaks/rest, other work —any work for the same or another employer other than driving—, an availability, which EC Directive 2002/15 (2002) defines as periods other than resting or breaks where the driver shall be available to answer calls and resume driving or carry other work —e.g., accompanying a vehicle in a ferry/train or waiting at frontiers/traffic prohibitions.

Common trucker problems

One of the most common and frequent problems for truckers worldwide is parking and traffic; as the Federal Highway Administration (2002) suggests for the U.S, the majority of parkings are not located near the most densely populated areas where demand for trucked goods is greatest. Prohibitions in commercial areas lead shippers and receivers preferring to ship in early and late hours resulting in congestion and safety compromises. A study by Parks (2009) also shows that sleep disorders and deprivation are a big risk factor.

Fuel, DEF and refueling in practice

The most common truck diesel type D2, is followed by D1 for cold conditions, which is more expensive to produce (Expeditersonline.com, 2007). The density of D2 is around 0,85 kg/L (Persianpetro.com, 2013). Freightbestpractice.org.uk (2009) says that in general, fuel equates to about 30% of total operating costs. Truck fuel is combined by injection in the exhaust stream a 2–6% rate with an aqueous urea solution (32.5%) called Diesel Exhaust Fluid (DEF) to lower the NO_x emissions from diesel engines, which is increasingly available in pumps at gas stations (Cummins Filtration, 2009). When it comes to the actual refueling, in a survey by Calstart.org (2013) we can observe the average stop is 20 min for refueling, of which around 5 min are spent in actual refueling. It is to consider that these stops add up to thousands of hours every year. Also, fuel is usually payed with fuel cards.

Truck configurations

There are many truck classifications. The type that is of interest in this project is O4 vehicle types in EU, which are vehicles with trailers above 10 tonnes of total weight that we will call long hauls. Within this category, different combinations can appear. Street class single-rigid trucks aside, it is apparent that the most common is a tractor attached to a —13,6 m standard (Larsson, 2009)— semitrailer. Multiple trailers can also be added in what is called LHVs (Longer and Heavier Vehicles), as long as 25,25m are not exceeded (Dutch Ministry of Transport, 2011). Within the LHV configuration we can find A to G configurations (figure 7). of these, the most common configuration is D, followed by A, B and E, as a in a fleet survey involving 118 logistic companies revealed (Dutch Ministry of Transport, 2011). As figure 7 suggests, tractors involved in LHV usually have 3 axles, but it is widely known that the ones dragging only a semi-trailer can also have 2 axles. Regarding the trailers themselves, semi trailers usually have three axles and —7,82 m standard (Larsson 2009)— trailers, most commonly, just two.

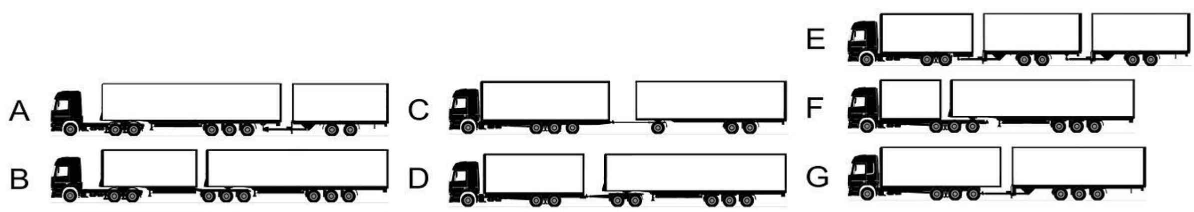


Figure 7: European Modular System LHV configurations.

Weight legislation and terminology

In order to understand the weight legislation it is essential to have a notion of the different common labels that refer to element's actual weights of element groups and maximum allowed weights that define legal overweight thresholds. Actual truck weights are commonly measured in terms of tractor tare (net weight of tractor) and trailer tare.

Allowed weights are more complex; the most employed are the following. Gross Vehicle Weight (GVW), specified for each tractor model by the manufacturer, defines the maximum permitted weight that a truck tractor can have, including a semitrailers' load that lays on it in case a semi trailer is attached. Gross Trailer Weight refers to the maximum weight loaded in the axles of a trailer or semitrailer, and it is usually specified in an attached plaque. Axle Weight refers to the maximum allowed load supported by any indicated axle, which in the case of the tractor, differs from axle to axle.

Last but not least, Gross Combination Weight (GCW), which is the maximum total weight of the full vehicle, and it is usually lower than the sum of GVW, and it is delimited by regulations and directives (Oastler, 2015; Gov.uk, 2017; and Tata Steel, 2013). Figure 8 brings some clarification to this respect. The latest EU directive 2015/719 sets a limit for most long haul vehicles of a Gross Combined Weight that, as it can be seen in the document by Tata Steel (2013), ranges between 40 tonnes —for most countries— and 50 t, where Sweden is allowed up to 60 tonnes in the case of some LHVs. Trucks carrying containers are allowed to weigh up till 44 tonnes in most of EU.

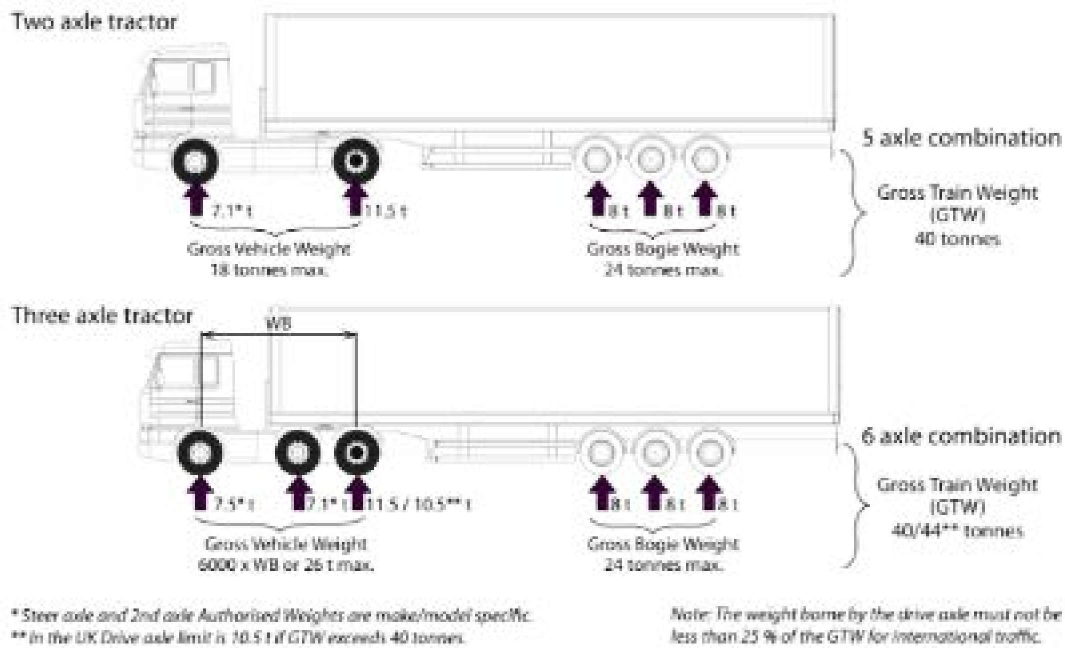


Figure 8: axle weight limits and combinations (Tata Steel, 2013).

Act (1972: 435) about overweight fines in sweden states a base penalty of 2000 SEK, that is increased by 400 SEK every 100 kg extra that are exceeded in eax axle. The margins for the base penalty are 500 kg of axle weight for exceeding the gross weight, and 1000 kg for the most loaded axle weight in the case of exceeding axle weight only.

Shipments

Cargo types

From the logistics point of view, cargo is most commonly seen as *container cargo* —already packed and apilable consumer goods, in a container—, *liquid bulk* —crude oil, vegetable oils...—, *dry bulk* —grain, coal, sugar, salt...— *break bulk or general cargo* —fragile cargo that needs to be secured and packaged in pallets, crates or racks, and finally (portofantwerp.com, 2017). Åkerman and Jonsson (2007) point out that according to Volvo, *general cargo*, which is most often volume sensitive, dominates long distance transports (>250 km). To this follow *parts for production by manufacturers*, where the time factor is critical.

Shipment categories

According to Freightcenter.com (2016), the most popular type of shipment is *Less Than Truckload* (LTL), which usually combines relatively small freight (68 kg max. parcel, to 9 tonnes). Pieces of shippings are often that the average weight and size of a standard pallet. LTL can commonly refer to “common carriers” who handle freight above parcel carriers like UPS or FedEx, and usually accept non-palletized cargo. It could also refer to full truckload carriers that place several orders. LTL carriers often use "hub and spoke" operations: small local terminals (end of line spokes), and central terminals (Distribution center hubs, DCs). DCs further sort and consolidate cargo for additional transporting, and employ local drivers who first make deliveries and then pickups to return to the DCs for sorting and delivery for the following day. (Freightwhisperer.com, 2017)

A second common category is *Truckload* (TL), where the whole truck is dedicated truck for the shipping of homogeneous cargo that generally fills an entire semi-trailer. It is ideal for unpackaged, refrigerated, flatbed or special cargo (hazardous, oversize or overweight), since TL carriers often specialize in these due to equipment/insurance specificity and legal compatibility of different cargo. TL is usually faster (average of 75 kph is usually assumed) but more expensive than LTL. When a sealed truck part is reserved for a shipment it is called *partial truckload* (PTL)***.*** Partial truckloads are reserved for medium-size loads that are booked by volume or require running feet of a truck (Freightcenter.com, 2016).

Last, *Intermodal transport*, involves transportation of freight in intermodal containers held by a flatbed trailer or chassis. These containers may be switched between rail, ship, and truck modes without any handling of the freight out of the container (European Intermodal Association, 2005).

Fleets and data tracking

Truck fleet sizes and types

Even though Park (2013) says large fleets (>100 trucks) can outpace, outperform, outbuy, outhire and outlobby the smaller fleets in the U.S., he also reveals that most of the fleets there are around 25 trucks, and very often fewer. In Europe, fleets are generally smaller, and Sweden in particular shows many fleets under 5 trucks as interviewed transport managers, drivers and experts agreed throughout the meetings and surveys mentioned in section 3.3.3. These can range from individual truckers owning their trucks offering their services to truckload carriers (which can be owners of some or all the trucks) or other customers, to bigger private fleets (owned and controlled by the manufacturer of the carried goods), less than truckload fleets, or intermodal CDLLife (2017).

TGW and privacy (data tracking)

The Telematics Gateway (TGW) allows remote communication between the truck and the Dynafleet fleet management system —which manages collected data from sensors. This is enabled in Volvo Trucks through the GSM/GPRS/3G mobile network and WLAN through antennas integrated into one on the roof. The TGW can also be installed on other vehicle brands equipped with an fleet management standard interface. (Volvo Trucks, 2014).

The Data Protection Act (1998) states that personal data shall only be processed for specified and lawful purposes, “fairly and lawfully”, and shall not be further processed in “any manner incompatible with that purpose or those purposes”. In the case of sensitive personal data, it must be “adequate, relevant and not excessive in relation to the purpose or purposes for which they are processed". It shall also be accurate, updated and deleted when it is no longer required for the specified purpose, and shall not be transferred to a country or territory outside the European Economic Area unless that country ensures an adequate level of protection. Technical and organisational measures shall be taken against unauthorised or unlawful processing of personal data, accidental loss or destruction of, or damage to it.

Fleet management systems interface

The Fleet Management Systems Interface (FMS) is a standard interface to vehicle data of commercial vehicles. In 2002, all European truck manufacturers collaborated to develop the FMS-Standard in order to enable manufacturer-independent (third party) applications for telematics. The latest version, FMS Standard 3.0, was issued in 2012 (FMS-Standard.com, 2002)

FMS-Standard.com, (2012) defines an array of data that is tracked and available from trucks and buses, of which data possibly relevant to this project is grouped and listed below.

- **Engine**: HR total fuel used, fuel rate (overall, instantaneous), torque (total and available for current speed %), RPM, operation hours, coolant temperature.
- **Fuel tank, DEF tank**: levels.
- **ID:** Vehicle, Driver.
- **Drivers' state (1, 2)**: working state, working hours, card in,
- **Gateway capability**: SW-Version, Diagnostics, Requests
- **Position, motion**: HR Total distance, motion (Y/N), overspeed, direction (orientation), tachograph veh. speed, wheel based veh. speed.
- **Tachograph**: events, performance (diagnostics)
- **Weights**: axle, gross combination vehicle weight.
- **Ambient air temperature**
- **Service brake air pressure** (1, 2)
- **Controls:** Clutch (0/1), Brake (0/1), Cruise control (0/1), accelerator (position)
- **PTO (power take-off):** status, engagement
- **Location of elements**: Axle, Tires location
- **Service distance** (distance left until inspection required)
- **Retarder**: torque mode, braking torque, selection/non-engine

3.1.2 Fuel consumption and truck weight

In the last decades, research has been undertaken regarding the effect of weight reduction in fuel consumption. Recent findings show that an increase in weight load of 10 tonnes increases fuel consumption by 0,11 L per 10 km, assuming all other independent variables remain constant (Walnum and Simonsen, 2015). Forsberg et al. (2002) found that fuel consumption was about 22% higher when driving fully loaded than when driving empty; also lowering vehicle weight by 1 tonne will lower the fuel consumption by 0,28% for forest-haulage driving in Sweden. Nylund (2006) found that increasing weight by 1000 kg (either dead weight or load) will increase fuel consumption by 0,7 L per 100 km for a truck-trailer combination in highway driving. Walnum and

Simonsen (2015) also highlight that in winter, vehicles use about 0,14 L more than in summer so there are differences in weather conditions between seasons.

Moreover, reducing vehicle weight (mass) results in less tractive effort and less rolling resistance from the tires. Consequently, the potential gain in fuel economy from weight reduction is greater at lower vehicle speeds (Walnum and Simonsen, 2015). Also, the larger the engine volume (more powerful) the less the benefits are (Casadei et al., 2015). However, when it comes to truck trip allocation, if horsepower is under dimensioned, the truck will run most of the time at near 100% torque, which does increase fuel consumption comparatively.

There was just a single source that was found where minimizing unused fuel is regarded as an active means of reducing consumption. In this case, it is about cars, and takes as an example a 90 L fuel tank. Coghlan (2015) assumes 43,2 kg as the weight of a fully filled tank of fuel, having 720 g/L as the density of fuel. The author estimates a decrease on fuel consumption from 8.16 L/km when driving with a full tank to 8,08 L/100km when driving with a half-filled tank. This reduction supposes an extra driving range of 3,5km or a decrease in expenditure of time of about 5 to 14 minutes, due to carrying less weight. However, the article also pinpoints the potential for significantly increasing the savings in larger vehicles, such as the Toyota Landcruiser 70 Troop Carrier GXL which comes with two 90 L fuel tanks.

3.1.3 Refueling

A survey by Calstart.org (2013) concerning drayage trucks in Los Angeles, revealed that 42% of the surveyees take usually 20 min for refueling time. 17% of the respondents stop for 10 min or less for the same purpose, and 43% said they stop for at least 30 minutes (including a short break). Hence, it can be considered that the average refuelling stop is 20 min. However, the actual refilling takes about 5 minutes, bearing in mind it was observed —during the fieldwork done in project reported here— that a truck fuel pump flow oscillates below 150 L/min and that most tanks capacities range around 500-900 L.

Little research was found related to fueling behaviors, and most of the material is focused on automobile drivers. Kitamura and Sperling (1987) discovered that drivers usually refilled at the beginning or near the end of the trip. A more recent study by Calstart.org (2013) also confirmed this, as “82% of respondents indicated that they refuel at the beginning or end of a shift, which implies they use fueling stations either at or near the depot”. Furthermore, drivers tended to choose gas stations nearby the journey origin rather than towards the destination. This findings were correlated to the tendency of refueling near driver’s home and workplace, areas that are “detailed in driver’s mental maps”. For this reason, drivers also tended to refuel before travelling to less familiar areas.

Langer and McRae (2013) took time and fuel price as variables, and stated that private drivers usually make a trade-off between the fuel price and the extra time taken to arrive to a refueling location. Furthermore, the authors found that drivers usually preferred to travel further in order to pay less for refueling. However, older drivers showed less interest in saving time while drivers with higher income tended to appreciate more the value of time. Similarly, drivers willing to purchase an alternative fuel vehicle were also less likely to deviate from their routes, even when the alternative fuel price was cheaper in some locations.

3.1.4 Routing and planning in truck fleets

As stated by Csehi and Farkas (2016), refueling cannot be solved separately from routing and planning, since the refueling location alters the route itself. It is also mentioned that a minor enhancement on the operational cost can decide if a shipment is profitable or not. For that reason, fuel stops cannot be fixed in the plan, so approximate solutions have to be given within an adequate range of time. As explained by the authors, routes “cannot be just optimal but robust” meaning that they have to be flexible and adjust to new information and circumstances, such as traffic variations, road conditions and human errors. Different types of routes undertake several types of costs such as road toll cost, fuel costs (due to different road lengths, speed limits, height fluctuations, time costs and variance in truck weight). Moreover, the awareness of specific tasks within jobs and activities performed by the drivers would ease route planning, but in most of the cases manual data input would be required.

3.1.5 Fuel theft

Fuel theft remains a considerable issue in the trucking industry throughout Europe. PlusGPS (2016) remarks that in France practically every truck has been or will be victim of fuel theft. In Spain, most of the crimes occur in major cities such as Barcelona, Seville and Valencia. Centre Tank (2014) pinpoints that 64% of all the thefts from Heavy Duty vehicles concerned fuel theft. However, it is difficult to estimate accurate figures about this topic due to the large quantity of unreported crimes. PlusGPS (2016) suggests to implement telematics for monitoring fuel levels to raise awareness. Schnable (2011) proposes to implement locking gas caps and anti-siphon security devices in the fuel tanks, park in secured areas, security alarms linked to sensors in the tanks, transport management systems that allow to track the fuel consumption in real time and ultimately, train employees to deal with this situations.

3.1.6 Motivations of truck drivers

The current section aims to expand on the literature material found regarding motivation for truck drivers not only for driving but also for undertaking environmentally friendly practices as well as the possible incentives for implementing those behaviors.

Dubey and Gunasekaran (2015) highlight the main sources of motivation for truck drivers in their profession, which are: pleasure of driving, self-dependence, opportunity to travel and decent income. On the other hand, the main motives of frustration are boredom, poor job respect, stress provoked by fatigue, being away from home, rising of fuel prices (for freelance drivers), the lack of proper training and issues derived from loading and unloading. The authors also pinpoint the pressures drivers have from regulations as well as the tendency of copying other drivers' behaviors where the goals of the companies are unclear. Dubey and Gunasekaran also conclude that "drivers usually lack of sensitivity towards environment and society" remarking the need of proper training in those topics.

Schießl et al. (2013) conclude that the main factors for encouraging eco-friendly practices in automobile private cars are time, environmental impact related to consumption and the possibility to change (freedom). In fact, Suzuki (2008) highlights that the "confiscation of freedom" of the drivers leads to low compliance rates, explaining that drivers usually feel bothered when they cannot choose the gas station to refill but at the same time do not mind the timing of the stop as well as the refill quantity. Hölt et al. (2012) expand more on the topic and remark the correlation between positive attitudes towards the environment and the actual lack of environmentally conscious behavior. In fact, environmentally friendly practices were usually found only when associated to lower costs. Furthermore, these behaviors were associated to several psychological factors such as internal control, sense of responsibility, education and specific knowledge in environmentally-friendly behaviors. The higher the ratings in this factors, the higher likeability of the drivers to implement eco-friendly behaviors. The paper also highlights the effect of the "tragedy of commons" (Neugebauer, cited in Hölt et al., 2012) which refers to the fact that the individual benefits of more polluting behaviors is instantly noticeable (e.g. higher speed, more aggressive driving etc.) while the disadvantages these practices suppose to the society only become apparent later. What is more, fleet managers usually underestimate the impact of eco-practices since are normally associated to cost such as investments in education. Moreover, company policies and commercial duties are prioritized.

Moving on to incentives for effectively implement these behaviors, Fleet Answers (2014) suggests three different types of incentives. First of, regular cash incentives for accomplishing specific tasks (e.g. inspections) meaning that the driver receives a percentage of the benefit of the performed task. Secondly, gift cards are suggested, although they require a larger gift structure (similar to the existing models of fuel providers for rewarding the fidelity of the users). Similarly, reward certificates with the usual points system are also an alternative and give the possibility of compensating with sponsored products that strength marketing campaigns. On the other hand, Hölt et al. (2012) suggest to use competition and gamification, using ranking and similar alternatives, where the drivers compete for the lowest fuel consumption. In addition, the authors state that the rewards should be "introduced slowly to sustain the positive effect".

3.1.7 HMI displays in truck driving

The lack of user acceptance of new information systems is a significant obstacle for implementation (Höltl et al, 2012). In fact, only 10% of the truck drivers use advanced monitoring systems (Liimatainen, Tacken; cited by Walnum and Simonsen, 2015). Research from Staubach et al. (2013) shows that 67% of private car drivers would like to have an assisting technology in their vehicles. Moreover, 37% of them would be interested due to comfort and traffic flow reasons, 27% for implementing environmentally friendly practices and 10% for safety reasons. In the same study it was found that 40% of car drivers prefer haptic feedback, 30% of them visual and 23% of the participants a combination of both. Additionally, 47% of the respondents wanted to turn on the notifications by themselves; 53% would like to have it turned on and 25% would like to be able to turn them off again.

Höltl et al. (2012) conclude that speech advices are the most appropriate way of providing information to the driver. The information should be shown “visually underlined with messages which are easy to understand”. However, the authors also pinpoint that, with the increasing amount of information drivers have to handle while driving, voice control can provide further possibilities to ease the management of these systems.

What is more, Krietsch et al. (2010) differentiate between three different levels of assistance: pre-trip for route planning, on-trip for planning updates and unexpected events and after-trip for feedback on the performance. In addition, the report provides several requirements to implement on-board coaching systems (pages 20-38).

Höltl et al. (2012) found variations related to the age of the respondents. In fact, older drivers preferred concrete instructions while younger drivers were more comfortable with adaptive navigation. The report also presents demographic variations in terms of eco-driving user acceptance. As a matter of fact, drivers from Central Europe (Germany, Switzerland and Austria) were the most skeptic about the environmental impact of this technologies. Northern Europe interviewees were the least environmentally concerned while Eastern Europeans believed Human-Machine Interaction displays had the highest impact among the rest of answers. Eastern Europeans were the ones were more eager to pay for this technologies but were more concerned about time expenditure and less about environmental reasons. Southern Europe drivers believed Human-Machine Interaction displays had significant impact in eco-friendly behaviors.

3.2 Market analysis

The current market analysis focuses on services directly related to the context of MindFuel —Fleet Management Systems and related software/packages—, services or assistants that necessarily would coexist with it —like route planning—, or either, assistants from which interesting inspiration or learnings can be extrapolated to MindFuel, —like eco-driving or fuel saving coaches.

On this matter, two interesting implications turn up, as it is explained eventually in this section: the retrospective or prospective character of the systems/assistants, on the one hand, and the implementation framework or stages that the status of development of the industry offers on the other hand. The latter is more difficult to relate to the actual content of this analysis, but it is a result of the general perception of the market in the explained and other searches. Additionally, it is worth mention that no equivalent services to MindFuel were found at all. Nonetheless, this market analysis also demonstrates that multi-app/multiplatform solutions for fleet management-driver involved purposes are active and implemented in the market. Anyway, most of the product-services investigated were rather vague about their actual use characteristics. Hence, a chart-like feature comparison was neither possible nor sensemaking, but only an overview of what is marketed today in the area, through what devices is marketer, and more vaguely, how proactively/prospectively these services work.

3.2.1 Fleet Management Software and Fuel Services

The increasing need of monitoring vehicle fleets is causing Fleet Management Systems to be more and more common. These systems record data of the vehicle which is subsequently analysed, allowing several services and products. Since MindFuel partially relies on the data gathered by these kind of systems and it is itself a Fleet Management Service component, a market research in other Fleet Management services was carried out. Hence, one of the aims of this analysis is to discover existing characteristics affecting the concept implementation.

Dynafleet and other Volvo services

Dynafleet is a transport information system provided by Volvo Trucks. It consists of a web-based service that communicates with mobile telematics devices in the trucks which provide real time data such as vehicle placement, fuel consumption, driver times, emissions and service intervals. Dynafleet also allows communication between the driver and the home office through its on-board messaging services. (Volvo Trucks, 2017)

Volvo offers different service pillars within the fuel area: *Dynafleet, Fuel and Environment, Fuel Advice and Driver Development* (Driver training & Coaching). Dynafleet provides the Fuel Efficiency Score (FES), which rates and ranks the drivers according to their performance based on four parameters: anticipation and braking, engine and gear utilisation, speed adaptation and idling. Fuel and Environment is an subscription to Dynafleet which provides access to reports that contain more specific data of driver's performance, including fuel consumption, environmental reports and service intervals. In case fleet managers need more support, Fuel Advice provides an enhanced support, with more comprehensive reports and personalized approach. As separate add-ons, one can find Driver training and Driver coaching within the category of Driver

Development. Driver Training refers to the training provided to fleet coaches and drivers, both theory in classrooms and practice sessions in trucks. Driver Coaching, moreover, refers to the live in-cabin driver coaching display, which is available in Volvo Trucks manufactured from 2012 on.

Services from competition

Among the several fleet management system software found, the minority had dedicated services for fuel management. Next, a summary of the different alternatives in the market is presented.

VeriLocation offers 24 hours full access to fleet through its GPS/GSM. The product focuses on fleet operation optimization, by encouraging efficient driving via providing benchmarks the drivers should aim for (figure 9). It combines two-way messaging with tacho updates, vehicle checks, etc., connecting fleet managers to drivers and vehicles altogether in a multi-application solution.

Ctrack by *Inseego* provides a ranking system (Driver Performance League) to identify areas within driving behavior to improve. What is more, the service includes an onboard device that alerts drivers about unexpected events and infringements, called Driver behavior Indicator (figure 10). Similarly to Dynafleet, Ctrack provides reporting services.

Fleet Genius offers a multi-screen solution, including detailed reports of trips and driver's performance which focus on detecting idle time and fuel waste during idling (figure 11).

Green Road focuses on reducing fuel consumption and raising awareness among the drivers about efficient driving practices, visualising data of past performance of fuel efficiency and trends, fuel consumptions and idling rates (figure 12). Moreover, Green road provides an specific service called *Stop Fuel theft* which integrates fuel card purchase data together with fuel tank level data and placement to detect irregularities.

Fleetio focuses on data visualization, providing insights to everyone in the fleet. Visualizes all the operating costs and allows to identify and manage exceptional cases. Fleetio also offers a multi-screen solution (figure 13).

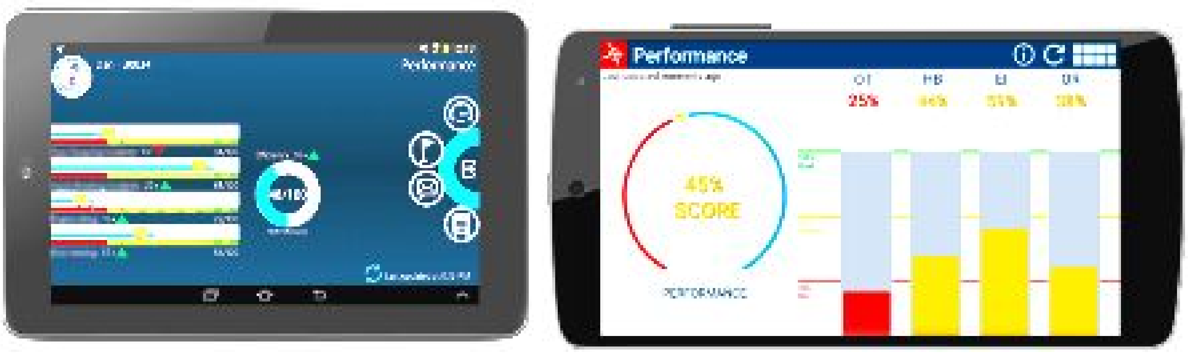


Figure 9: VeriLocation interfaces (fleet managers, left; dashboard/mobile for drivers, right).

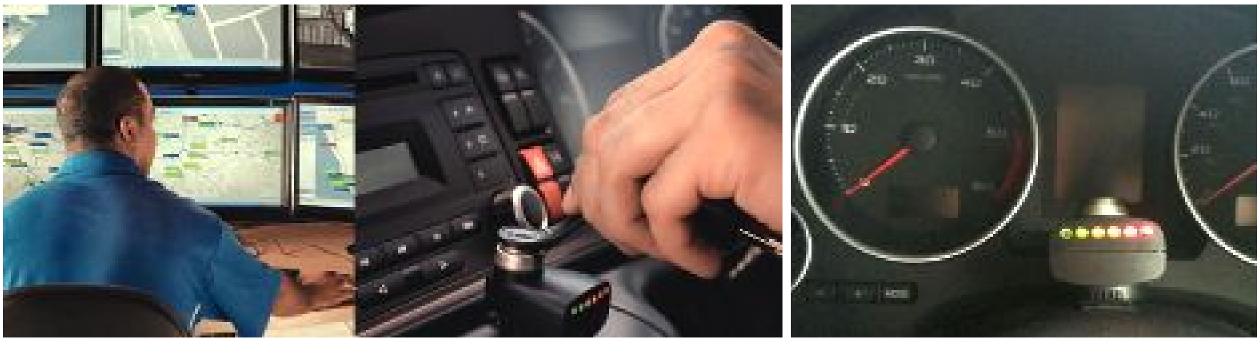


Figure 10: Driver behavior Indicator from Ctrack.

Figure 11: Fleet genius multi-screen displays.

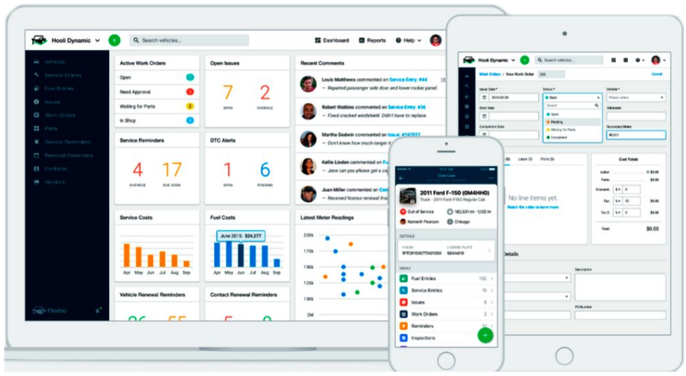


Figure 12; Figure 13: Green road multiplatform user interface; Fleetio multiplatform interface.

3.2.2 Eco-driving solutions

The MindFuel concept presents certain similarities to eco-driving assisting solutions. Both aim to encourage or coaching drivers to save fuel by influencing driver's behaviour and hence need to deal with issues related to it, such as driver freedom, user acceptance, driver motivation as well as human-machine interaction among others. The main difference would be that eco-driving does require a prolonged action or dedication, while in MindFuel is just a matter of one time decision making and execution —at the most, one per day. In addition, the consulted systems have an onboard proactive component. Hence, some eco-driving assisting technologies exposed by Höltl et al. (2012) were analysed due to the similarity of this services to the characteristics wanted in the final concept of the project, such as driver performance monitoring and later feedback.

Ford's SmartGauge visualizes improvements in fuel efficiency by increasing the amount of leaves in the dashboard display. By using two extra screens on the sides of the analog speedometer, the user can visualize different data such as fuel tank/battery levels or fuel consumption (figure 14).

Honda Ecological Drive Assistance System provides data of driver performance during- and post-trip, including long term fuel efficiency reports. It also gives on-board tips on how to improve driving behavior and an speedometer integrated ambient meter (figure 15).

PLX Kiwi records acceleration and deceleration parameters to later provide long term tips on driving behaviors. It also records optimal revolutions per minute (rpm) and the amount of fuel saved and wasted. It is available as an stand-alone device but also has a supportive mobile phone application (figure 16).

Vexia Econav records driving behavior data and provides feedback for long term improvement. The product focuses on routing, analysing the previously chosen ones and then suggesting more efficient alternatives (figure 17).

Fiat Blue&Me consists of an USB interface that records driving data and can be visualized later on a computer. The interface focuses on data about fuel consumption and emissions and also provides driving tips for improving. Additionally, it also uses a ranking system called Eco Index that is used to rate driver performance (figure 18).

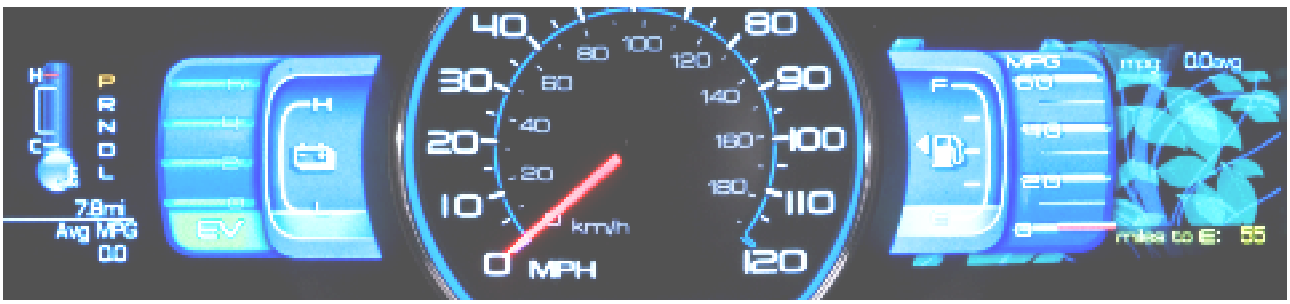


Figure 14: *Ford's SmartGauge* on-board display.

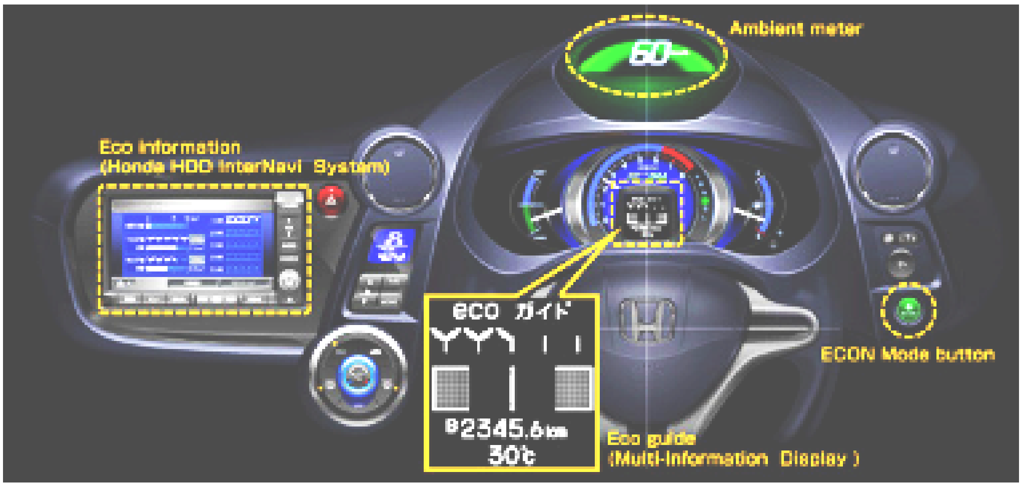


Figure 15: *Honda Ecological Drive Assistance System* on-board display.

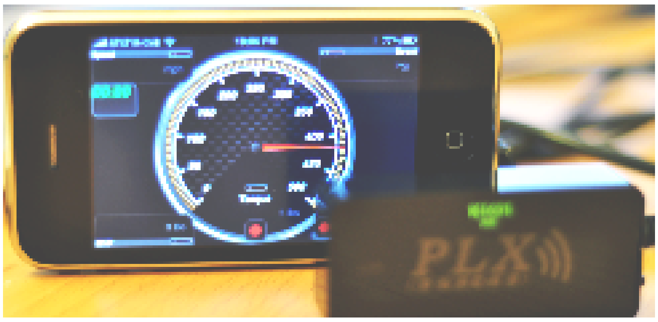


Figure 16; Figure 17: *PLX Kiwi* stand-alone device and phone application; Vexia Econav onboard screen.

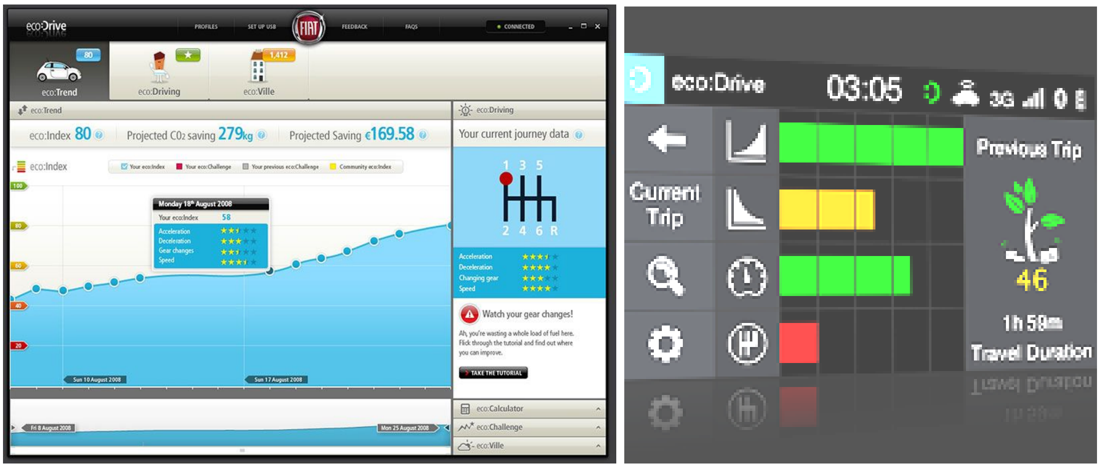


Figure 18: Fiat Blue&Me user interfaces.

3.2.3 Market analysis conclusions

Retrospective and prospective services

The market analysis reported in this section in conjunction with the experts' clarifications about the reality of the market and fleet management in general, led to a distinction between retrospective and prospective items (activities, systems, products…). As it is suggested in figure 19 below, we refer to retrospective actions/systems as to those which provide feedback or analytics about past events for monitoring. This could range from a simple rather unprocessed statistics display of tachograph data to more selectively processed displays. In this cases, the decision on what action should be taken in response remains to be figured out by the fleet owner, dispatcher or, failing this, the driver. Opposedly, we understand that prospective systems are those which process historical and live data, together with relevant databases of other elements that take play (e.g., available routes, stops…) in order to provide with planning alternatives (advanced route planners/optimizators) or behavior suggestions, only in the case of the most advanced eco-driving coaches which also include these external variables.

Thus, the interest steered from retrospective fleet management tools and eco-driving assistants towards route planning systems. This is reflected in the final concept design, but in terms of further study, a proper market analysis of transport and route planning —and its implementability within the company— would take another whole project. This realization was concluded from the fact that, as revealed by the fuel experts, the biggest interferences with the concept to be implemented would necessarily happen within a prospective system, as it is the case of MindFuel.

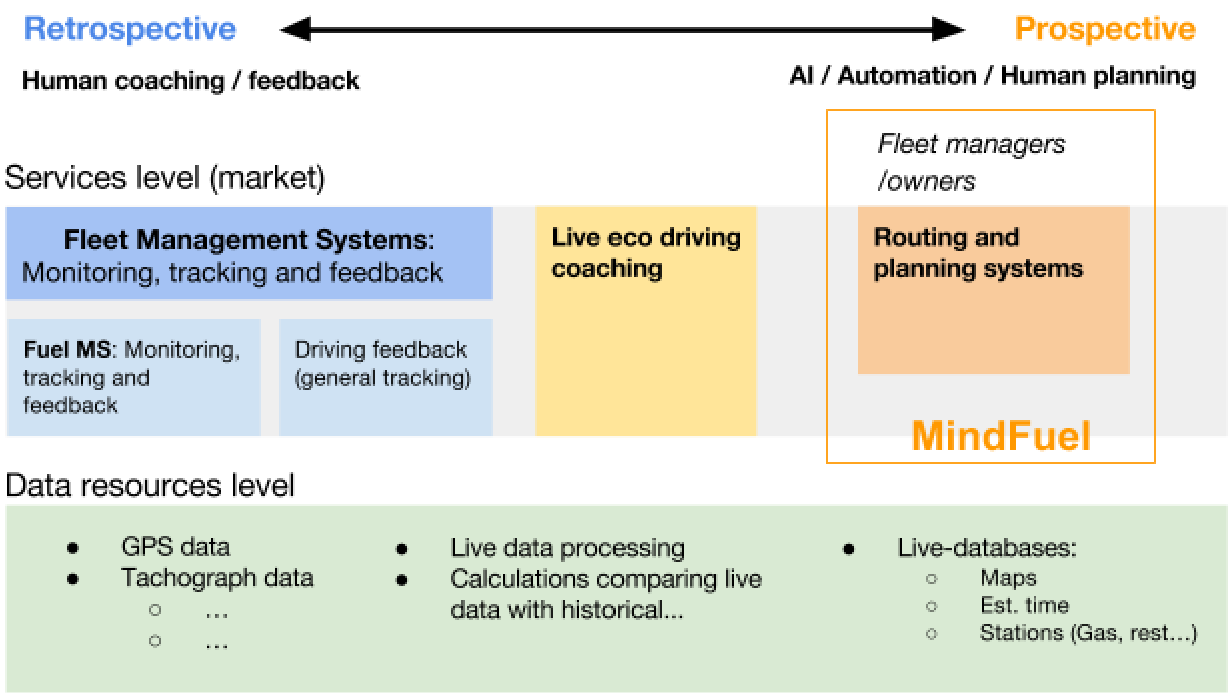


Figure 19: types of assistant related services in a retrospective/prospective axis.

Implementation window

The average active truck age rounds 5-6 years (Expert 2, section 3.3.3). This fact turns essential to consider when it comes to implement a new service that could need to be implemented in a bigger service system. The implications here are twofold; both in terms of software in, say, by having a fleet management system or route planner environment, and in terms of hardware including available sensors and display solutions, both external and integrated.

Also bearing the low margin nature of MindFuel a further important question arises regarding when and where MindFuel has the highest potential within the constantly developing industry.

In the short term, we find a clear growth in the richness and quality of integrated solutions and assistants, including display screens, sensors, intelligent assistants for different matters like navigation, routing or fuel efficiency (all prospective). These obviously rely on some degree of artificial intelligence, especially when it comes to advice or instructions, which is the case of the hereby reported design. Nonetheless, in the bigger picture, we cannot but consider these as mid steps towards autonomous vehicles, which would be completely driven by artificial intelligence. In this context, a potential for transitional added value turns up: artificial intelligence, to be trained effectively, requires a considerable volume of relevant data of the context where it is to function, in this case —similarly to eco-driving— fuel efficiency in sharing roads with other humans and/or autonomous vehicles.

After all these considerations, the most reasonable implementation window appears to be "the currently existing majority of trucks". Relevant data collected for a presently effective service can still be valuable for future artificial intelligence machine learning and training, that could run autonomous trucks.

3.3 User studies and fieldwork

This section deals with all the activities related to direct (interviews, surveys) and indirect (user profiles, personas and scenarios) interactions with the stakeholders of the project.

3.3.1 Product stakeholders

Understanding the general picture of stakeholders in this project is crucial. Moreover, the very action of clarifying the roles of the different parties involved had an important impact in reframing the aims. In fact, it was stated by interviewed experts (mainly in meeting #1 with the fuel management expert) that the interests and priorities of stakeholders responsible for coordination and ownership often override personal preferences or concerns of truck drivers.

This insight is key in order to frame the designed solution so it can be effectively implemented, for which truck driver acceptance is just the end link of the chain; the acceptance of dispatchers is essential and conditional for the implementation. These managers most often do the route planning and fuel management strategies, so any new component added to the various variables that affect costs and delivery compliancy must not interfere with these other components.

Hence, a map of stakeholders was outlined as depicted in figure 20. This one focuses in the main relations of parties that have a direct influence on fueling or that are influenced by fuel management. All stakeholders, including other stakeholders that could also benefit from the MindFuel are further described in the context of trucking in table 1. Note that in some cases, the fleet owner can be also the manager or dispatcher. Likewise, big carriers may own entire fleets.

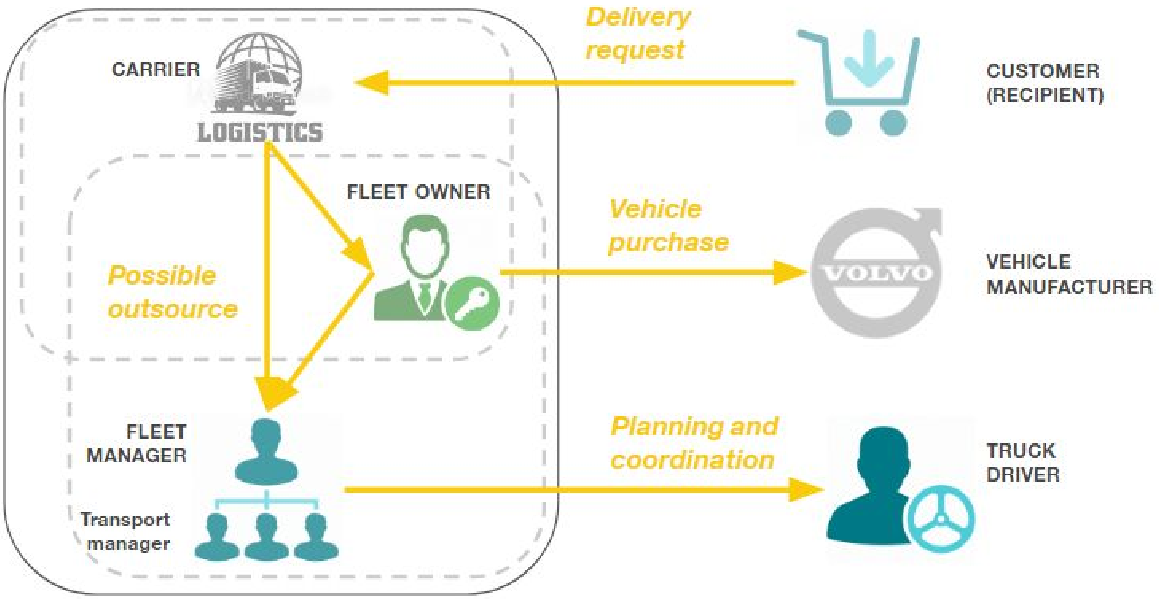


Figure 20: map of main stakeholders.

STAKEHOLDER	DESCRIPTION	MOTIVATIONS / CONCERNS
Manufacturer	Vehicle manufacturer.	• Sell trucks • Meet carrier/truck owner/truck driver needs. • Proper use of their products. • Brand image
Carrier	Company transporting, logistics company.	• Have demands on orders. • Minimize operational costs • Meet client's needs (cost, quality, time…), customer satisfaction • Develop drivers' competences and commitment (if employed by carrier) • Cooperation with other carriers (exchange/split/outsource orders)
Freight customer	Entity orders and gets the logistic service.	• Get the "best" transport according to costs, quality and reliability
Fleet manager	Makes sure the transport capacity is available (Expert 4, check section 3.3.3).	• Run the freight transport as efficient as possible (operational costs, duration, customer and driver satisfaction) • Stable and reliable tour & route planning • Cost of carbon footprint calculation on shipment level
Dispatcher, transport manager /planner	Responsible for the utilization of the capacity that the fleet manager ensured and more in contact with the customer than the fleet manager, usually (Expert 4, check section 3.3.3).	
Fleet Owner	Finances and legally owns the trucks. Can be the Carrier or leasing company.	• Proper use of his vehicle • Return Of Investment and benefit
Truck Driver	-	• Salary • Working conditions • Support daily work by helping to meet objectives (e.g. fuel efficiency) without adding workload.
Schools of Truck Driving	-	• Prepare students for the real laboral environment • Concern about the future (latest adaptations).

Table 1: stakeholders and potential relationship with MindFuel.

3.3.2 Surveys and interviews

Surveys were elaborated in order to expand the literature findings and gather specific data about refueling behaviors from the two main stakeholders of the project: truck drivers and fleet managers. Different categories were elaborated: “refueling practices”, “can planning refuel save fuel?/refueling strategy” (awareness), “motivations for eco-practices”, compensations for optimal refueling, current assisting solutions, supporting devices in the truck and service privacy. Two different questionnaires were designed, one for truck drivers and other for fleet managers; both can be found in the appendix 9.4. At the same time, unstructured interviews followed some surveys in order to deepen the topics. The interviews were conducted in three main spots: Stigs Center, a common refueling location at Gothenburg; Stena Terminal, a location where trucks unload containers ready to be shipped; and Halléns Transport AB, a transportation company dedicated to bulk cargo and containers.

Truck drivers

In respect of general characteristics truck drivers interviewees, all the respondents were not owning the truck they usually drive, drove long haul (big distances) and had most often more than 5 years of experience. Fuel tank capacities ranged from 450 L to 1500 L and the delivery windows range from very small (a concrete time) to large (one day).

Moving on to refueling practices, a concern that appeared was “spending as little time as possible”. A very important concern mentioned by one driver was that sometimes fuel cards do not work (in the agreed suppliers stations), needing to move to another station, thus loosing time and risking running out of fuel in extreme cases. Another concern was with spaces for parking trucks: many places you can only refuel and go. Therefore, they were not able to combine it with a break in some cases. In the case of shorter trips, drivers stop only to refuel in several cases or it will not bother them if it was necessary. They usually have known, favorite and preferred stops were the fuel is cheaper; but managers only encourage those stops when is possible and the fuel level is low (pinpointed by the driver of the fleet performing one day deliveries). What is more, all respondents filled the fuel tank till the top (100%) in every refuel event; this was also pointed out by Expert 2 (check section 3.3.3) for other fleets. Moreover, in the cases where fleets change drivers overnight, drivers usually refill the tanks before leaving the trucks for comfort of the next driver (mentioned by Expert 2 as well). However, some companies encouraged to leave the tank with least fuel as possible to avoid fuel theft during the weekends, in occasions where the truck would remain unused for several days. On the other hand, most participants refueled with about 25% of the capacity in the tanks, only a few usually refilled with 10% or less. Expert 2 mentioned that in many cases refueling and driving breaks are combined (not so desirable in Halléns case due to the type of trips and the possibilities of the area). Some of them also prefer not to worry about having to fuel first thing in the day. All respondents used a fuel fleet card and knew where the closer gas stations providers were either by looking them up in their smartphones or knowing beforehand the locations (confirmed by Expert 2 for other regular fleets too). Furthermore, fleet managers did not generally give tips on refueling, just recommended to refill in the cheapest places in some cases. However, a driver mentioned in a previous fleet they told them not to park the trucks with less than 50% of the tank empty, in order to minimize water condensation in the tank in extreme cold conditions and maybe also thinking on the next day’s driver.

In addition, none of the respondents followed any methods for planning routes and stops, fact which was also supported by the explanations of Expert 2. However, drivers pinpointed that they usually split breaks when long-hauling, as loading/unloading usually took around 15 min.

Regarding awareness of the impact of refueling in consumption, none of the respondents (nor Expert 1) ever questioned if fueling behavior affects consumption. The majority think the consumption savings with optimal refueling would be negligible compared to eco-driving impact, while the current effort they make for eco driving was either quite high or very low.

When it comes to motivations, none received a bonus for efficient driving, so there was no current economical motivation, while their motivations for reducing emissions were moderate.

On preferred bonuses, plain monetary compensation turned hegemonic. In fact, Expert 2 shared the case of a company that awarded drivers with monetary bonuses for eco-driving based on Dynafleet Fuel Efficiency Score, so this company reached an average FES of 92; a trucker of the company reported having bought a nice guitar with the bonuses alone. All in all, the means and mere existence of actual bonuses is sensitive to each company. Anyway, reinvestments on the driven truck also rose up interest (either a lot or total rejection). Regarding rankings, only a few would like it, while most would dislike it. Expert 1 supported this by saying it is only interesting for the best drivers, “drivers that drive not so good are aware of it”. This expert also clarified that deliveries close to home are often preferred by older drivers, not applicable in Halléns fleet (provider of most of the answers) as their trips are rarely multiple-day, long distance trips.

When asked about current assisting solutions, most would appreciate an assisting technology for planning, if they had to plan their refuel. Currently none of the respondents use fuel management systems as well as assistance for eco-driving or route optimization. Furthermore, none of the respondents receives any sort of feedback on their driving. However, almost all the respondents owned feedback-capable devices like a smartphone, most had a GPS device screen, and half of them had an integrated truck screen, while few owned a tablet. Regarding displays for a refueling assisting technology, the smartphone and the truck screen were pointed out as most convenient.

On the topic of privacy, none of the drivers opposed their fleet owners having access to their personal truck location, consumption and tank level data. In cabin video was accepted when only closed to software learning. Out-cabin video privacy tolerance spreaded evenly.

Fleet managers

In general, the fleet managers worked at fleets of around 1-5 vehicles. When asked about Key Performance Indicators, respondents ranked the values proposed as follows: 1st Competitive prices, 2nd Flexibility, 3rd Fast delivery, 4th Minimizing Emissions, 5th Safety and 6th Reliability.

Answers showed a complete lack of awareness regarding the impact of refueling practices in consumption. What is more, no tips on how to refuel were usually given to the drivers. Fleet managers estimated that drivers refilled just when they are low in fuel and coordinate refuel with short breaks. Also, they thought that drivers usually refueled in gas stations they had visited before within network of their fuel card. The respondents expected the drivers to refill with a gauge level of 30-50%. The fleet managers also thought drivers usually refill till the top. Moreover, they would appreciate assisting technology for refuel and reduction of emissions was a key reason for adopting this kind of technologies and enhance company values.

They also explain companies do not have to pay extra fines for emissions and the preferred way of compensation was money (cash). However, no bonuses were given for efficient driving practices. No routing support system was used and the knowledge from consumption and eco-driving performance was gathered from Dynafleet or similar services. In some cases, feedback to the drivers was given in the lunchroom but it was more usual to find it on the onboard screen. The supporting devices available werre: GPS, Smartphone, Integrated truck screen (also tablet in some cases). Onboard feedback was preferred to be given by smartphone and integrated truck screen since it is the existing equipment. When asked about privacy, fleet managers were open regarding truck location, fuel consumption and fuel tank level.

3.3.3 Meetings with fleet and experts

Accessed Fleet

Two meetings were done at Halléns, a fleet in Göteborg specialized in intermodal cargo. Part of the surveys were conducted there and these were also combined with more qualitative yet brief interviews with the fleet manager, a transport manager and drivers.

Figure 21: Halléns fleet.

About their fleet case, both the fleet manager and the transport driver clarified their delivery profile and needs: they mainly carry full containers of drayage, which need to be cleaned —so they usually come empty, or deliver international intermodal containers, where other customers mainly have the saying on the cargo (export) or Halléns has not a saying at all (import). Among these, in the theory, the most interesting for cargo optimization would be the dry bulk. Nonetheless, they clarified that in reality most delivery requests and orders they handle are quite below their full load capacity. Regarding the routes they do, most of the times are one day medium distance line hauling. For all this reasons, it was not possible to answer questions regarding multiple day trips and circular routes in a real case fashion.

On general transport planning practices it was found it is common to have a software to file the orders, but not so much to optimize allocation and arrange trips. That is more in the hand of the planner, although it was suggested at Halléns that bigger companies might use some software. Anyway, they can export most the order's data which may be required to operate MindFuel properly.

In a general truckin perspective, and regarding cargo overweight responsibilities, they all clarified it is on the side of the driver to be sure that the load distribution and weights are correct. They also confirmed more than one refueling stop per day would not make sense virtually for anyone.

The Experts

Expert 1: Teacher at MTG truck school, trucker for many years.

Expert 2: Coach working with fleet managers and customers of Volvo Trucks fleet efficiency services including uptime, onboard and offboard telematics, tachograph data, etc. All related to Dynafleet and its sub-products. He also educates drivers on the products to get the most of them.

Expert 3: HMI designer at Volvo, Ph.D. in Appointed Technology Specialist in Driver behavior/driver coaching for safety and fuel, and expert in human factors.

Expert 4: Consultant of services linked to Fuel Advice and others for Volvo Trucks Europe and former head of fleet and driver development team where Fuel Advice was developed.

Experts, about the questions in the survey

Some of the experts (the ones that worked with fleet managers) could speak on the behalf of some of the actual fleet managers at least for some questions in the survey. Hence, comments were interwined and referenced in the previous section about the survey, in this case observations from Expert 1 and Expert 2. These bring more richness to the answers since the fleets they have interacted with are varied and not of the special type of Halléns, necessarily.

General about trucking, trucks, logistics and refueling

According to Expert 1, in the truck driving school, sometimes students plan the routes, fuel consumptions, rests, etc. It is the same in the “real world” specially in small fleets. Regarding ecodriving, they teach mostly letting go the gas pedal and using the engine brake while still getting in time, but nothing about refueling in this regard.

When it comes to some sort of taxes or fines for CO_2 emissions, Expert 2 clarified that currently there are no taxes/fees for emissions, but that there will probably in the future. However, there are limitations already, like not entering urban areas with trucks landing in the euro-categories for emissions prior to Euro 5 or Euro 4.

Regarding routing optimization software, unlike navigation, Expert 2 points out is not common among the fleets of the customers he works with. When it comes to fleet roles, (owner/dispatcher/manager/driver...), there are very many possible structures, it depends a lot within companies and there is not a clearly most common structure. On fleet truck sizes in

When talking about general trucking, Expert 2 remarked that generally, driving with an empty truck is avoided and that in Sweden, this expert mentioned most fleets are small, meaning 5 or less trucks, and there are so many single-truck self-own trucks. Expert 1 also agreed fleets in Sweden are rather small.

On the topic of refueling and times, Expert 2 explained that, when refueling, drivers set the tachograph to working time. If they were to set the switch to resting, they would only have 29 sec., so if they can achieve this, it would count as a rest, (only if they get till 15 minutes as Expert 1 clarified) so that they can continue driving by law combining it with an actual rest the min. legal break, and thus cut time, for example. It was also mentioned that usually fleets do not have a refueling spot in their homebase and drivers usually coordinate stops with short breaks of at least 15-30 minutes. Expert 4 also mentioned not to make drivers skip their favourite stop.

Regarding the average age of trucks (affecting implementation infrastructure), Expert 2 assured that the average truck age is somewhere between 5-6 years. Related to this, he also mentioned that Volvo FH trucks have onboard screens integrated since 2013.

In addition, it was mentioned in several interviews that the handlers of most trip-data are the dispatchers; drivers would probably reject or complain if told to put data into the system.

Prioritizations within stakeholders

This topic gained importance from a meeting with Expert 3, source of all the unreferenced content under this subsection. Bear that in that moment the focus was mainly on driver behavior. The expert's reaction to explaining the concept was to report his experience with some companies KPIs, and how real priorities of fleet managers and owners usually override or filter out others parties interests. A first example of this was safety: if asked, managers will say they care a lot about safety. When one shifts focus to the actual actions, we can find out a number of scenarios where trade-offs turn up between safety and delivery time compliance. Owners, managers, and hence truck drivers, will thus prioritize delivery time. Poor safety is expensive, but a dissatisfied customer is the highest expense within their mindset. The extremely high costs that poor safety carries are difficult to convey and realize, for a number of reasons, including the preventive aspect and that damages are not always fully reported. This example provides a glimpse on how the mental model of fleet managers can influence real investment choices, measures, and priorities.

As the expert suggested, we can extrapolate this reality to eco-driving: if the schedule is tight from planning or due to trip contingencies, the act of fully focusing on eco-driving can be perceived as a hinder for delivery compliance in certain moments. In other words, fuel is just a means to achieve a delivery (aim). Additionally, the expert points out truck drivers have not so much saying on the planification (routes and fueling), with the exception of some experienced drivers may replan some aspects of routing when it comes to the given instructions by fleet owners. Also, the smaller the fleets, the higher the freedom, responsibility and saying in the planning of truck drivers. To this adds a comment from Expert 4, who also brought up the question of how cargo can be optimized. "If you can add more, then you order more?" He mentioned it depends a lot on the type of transport and customers. "The fleet manager would be responsible for that".

Fuel related services in Volvo Trucks and Dynafleet

Due to the extension and complexity of the services in the fuel area that Volvo Trucks provides, among where MindFuel would be naturally located according to Expert 4, it was necessary expert clarification. This expert mentioned three main pillars offerings within fuel area: the Fuel and Environment package (basically a subscription to Dynafleet and access to basic reports), Fuel Advice and Driver Development (training part). He also added that Volvo does not offer any route planning, optimization or management services at the moment. The most similar thing is the integrated TomTom navigator that onboard Dynafleet has. Expert 2 added that from about 130 companies using dynafleet in Göteborg about 5 use Fuel Advice package.

Another initial clarification by Expert 4 was that a common term used in the area, Driver Coaching could refer to two different things: a) coaching done by an intern fleet manager fuel coach supervising driver activity (often Volvo coaches train the fleet coaches). Or, b) the live driver coaching onboard available in the new trucks though Dynafleet, where push notifications arise on the onboard screen. There was a time where drivers could not turn it off, causing rejection.

Thus, Expert 4 explained that a logical process entailing these services would start from assessing collected data from driver behavior with the FES (Fuel Efficiency Score) and FER (Fuel Efficiency Report) —both available in Dynafleet— which puts most of the work so the customer to understand the data. Then, If the driver lacks of the skills to improve enough, Volvo offers Driver Training outside the Fuel and Efficiency package, including personal training theory and practices. The main downside is that drivers quickly fall back to old patterns, where Fuel Advice can be especially valuable, with expert consultancy and more comprehensive reports revealing what the driver and the fleet should focus on.

Finally, on details not available in the Dynafleet demo version, Expert 2 clarified that the rankings and FES points per each driving category are optionally anonymous, both for drivers and fleets.

Considering the prospective/retrospective scheme explained in the conclusions of the market analysis, we would locate all services except the onboard driving coaching in the retrospective part, having external feedback from experts or interpretation of the retrospective data for future improvements (see section 3.2.3).

Implementation of MindFuel and relevant factors

When introduced to the concept, Expert 2 was skeptic that fuel can be saved by carrying less fuel, he pointed out that the key is the cargo. This probably reinforces the initial skepticism that many drivers might have.

In the case of Expert 4, he pointed out it would be interesting to check which segments are more interesting regarding truck and tank size, type of cargo, etc. For example, extra value for different values of cargo per weight. In addition, he suggested the potential of a salesman as a stakeholder, due to added value of optimal tank size acquisition for new incorporations to fleets.

This expert also questioned the time saving approach of MindFuel since drivers need to stop anyways, which is somehow resolved by the information that Expert 2 provided about tachograph use during refueling (mentioned before at “General about trucking, logistics and refueling”). The topic of how much would MindFuel be saving in fuel price was also brought up. During the discussion, there was an agreement that, on the one hand, local prices are very similar, and on the other, there are bordering countries where prices vary significantly.

Regarding the implementation of such a service, Expert 4 said MindFuel would not be a consultancy service, but an operational tool. Hence, he said, it fits more in the Dynafleet context, supported by an app. For the driver needs, to be mobile or nomadic device, ideally onboard. “It could be good to have it as an extra service in Dynafleet”. Moreover, he mentioned there are no contradicting instructions to or opposed interests in respect to the current ones of Dynafleet. Regarding hardware, he confirmed that current weight sensors exist in some trucks, but pointed out that their accuracy is not sufficient for this grade of optimization, which was confirmed when the +/- 200 kg error was found for Volvo integrated sensors in Todts (2013).

3.3.4 User profiles and personas

Having driver behavior as one of the initial pillars of this research, the use of personas was considered suitable in principle. Actually, personas were developed with different traits gathered from different truck driver interviews. However this was not found so useful for idea generation, but to convey problems (and how are solved) instead. While driver motivations and specially concerns are relevant, the product does not respond to their needs as consumers (for example). Instead, It is adapted to their preferences and concerns within a framework of a service that lays quite in the background. Hence, using typical personas for ideation was not found very useful. However, in this case personas that gather those relevant traits of the interviewed truck drivers that affect the product acceptance and engagement can be useful in the order direction, meaning to convey the frustrations that MindFuel could generate and how was this avoided for different personas, as well as other pitfalls; for example, in a product presentation. These personas are locatable in the appendix 9.3. Other than that, specific comments of drivers sufficed to get ‘persona related’ problem areas through.

3.3.5 Preferred cargo and delivery profiles

Truck characteristics, shipment and cargo types definitely influence the profitability and suitability of MindFuel and its optimization alternatives. For example, the better the tanks of a fleet are sized or allocated for their trips the less overall optimization can be done. Likewise, low value weight sensitive cargo may not benefit from an extra cargo optimization. Moreover, in this same optimization alternative, the fuel weight exchanged by cargo should remain more or less similarly distributed on the tractor axles. In this regard, liquid bulk distributes evenly, and dry bulk is, as Halléns fleet mentioned, discharged in piles that have to be distributed. Closed containers are out reach of the cargo optimization, since the goods are just intermediated between third customers. General cargo varies on homogeneity and volume. All in all, it is difficult to determine within the project limits which specific cargo types are optimal or definitely valid for the purpose.

Regarding routes, the longer the route the more optimization possibilities are available in general. Also, many case scenarios involving line hauling (cargo in go and return to a point) and longer and multiple days (and loads/unloads) circular routes —simulated in the following section— could not be compared with real cases since the fleet that could be accessed mainly dedicated to short and medium distance intermodal one-way transport.

3.3.6 Simulation scenarios

In order to develop a richer picture of the context of use, several scenarios were created. Having previous research as a basis, the four different scenario alternatives aimed to discover further problem areas. The scenarios were based in reasonable distances and delivery timeframes. The aim was to find out how different variables interact within a simulation based in assumptions, in order to identify problem areas and thresholds. Hence, spreadsheets were generated for each case linking variables and changing parameters to reveal which are most relevant. Thus, these spreadsheets (available in appendix 9.2.2) are just a snapshot of a dynamic explorative document.

Equation for fuel consumption

As it can be seen throughout this research, fuel consumption depends on a number of mentioned variables and many more. However, exclusively for the purpose of generating meaningful simulation scenarios it was still important to find and employ an equation for truck fuel consumption that would include weight, so that the cargo condition impact was also included, as this directly affects the optimization possibilities contemplated by MindFuel MindFuel. Thus, franzese (2011) shows an approximation to fuel efficiency (logically inverse to fuel consumption) depending on truck weight at 65 mph speed in flat terrain (figure 22).

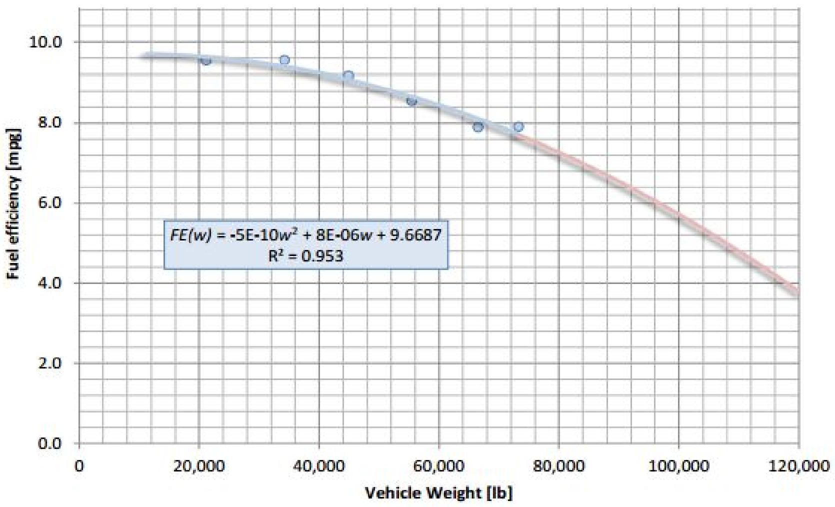


Figure 22: Fuel Efficiency versus truck weight at 65 mph in flat terrain (Franzese, 2011).

It is assumed that this formula is useful for a rather conservative approximation where the 65 mph (105 kph) in flat terrain evens out with the accepted 75 kph of average truckload delivery speed in an uneven terrain, given the higher consumption due to higher speed vs. the higher consumption of non flat terrain. What is more, one would expect that hilly terrains are comparatively more energetically demanding than the extra friction that the higher speed supposes. From this point, what remains to have the formula useful is to turn it to metric system and fuel consumption instead of fuel efficiency. These transformations were carried out in spreadsheets, and checked that are sensemaking, as it can be seen in Table 2.

Weight (kg)	**20000**	**30000**	**40000**	**44000**
Weight (lb)	44000	66000	88000	96800
Fuel Efficiency (mpg)	9,05	8,02	6,50	5,76
Fuel Efficiency (km/L)	**3,85**	**3,41**	**2,77**	**2,45**
Fuel Consump. (L/km)	**0,26**	**0,29**	**0,36**	**0,41**

Table 2: sample results using the adaptation of the fuel efficiency formula by Franzese (2011).

Variables and initial considerations for scenarios

Initially, several variables for designing the scenarios were noticed. This factors were divided into seven different categories listed below, which contain the different variables considered:

1. *Initial conditions*

- Initial fuel tank level
- Starting time
- Starting location

2. *Pre-trip fixed conditions*

- Deadline delivery time span:
  - Delivery window: narrow, broad, mixed (multiple pick-up)
  - Multiple stop coordination (routing)
- Type of cargo: weight/volume sensitive
- Type of trip:
  - Length: short (< 700 km, one day) or long (> 700 km, overnight stay)
  - Shape: circular and linear (appendix 9.1)
- Pickups:
  - Single delivery
  - Multiple stops delivery
- Driver profile: routines
  - Beginning/end for refueling
  - Refuel close to the origin

3. *Pre-trip conditions variable during a trip.*

- Load quantity: fully/partially loaded
- Possibility to find a gas station
  - General frequency/availab. (pre-trip)
  - Specific availability: live changes
- Fuel price: cheap/average/expensive
- Road cost: toll road/freeway

4. *Variables*

- Traffic conditions: fluid/traffic jam

5. *Costs*

- Emissions (taxes, fines)
- Driving hours
- Tolls
- Fuel consumption

6. *Revenue*

- Cargo

7. *Legal minimum breaks and maximum driving times*

Initial considerations were made before starting the design of the use cases:

- Trucks never go empty for long distances (only some intermodal do).
- Truckers refuel at the end of the day when next day a relay occurs.
- Truckers never leave filled tanks during weekends to avoid fuel theft.
- Average intercity speed: 65-75 km/h
- Average. city speed: 30 km/h
- Consumption reference, transformed to metric and to fuel consumption within spreadsheets: *FE(w) = -5·10-10w2 + 8·10-6w + 9.67* (*w: lb; FE: mpg*)

Four scenarios

Next, four different scenarios were developed comprehending route patterns found in the data analysis (see appendix 9.1), different distances, route patterns, initial conditions and delivery types as well as creating a sub-case for all the three refueling optimization alternatives. Note that the repeated insights of subsequent scenarios are omitted.

Use scenario 1: Long linear overnight

Use scenario 1 was designed with the characteristics and initial conditions shown in figure 67 in the appendix 9.2.1 When applying the OA one (eco), only 170 km away from their sleeping location, the user would have to decide whether to add a small quantity to the current 12% tank level in order prevent fuel theft overnight or refill the quantity needed for the following day and complete the trip. Moreover, this use scenario triggered the question about the driving range the driver should leave the truck with when finishing a trip. A 15% level would be acceptable as the warning sign for low fuel is usually triggered in a 10% level with an error of +/- 4% according to Volvo Trucks (1998). However, more driving range may be desired when a driver relay occurs.

The application of the OA two (cargo), highlighted the need of sub-preferences or sub-alternatives: when the main OA chosen is not applicable, the system should provide with the best next option. As a matter of fact, the driver had to refill with 11,7% with 170 km left (as before) and since there were no more loading events during that day, the driver had to decide between the same options as when applying before the OA one (eco) or refueling the whole tank (time).

The OA three (time) did not bring any findings apart from remarking the incompatibility of the alternative with preventing fuel theft by leaving less fuel in the tank. In this case, the driver ended the trip with 60,5% of fuel left. The spreadsheets are located in the appendix 9.2.2.

Use scenario 2: Long circular multiple deliveries overnight

Use scenario 2 was planned with the characteristics and initial conditions shown in figure 68 (appendix 9.2.1). The main general insight from this case is that a 1500 L (max. standard tank capacity) is not optimal for a unit trip of even 2000 km (3 days), 900 L suffice for a 40 tonnes cargo average. This means that, virtually most trucks with this fuel capacity have very optimizable tanks and still a great driving range after optimization, remaining with high flexibility for refueling possibilities during a route. In fact, in the extra cargo OA, after different trials, a fuel tank level limit of 33% was set. This showed to be perfectly effective to add about 600 kg of extra cargo and still finish the day with 10-15 % of fuel having just a quick refill per day.

Use scenario 3: Multiple delivery, one day (short)

Use scenario 3 was planned with the characteristics and initial conditions shown in figure 69 at the appendix 9.2.1. All three optimization alternatives allowed the driver to finish the trip without refueling if he/she waited till 11,5% level of fuel left. This arose again the question of the driving range desired to have left in the truck. The specific spreadsheets can be found at the appendix.

Use scenario 4: Long linear, one day

Use scenario 4 was planned with the characteristics and initial conditions shown in figure 70 in the appendix. This scenario illustrated the case when the driver could either decide to refuel at the end of the day till maximum (OA three, time) with 10% of fuel left in the tank or wait till finishing the trip with around 10% or leave the truck without refueling in the other two optimization alternatives (eco and cargo). Therefore, optimization alternative three would be desirable when shifting drivers and more driving range is desired. More detailed spreadsheets of the use case can be found in the appendix section.

Delivery timeframe compliance (DTC) vs ECO

Linked to the time demands and priorities of dispatchers (and the sector in general), there is a general tactic opposed interest confrontation between ecodriving (ECO) and delivery timeframe compliance (DTC). An optimal steady and energy efficient driving is not necessarily faster, especially where pronounced and persistent uphills are in the way. Considering the hierarchy of priorities and demands of the sector can define the potential of acceptance for implementation, DTC is an important priority to consider. For this reason, we want to find out through fictitious scenarios, how the concept of MindFuel can affect DTC.

The key variables in this case are the combination of needing to stop with compulsory breaks. In fact, the threshold that can allow cutting considerable time in tight DTC situations —within legal speed and break regulations— is saving a break in a (last) trip section. This could be done in cases where normal or ECO driving would take above 4 ½ h (max. continuous driving time allowed) but where, by driving faster especially in uphills (legal speed but increased consumption), the driving time for this trip section can remain within the legal 4 ½ h. (See Figure 23 showing the different possibilities and thresholds). Changing this environmentally nonoptimal reality of the sector is out of the action reach of this project, and hence we cannot consider related ethical implication. However, it is important for the reasons described, at least to not hinder or compromise necessary driving decisions and strategies for a lower priority optimization.

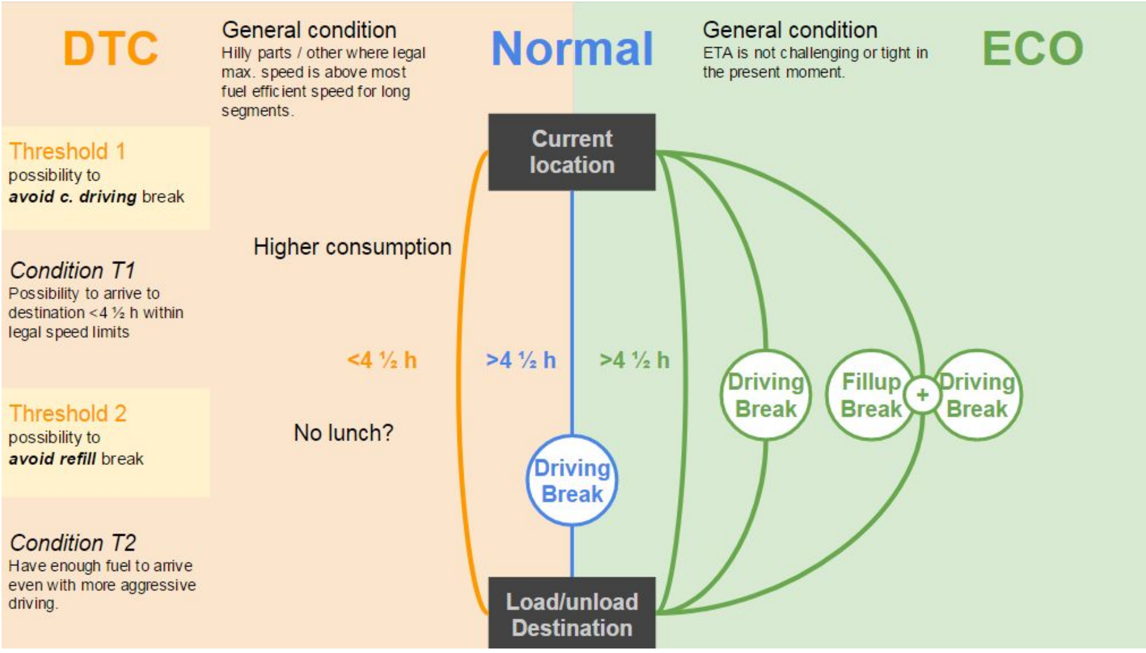


Figure 23: DTC vs. ECO strategic conflicts in potential time cutting scenarios.

In this context, it was reasoned that MindFuel could only have a hindering role in scenarios where a refill would had been planned for these trip sections where a possible time cutting was to be performed. Anticipation is key in this case, and by playing around with the fictitious scenario variables, it was confirmed that it is very complex and out of scope of this project to define how this can be effectively avoided in general. Hence, it was set as a wish or guideline for the future in the requirements and specifications.

3.4 Problem Areas

After finalising with the problem exploration phase, all the insights and conclusions were put together and categorized, in order to set the framework that would help to define requirements and design specifications. All the areas and related topics as well as the sources are located in the appendixe 9.5.

The described 13 categories were:

- Timing
  - Compulsory breaks, driving hour limits
  - Time constraints, commercial priorities
  - Units of planning
- Driver habits and motivation
  - Motivations
  - Compensations
  - “Confiscation” of driver freedom
  - Refueling and related habits
  - Awareness

- Cargo related variables
- Fuel related variables
  - Tank size and fuel level
  - Fuel prices
- Routing, allocation and linking deliveries
  - Delivery day and driver transitions
- Fuel theft
- Trip unexpected events
  - Changes within trip, unexpected events
- Customer and trip priorities
- Customer desirability
  - Fleet owner/dispatcher
  - Driver
- Implementation environment and conflicts
  - Dynafleet environment
  - Current assistance for drivers
  - Current assistance for fleet managers
  - Current display solutions
  - Current driver coaching system
- Input, display and invasiveness
- Privacy
  - Truck drivers
  - Fleet managers

3.5 Requirements

Due to the fieldwork and context research nature this project had been acquiring, requirements those which can be continued with further studies, can themselves be considered as an outcome of this work for future refinement. In face, some of these are more straightforward in their implementation and evaluation (e.g., Requirement R9b below) and others could require a whole project only to be analyzed in their complexity (e.g., wish W6).

Thus, down below a list of General Requirements and a list of Specific Requirements is posed. Mind that elements labeled after ‘W’ and stand for wishes (the more it is fulfilled the better), and elements tagged after a’R’ are requirements (they should be reasonably fulfilled). Due to the complex nature of the project regarding stakeholders, sample sizes and variables, in some cases it can be difficult to assess whether some requirements are fulfilled. Nonetheless, they are still very indicative of what the product service system should achieve specifically.

3.5.1 General Requirements

W0 ***Integration*** **&** ***Discretion*****:** responding to the low margin and low priority nature of the service, while smart and proactive, the PSS should remain within as modeless and integrated as possible within the existing environment, taking as little time, effort and attention from users to allow its correct functioning unless active involvement from their side is desired (e.g. optional gamification).

Multiple level solution

R0a ***Adaptation to roles*****:** design an interactive PSS concept that, through a single multi-layered or multiple platform and interface design, will be suited to the needs (display) and responsibilities (input for system) of the different roles, which can sometimes be delivered by the same individual:

- Truck driver
- Dispatcher or transport manager

R0b ***Relevance****:* depending on fixed features of the fleet or common features of a type of delivery, certain alternatives may be discarded.

R0c ***Optimal setting structure***: the PSS should provide an optimized and flexible structure minimizing the amount of input to avoid excise, by agglutinating common features in relevant groups and considering exceptions, from fleets to particular deliveries, or even considering vehicle features.

*This aims to set presets and “by defaults” that should automatically be changed in particular cases (e.g., a Shipment feature) where an alternative is impossible or lacks sense.

3.5.2 Specific Requirements

Customer desirability

W1 ***Greenness:*** the delivered PSS shall communicate and promote the green aspects of MindFuel for the reinforcement of logistics companies values, by at least showing the environmental impact of the different behaviors undertaken, beforehand, while they are being conducted and afterwards to the relevant users.

R1 ***Credibility & Trustworthiness***: show the gains and lack of pains of specific strategies and alternatives, for example by compensating the dispatchers' initial skepticism about OA 1, eco. Likewise, the PSS must ensure and effectively communicate that the commercial priorities are met regardless of the alternative chosen.

Adaptability to user and context

R2 ***Flexibility:*** provide various alternatives in order to make the driver able to choose between the most optimal ones.

R3 ***Optionality:*** make drivers always able to choose whether they want to receive information and/or undertake the alternatives or not.

R4 ***Integration of freedom***: ability for drivers to input in any moment desired stops with the flexibility of the PSS to adapt and suggest the most suited tips, e.g.: "if you stop here, you do not need to refill, not until..."

R5 ***Legality:*** the PSS should integrate the existing legislation regarding truck driving; including, speed limits, compulsory breaks and cargo weight limits.

R6 ***Reward system***: the reward system should not create conflicts between the driver and the fleet owner. Therefore, a set of alternatives should be tested to analyse reactions.

R7a ***Distribution of data input; invasiveness***: the PSS should receive the information concerning the dispatcher from the very dispatcher in order to minimize driver invasiveness. Likewise, drivers would be required to provide information of their own interest, like preferences for a certain stop or other routines. The system should then adapt to meet **R0c.**

R7b ***Minimization and convenience of data input; invasiveness***: the information required should be minimized to the most simple expression and demanded in the moments when is less bothering and most appropriate for the user, limiting requests to actions the driver can affect.

R7c ***Optimization of feedback; invasiveness***: the feedback provided should prepare the driver (pre-trip) to anticipate and plan effortlessly, and hence minimize interaction excise during trip. Post trip feedback should be optional and according to the driver's interest.

W2 ***Anticipation to driver actions:*** the system should allow easy input of driver actions to avoid late reaction of the system and errors, especially when the suggestions of the system are (going to be) ignored. The system should then adapt to meet **R0c and R7b.**

W3 ***Driver workday friendliness***: the PSS should tend to suggest strategies that save time especially when it comes to one day trip drivers that can go back home.

User motivation

W4 ***Ideal compensation***: the PSS should effectively communicate a suggestion of the incentives achieved by the driver as a result of the different behaviors undertaken, both beforehand and while they are being conducted.

W5 ***Assistant & environment oppositor comprehensive***: the system could offer simplified alternatives for improvement that could be accepted by people that do not care for environment, or at least avoid behaviors that worsen the current situation.

Optimization and priorities

R9a ***General optimization:*** the PSS must provide optimization alternatives according to the priorities of the fleet: fuel consumption, fuel theft, maximising cargo and minimizing working time.

R9b ***Back up alternative:*** optimization should be provided for sub-alternatives, meaning alternatives that pop up when the main alternative is not possible or it is compatible with other ones, always respecting **R9.**

W6 ***Dynamic adaptiveness:*** the PSS should adapt to changes during the trip that can affect the deadline, such as routing and integration of DTC, which is the most common specific end customer (recipient) priority, as an opposed strategy to ecodriving.

Display implementation & infrastructure

R11 ***Dynafleet context***: the PSS should be conceived to be implemented in the Dynafleet context. The PSS should be delivered at least considering the platforms and postures in which dynafleet is commonly used; namely, smartphones (satellite for drivers and managers) and desktop for managers.

W7 ***Navigation systems***: contradictory instructions between navigation systems and MindFuel should be foreseen to be avoided if possible.

R12 ***Truck implementation***: The PSS should be able to be implemented in the majority of trucks, compatible for present, existing, and future display and interaction infrastructures.

Privacy

R13 ***Configurable privacy***: the privacy level of any sensitive information or data gathered or introduced by the user (Fleet manager/Dispatcher/Driver) that is not currently gathered by Dynafleet should be able to be configured according to the privacy preferences of the user.

Responsibility and critical weights

R14 ***Responsibility conveying***: dispatcher and driver action compliance that is out of the control of MindFuel that can have legal implications must be considered and properly warned to the user. Two main examples arise:

R14a weight limit compliance:

Aided by MindFuel, the dispatcher shall calculate and set a fuel tank level limit, which if exceeded, may risk legal weight limits of a loaded truck. In such case, MindFuel -as an aiding platform- cannot be a middleman between dispatcher and driver that will ensure this limit is not exceeded. Hence, the system must unavoidably warn the dispatcher (and driver if suitable) about this.

R14b allocation of responsibility for weight distribution:

In most cases where the extra cargo optimization is employed, the capability of optimizing fuel weight for cargo weight within legal limits relies heavily in a effective weight distribution as the weight transfer from the tank should occur almost solely within the part loaded in the truck tractor (further explanations in weight section).

R14c limitation of OA2 for trailers:

(see limitations) The option for OA2 should be removed for the part that is loaded in a trailer when selecting the standard combination configuration.

3.5.3 Technical limitations

Only general weights: as weight sensors are seldom implemented in the present trucks and are not very accurate, loads per axle will not be considered.

OA2 not available for trailers: only semitrailers or rigid trucks can be subject to weight transfer from the fuel tank to the trailer box part loaded in the truck axles, and not semi-trailer axles. For this reasons, OA2 cannot be applied to independently supported trailers which are attached to a rigid truck or semi trailer.

4 Ideation

4.1 Interaction design framework

Within the project framework and results of analysis, including Volvo services experts opinions (section 3.3.3), it was decided that a set of interfaces should be designed to reach a basic concept implementation. For this reason, the interaction design framework by Cooper et al. (2014)

was used, allowing a process that enabled connecting all the functional characteristics, in this case into a usable multiple platform interface.

4.1.1 Form, factor, posture and input

Considering the reality of transport managers, drivers and the technology push, we find different platforms suitable for different users, situations and cases.

MindFuel for dispatchers

It was found that transport managers mostly work in front of the computer. Hence, a desktop version would suit them best, also since as it was mentioned in the interviews (section 3.3.3.) that they receive most of the orders digitally. For this reason, a smooth workflow could be attained between the system they use, which does not aid them organize trips, and MindFuel desktop for dispatchers.

Among desktop behavioral stances —postures, as called by Cooper (2014)—, we mainly find sovereign, transient and daemonic. Although the sovereign attribute of “monopolizing users’ attention for long, continuous periods of time (Cooper, 2014)” is definitely pursued to be avoided in this case, a general sovereign layout is required, as rather rich that needs to be imported, labeled and optionally edited by the user for the concept to work. This can be seen in the functional data section that follows. Hence, in this case, generous real screen state, modeless feedback, a reduced color palette and rich visual feedback are some of the desired sovereign attributes among those described by Cooper (2014). On the other hand, the aim would be to have the product as transient as possible within the functional requirements. For this reason, transient features mentioned by Cooper (2014) are desired and some are still compatible, like having labels for most functions, remembering user choices or avoiding multiple subwindows (keeping it somehow simple).

When it comes to the input for the desktop, import, quick labelling and easy edition of elements is key, and direct manipulation is only desirable for attribution/linking elements (labeling) or initial settings, since specific figures need to be entered most of the time. Mouse and keyboard is expected.

MindFuel for drivers

We find the technology pull of the onboard screen, which is very useful for quick notifications. However, this might not be enough (or always available in all trucks) for all the interaction that a driver may require to incorporate MindFuel. It was also mentioned on surveys that the smartphone was a prefered interaction element for convenience reasons. For all these reasons, both interface platforms were considered for different specific uses. Note that the smartphone or a tablet (with some kind of physical support in the cabin) could also replace the onboard screen, but this is not prototyped.

Regarding the posture for the mobile version, we could say it should play some special satellite stance —clearly aims to “emphasize in retrieving and viewing data”, as Cooper (2014) points out— while it covers its main purpose. In other words, drivers do not need to enter most of the data except for their general preferences and basic confirmation of actions they are performing (see functional elements section below), while the main purpose of the MindFuel is to visualize and have feedback within the driver environment, which can only be made by the aid of the transport planner preparation (desktop). Anyway, the transient characteristics that Cooper (2014) attributes to smartphone postures like self-explanatory (either for satellite or standalone) are desired. Likewise, the input methods should be simple and direct. It is especially interesting for driving situations to use the voice control, should the smartphone replace a lacking onboard screen.

In the case of the onboard screen, minimum distraction is desired. For this reason, although when integrated in the navigation it shall take some more attention, the notifications and consulting functions that this interface could have should remain just informative, brief, and legible at a glance, like a traffic sign, where the information bits are well prioritized and distinguishable.

Optional voice commands and information can be very useful for this purpose as supportive information to increase effectiveness of the message and reduce risk of distraction or rejection due to excessive demand of attention versus the priority of the issue. In fact, within the cognitive resources model Wickens and Hollands (2004) suggest for attention and cognitive workload, we can deduce that most of the drivers will not have their auditory verbal encoding channel especially overloaded, unless they are talking to somebody. Moreover, since the frequency of the notices is not very high, it would not be annoying —within the optionality of the feature.

4.1.2 Functional data and elements

One of the challenges of this design is to gather all the necessary data for the system to work without generating rejection or frustration to the users inputting and editing the data for a product that aims for fine tune, low margin optimization. For this, reason it is essential to list all this necessary data to later distribute its input demand it suitably among users depending on which has the information available for input in the quickest way and hence create functions accordingly throughout the different platforms and versions. With similar purpose, data is classified depending on its current availability and importability (importable from Dynafleet, external, required for manual input, and data generated from all the previous, by the system).

Data elements

FROM DYNAFLEET/TELEMATICS:

- Local time & driving time
- GPS location
- Stop and driving break registration
- Distance driven
- Consumption (rate and total)
- Fuel level (% and L)
- Speed

EXTERNAL SOURCE/THIRD PARTY:

- Database of max. legal weights for 2 & 3 axle trailers/semitrailers across countries
- Gas station database (sel. provider/s)
- Connectivity with navigation device
  - Speed limits through route segments
  - Traffic conditions
- Truck models database: GVW & tares

MANUAL INPUT/IMPORT FROM SOFTWARE:

Trip and shipment

- Expected stationary-truck days (not applied eventually but feasible if confirmed actually useful).
- Countries crossed during trip (from nav.)
- Starting time and location of a trip
- Delivery timeframe
- Load/unload stops (location)
- Type of cargo - volume / weight sensitive
- Trailer change / unload / container change (intermodal)
  - Estimate load/unload times

Preferences / configuration

- Home base location
- Fuel card diesel supplier of fleet
- Optimization alternative sel./adjustment
- Preferences on refueling routines:
  - Favourite refueling spots
  - Favourite break spots
  - Other preferences: e.g. not refueling at the beginning of the day
- Priorities selection:
  - Maximizing cargo
  - Time

Enabling weight and cargo calculations

- Approx. cargo value per kg / km
- Cargo weight in / out from dispatcher plan + auto GPS sync
- Tractor truck related (if not from datab.)
  - Truck model/year: tare and GVW
  - Truck model/year: number of axles
  - Total tractor weight (except fuel)
    - a) tare weight from manual + estimated passengers luggage, or
    - b) fully equipped tractor weight
- Semi-trailer or and trailer(s)
  - Number of axles
  - Trailer GTW/tare (if not from datab.)
- Gross train weight/gross combination weight GCW (manual/from combination of number of axles of each element)
- Shipment profile, trip profile/favorite trips

ADDITIONALLY GENERATED

- Driving time & length of the trip
- GCW (combined weight), depends on:
  - Trip countries input
  - All previous weight input
- Refueling stops proposals
- Most optimum refueling stops, detour times and impact on driving time
- Most optimum break stops
- Most optimum refill quantity
- Impact on emissions
- Break spots proposals
- Estimated Time of Arrival
- Tank level limit for partial refill alternatives (OA1, eco and OA2, cargo)
  - In the case of OA1, maximum optimization by pushing fuel tank level to only what is needed or setting a fixed tank level to fillup.
  - In the case of OA2, maximum optimization of cargo by pushing cargo weight till reaching the overweight limit or setting a fixed amount of extra cargo.
- Awarded points (deserved reward)
- Total optimum refuel stops chosen
- Business Case, impact on revenue
- Truck refill quantity breakdown

Elements

Regarding elements, the following are considered the most interesting and essential to explain. These naturally arise responding to the core idea of MindFuel —like stops—, or elements mainly managed through the dispatcher's desktop app, created to make the driver use possible —trips, orders, shipments, drivers, trucks and trailers—. These are described as follows:

Stops: these are events that pop up in the driver's interfaces to indicate refuel stop possibilities or a selected refuel stop, entailing different information about refueling amount or live data attached to the stop indicating distance left or detour time, being these last dynamic properties of the element generated and updated within the system.

Trips: refueling optimization cannot work only with separate shipments all the times, since these are often combined in what we will call 'trips'; these are combinations of shipments that determine a route, starting time and location, finish location, etc. A trip is also assigned a driver and a truck. Most often, we would say that a trip is a cycle (for example, returning to the homebase).

Orders and Shipments: both have the same general properties; load and unload locations and timeframes, cargo weight, a reference number or label and any other characteristic like 'customer' related to the cargo…, but not a driver or a truck, due to the fact that this is defined by the transport planner as a central part of its work to what we call 'trips'. In addition, an important distinction was found necessary between what we would distinguish as 'orders' and 'shipments'. Orders are initial requests of customers, while shipments are the final agreed order. This was found crucial since negotiating extra cargo needs to happen between an 'order' is received and a 'shipment' is agreed. Hence, their properties are the same, but the may vary, as they come different in the chronology.

Drivers, trucks and trailers: all these have embedded properties essential for creating the trips and calculating optimal stops for each alternative.

4.1.3 Functional groups and hierarchy

Functions structure

Taking into account all the mentioned data input, data throughput and considerations, functions were designed and grouped. A preliminary, rough scheme (figure 24) served to discuss different issues and have an overview of all the topics, users, and interrelation of functions and data. There, some of the most important functions are contoured in solid line. These are: trip information, stop preferences, optimization alternatives' adjustment, actions display, and overview display. Actions display refers to what will bring the actual optimization action by the driver (what will be the onboard display afterwards), and overview display refers to the screens where the driver performance can be seen. In the final concept it can be seen how these preliminary functions persist, with minor adaptations of naming and organization within the different tabs.

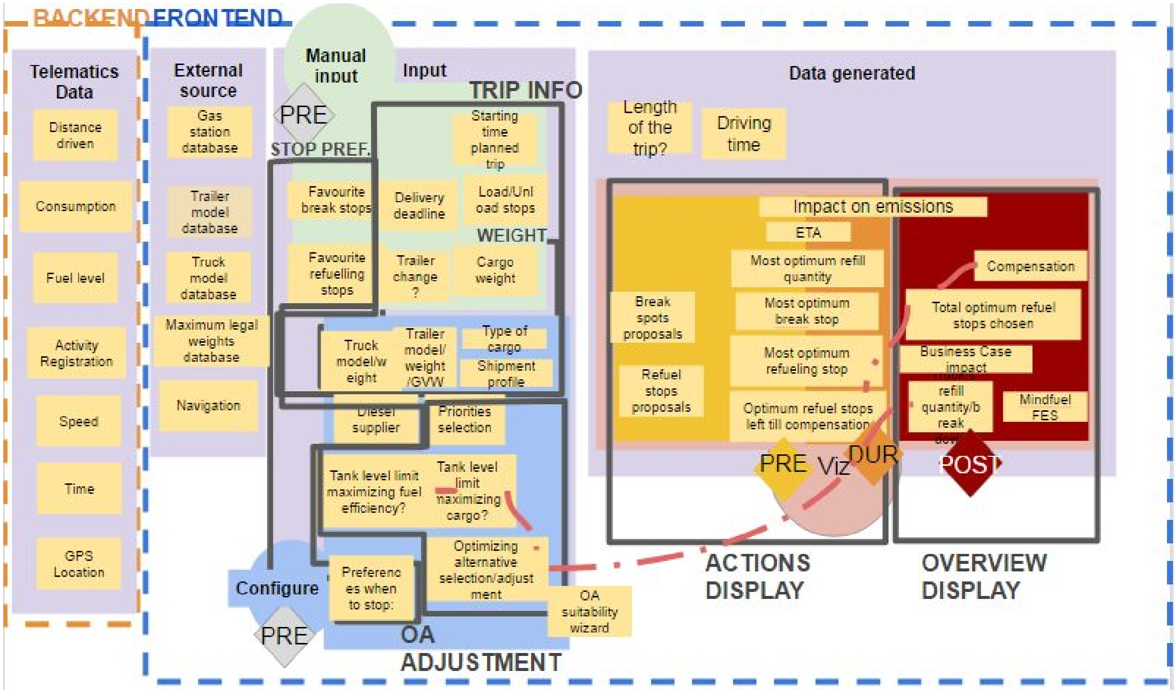


Figure 24: initial scheme of functions and topics.

Key function development

A further analysis of those functions requiring most input and/or complex visualization led to different possibilities of minimizing user effort. Likewise, some functions like optimization alternative references and sub-preferences had to be further discussed in order to see how they would affect fuel suggestions in a general basis, defining a criteria for each of those.

Input and visualization

After gathering necessary data considerations for shipment properties and characteristics of the weight available by default in some trucks sensors revealed by Todts, 2013 (figure 25, top right corner), as it is shown in the same figure, different paths to attain the so necessary GCW for the extra cargo alternative were considered.

Optimization alternatives selection and adjustment

First, a table with the values and priorities for each OA was done, in order to define the criteria that would determine different parameters of the suggested stops and refilling amounts. Table 3 shows and explains these; note that minimum upper FTLL stands for the lowest Fuel Tank Level Limit that can be set by the system in a particular case, being the limit the indicator of the fuel tank level that the driver should not exceed while refueling in that particular stop.

This being said, there are some aspects of the table worth explaining. First is the “no optimal” in the first OA alternative: as the main value is saving fuel, no other criteria was found to set a minimum FTLL that we could call optimal.

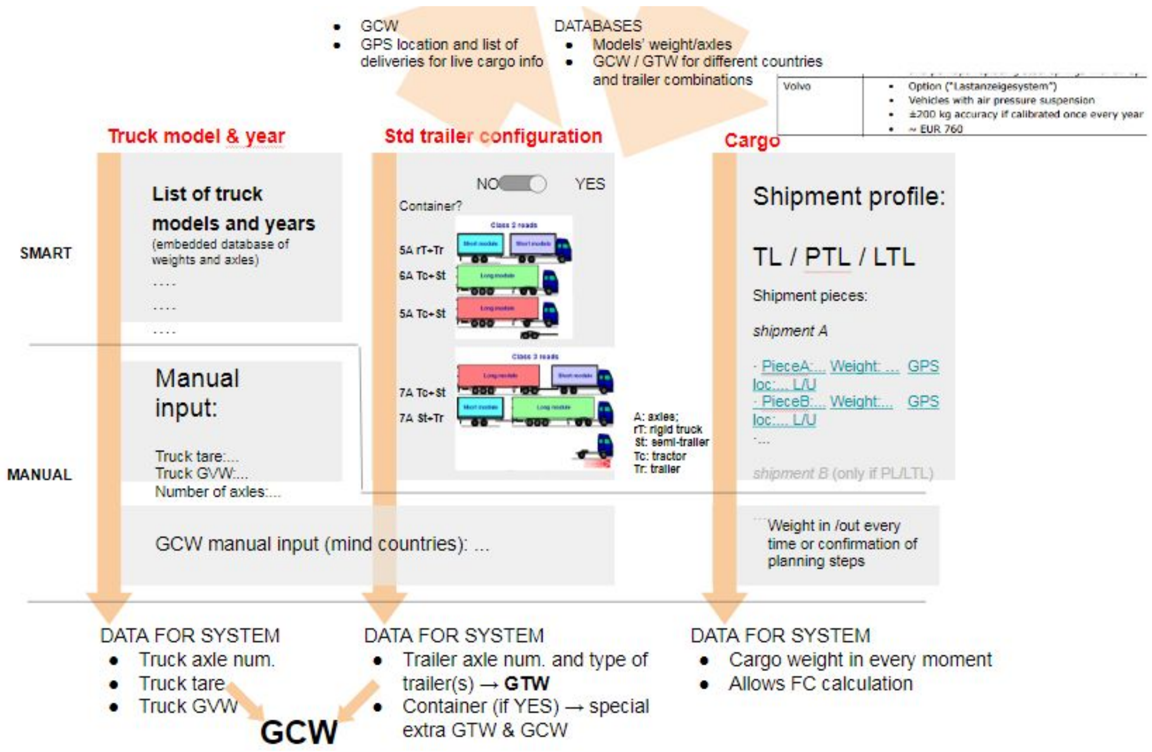


Figure 25: Necessary data for shipments. Weight sensor infor (upper left corner): Todts, 2013.

	Partial Fillup (ECO)	**+Cargo**	**Time**
Values/priorities →	**FUEL EFFICIENCY, reduce emissions**	**+CARGO capacity, revenue**	**Save TIME + working hrs**

Criteria defining "MIN. UPPER FTLL"	**Min. upper FTLL**
	• Delivery **timeframe** compliance
	• Avoid unnecessary stops (considering legal and desired breaks)
	• Not losing money for extra stops (working hours vs. fuel saving) **in respect to current revenue.**
		Min. upper FTLL (rigid within trip)
		• Delivery **timeframe** compliance
		• Min. autonomy **1 day** with estim. FC (to avoid 2 refills /day situation), defined by:
		  ○ Tank size
		  ○ Trip / shipment characteristics (dist. and cumul. steep if possible)
			[None]
			FTLL
			always 100%

Criteria defining "OPTIMAL" FTLL	**There is no optimal (depends exclusively on preferences)**	• **Highest revenue:** maximize cargo while minimizing paid hours for extra stops.	
Criteria for Refuel stop suggestion	• Available compatible gas stations • Route and reasonable detours	no different?	no different?
Key functions, inherent value	• Fuel theft reduction (regardless pref.) and flexibility to switch to OA2 • Flexibility, and doing more optimal stops may prevent	• Fuel theft reduction (regardless preferences)	**Avoid early fillup (only strategy resource in Uptime)**
Fine tuning preferences	• Optimize for day / shipment / trip	• Optimize for day / shipment / trip • Extra cargo amount preference (complying with the optimal base).	

Table 3: optimization alternatives' effective criteria.

Second, is the limit that was set for one day in the minimum FTLL for the extra cargo option. The rationale behind this is that having FTTLs which would give autonomies of 0,5 to <1 days would result in the system suggesting two stops per day even if, for example, a three day trip could be done with two stops (driving range = 0,66 days per refill) This would happen because the system is designed to finish the day with as little fuel as possible by default to avoid fuel theft and inactive actives' (fuel) retention. An additional reason is that the risk to miss the DTC increases until it is finally missed after an (n) number of stops, which could be any number, even one. The chart in figure 26 shows an abstract theorization of this issue and the extra cargo and consequent amount of stops versus revenue. Note that "WH+Det" stands for a constant drop in the revenue (assuming same stop conditions) when a refill is done, due to extra working hours (WH) and the detour cost (det). Also notice that this drop could be bigger than the rise —due to increased cargo capacity— that precedes to every drop, if the cargo value was sufficiently low. Finally the concavity or convexity (exact curve) of the rising bits is not studied here for this matter, nor it is the directly proportional relation of extra cargo capacity and number of stops (which is directly proportional). The aim of the chart is to detect or explain qualitative thresholds.

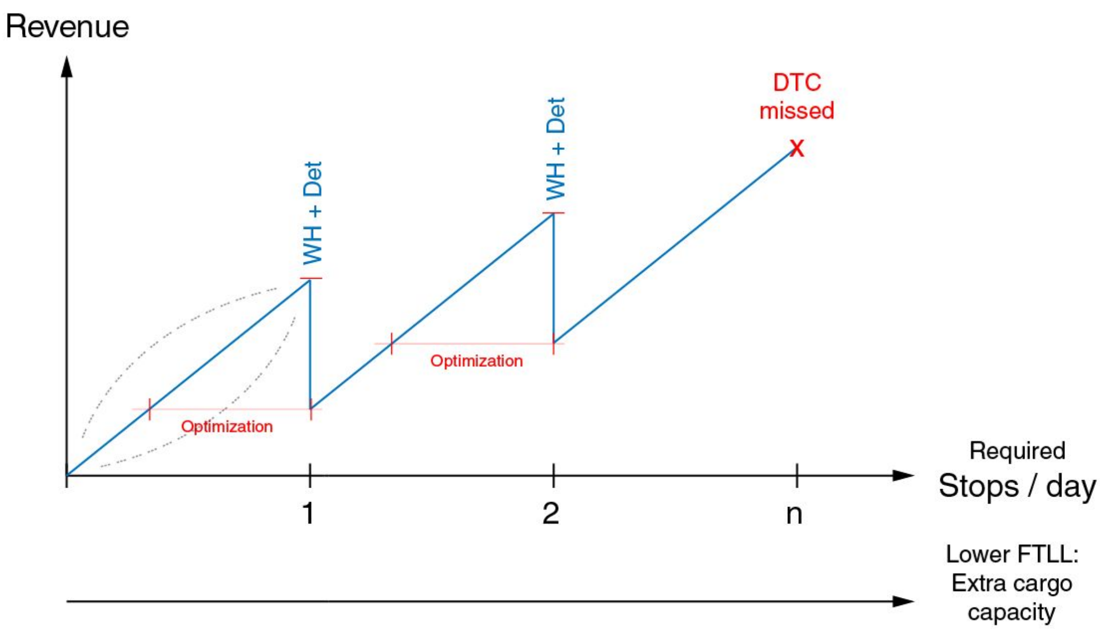


Figure 26: qualitative chart; stops per day and extra cargo versus revenue in cargo OA.

Thus, a segment can be found in the stops/day or extra cargo axis where it is more optimal (revenue-wise) to do one stop less than adding a bit more extra cargo and needing to stop once more to reach the destination safely.

After all these considerations, a summary was done (table 4) on how each alternative would behave and shape in general terms the suggestions by the system. This would depend on the selected alternative and adjustment (day, trip or shipment), which aim to affect on what is the preference for a refueling cycle, this is, when should 10% preferably be reached (end of day, trip, or shipment). Note that depending on shipment and trip characteristics, these might not exclude each other. The time option does not have day/shipment/trip preferences since, e.g., finishing a day (or any shipment/trip not matching a full tank usage) with 10% will be contradictory in most of the cases to the full utilisation of the tank.

OA	Partial Fillup (ECO)		+Cargo	
Day	**Suggests refilling amount for a day** based on total weight derived consumption and navigation data from route (distance and ideally cumulative slope. Expected FC, from now on). It is assumed no more than one refill will be required in a day*.		One or more day(s) autonomy with established FTL	Suggests refilling amount for a day (lower than current established FTL) based on expected FC. **LESS THAN A DAY NOT APPLICABLE**
Shipm.	One day shipment	**Suggests refilling amount for a single shipment,** based on expected FC. (same assumption as above for upper FT limit). The initial assumption (above) prevails. If a single refill would suffice but the FTL exceeded the recommended in OA1 for the case, 3 options: *a) switch to OA3,* *b) exceed the limit exceptionally,* *c) perform two (or more) refills, where the first(s) is/are the recommended FTL and the last just to complete the shipment (close to 10% remaining).*	One day shipment	**Suggests refilling amount for a single shipment,** based on expected FC. (same assumption as above for upper FT limit). The initial assumption (above) prevails. If a single refill would suffice but the FTL exceeded the established in OA2 for the case, two (or more) refills, should be performed where the first(s) is/are the recommended FTL and the last just to complete the shipment (close to 10% remaining).
	Several days for shipment	If a single refill would suffice but the FTL exceeded the recommended in OA1 for the case, 3 options (same as above): If multiple refills are required, other preferences are met (like day optimization) with the only condition that when the shipment is over, the expected FTL is as close as possible to 10%.	Several days for shipment	If a single refill would suffice but exceedin the FTL as established in OA2 for a case, same as above applies. If multiple refills are required, other preferences are met (day optimization and others) with the only condition that when the shipment is over, the expected FTL is as close as possible to 10%.
Trip	Same as shipment but trip measure.			

Table 4: Summary of OA principles regarding the refilling alternatives.

Reward system

As mentioned earlier in the purpose section and remarked in the requirement list, a way to engage and motivate the users to use the concept had to be developed. For this reason, a brainstorming session was conducted in order to come up with different alternatives (figure 27). From here, a final concept was developed paying attention to attributes previously explained in the requirement such as adequate relevance or low intrusiveness. For these reasons, the final solution is simple, straightforward and follows literature recommendation such as compensating for completed optimal actions as well as gamification (level system) for achievements, allowing the rewards to be introduced slowly to maintain the positive effect (Höltl et al. 2012).

Further gamification ideas turned up, but at this stage of implementation were found not having a sufficient implementability or testability basis, or not compliant with the low priority/discretion requirements. Nonetheless, some can be mentioned for future inspiration purposes. Examples of this would be awarding “medals” or “milestones” for achievements, challenges with similar cargo/route conditions between same fleet or different fleet drivers, collective fleet challenges empowering a fleets communication, awareness and image, and many others.

4.1.4 Sketching and prototyping

Following Cooper’s (2014) process, the sketching phase consisted in very simple sketches, focusing on setting a solid top-level framework with consistent elements, paying few attention to details and instead aiming for coherency. At the same time, different groupings and relationships of elements were tested. In general, sketches were quick visualizations consisting in boxes and brief descriptions, in order to create a larger quantity of variants. After discussions during the brainstorming sessions, some of the alternatives were rendered and low-fidelity prototypes were created. Figures 27, 28. 29 and 30 show some examples of sketches and low-fi prototypes.

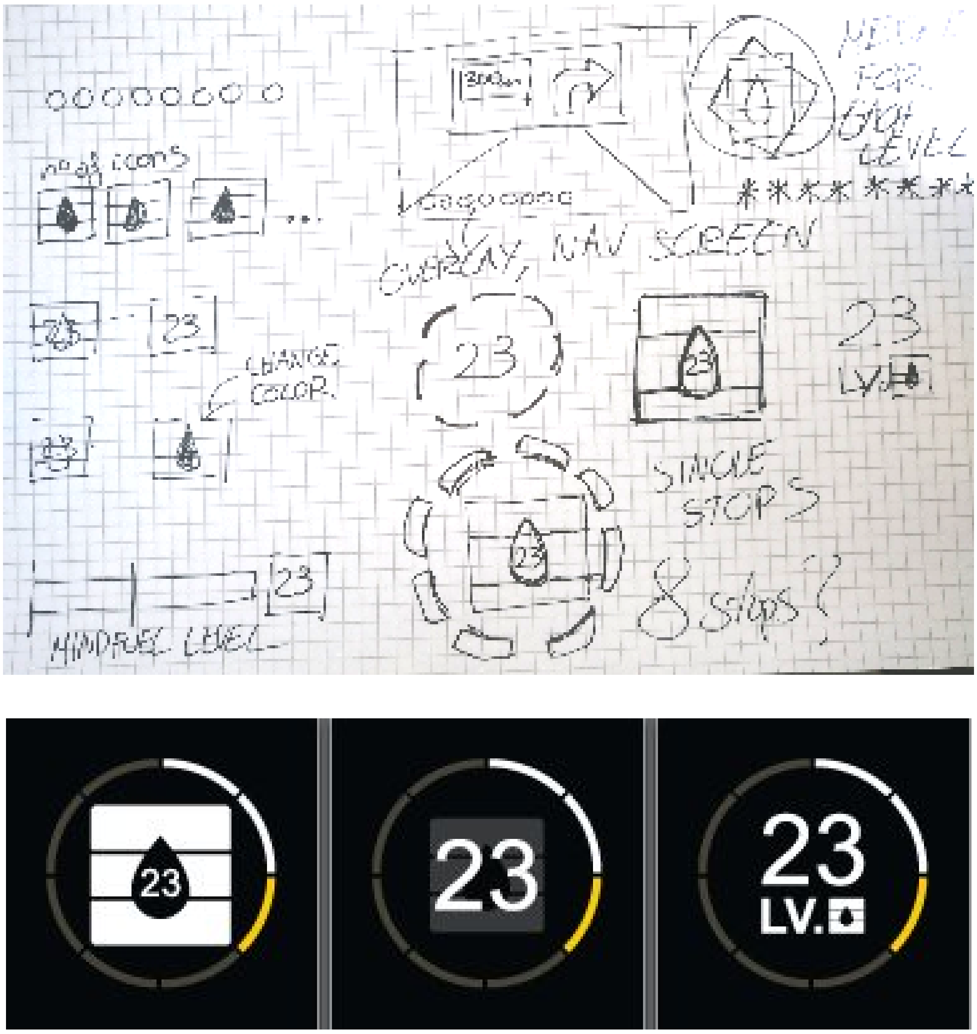


Figure 27: Sketches and prototypes of the reward systems.

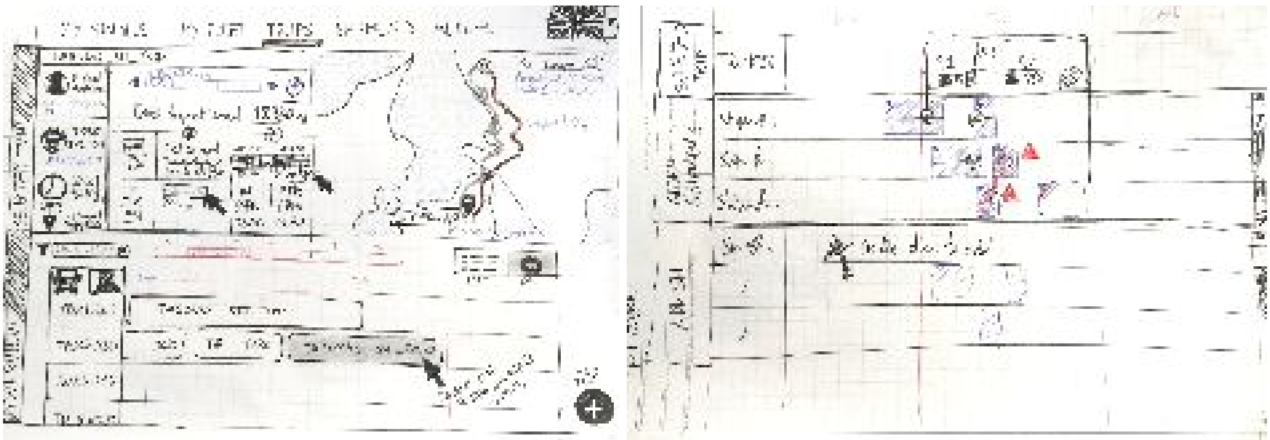


Figure 28: Sketches of the trip tab screen.

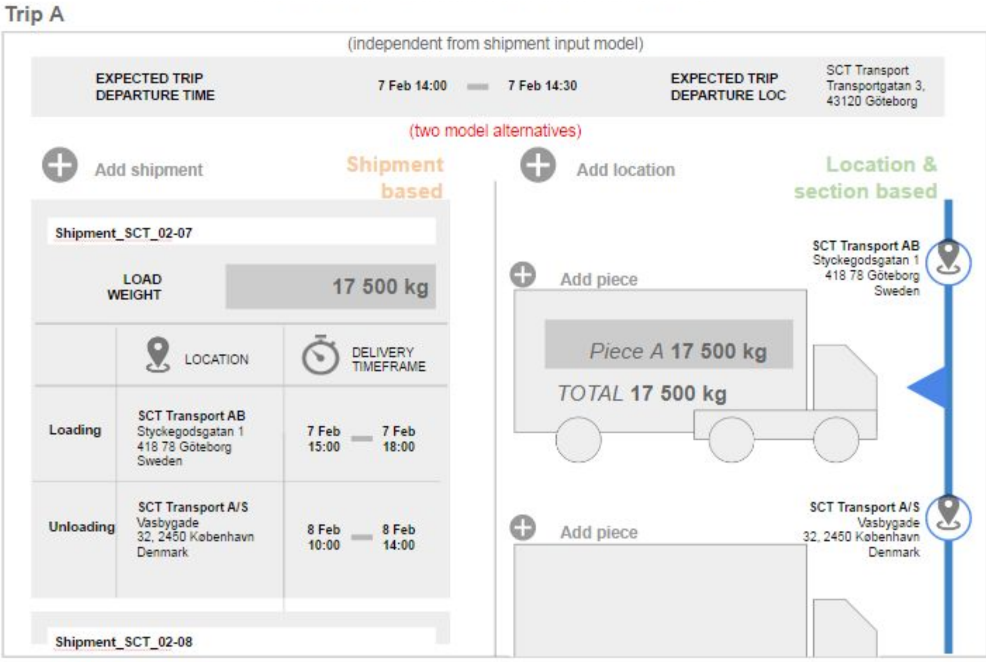


Figure 29: possible mental models for trip input interface, low-fi prototype.

Figure 30: low-fidelity prototype of the refueling tab screen.

4.1.5 Keypath and validation scenarios

Keypath scenarios, as Cooper (2014) explained, are those task-oriented scenarios that consider different use situations that are most common. Among the different platforms, iteration and ramification of pathways occur. For this reason, especially during the concept development, the possible use scenarios were considered and the prototype updated. Thus, this method led to consider all the essential paths the user could throughout the different platforms and thus not miss any basic interaction flow in between functions and elements to be considered in the design. The final considered keypaths are located in the appendix 9.6. Regarding validation scenarios, from those described by Cooper (2014), only alternative scenarios were considered, but more as alternative keypaths. Necessary-use scenarios (like upgrading, purging…) are out of the scope of the project, as well as edge-case scenarios.

It was seen that multiple factors shape the spine of keypath alternatives. These factors and variables are listed below, and helped consider all the possible elemental scenarios.

Variables for keypaths

GENERAL

Optimization alternatives

- Eco
- Cargo
- Time

Types of trip alternatives

- Single shipment trip and empty return
- Return trip
- Round/circular trip

History of use

- New user (company), first uses
- Have used MindFuel for a while

Types of cargo (linked to OA)

- Volume sensitive
- Import/export (middleman)
- Bulk
- LTL

Trailers

- Fleet owns the trailers / container trailer chassis
- They just pick semitrailers /+ trailers

DRIVER

- Understanding MindFuel
- Using MindFuel
- I know it, now I can do it by heart, I don't need the interface I still get points? (MindFuel as education, increase acceptance

4.2 Visual profile

Even though MindFuel would ideally be integrated in the Dynafleet environment, the fact that it is conceived as a separated product remarked the need of designing its own visual identity.

4.2.1 Volvo Visual Guidelines

Volvo Brand Mobile App Handbook (2015) as well as Volvo Brand Web and Portal Handbook (2015) guidelines were considered in genearal terms. As mentioned before, the fact of MindFuel being a separate product integrated at the same time in the Dynafleet environment led to make a tradeoff between Volvo Brand and third party products.

Starting from the desktop interfaces, MindFuel keeps the distinctive white header of all Volvo interfaces with the logo on the left and the user login on the right. Moreover, tabs with names are also kept for grouping categories of functions (figure 31). Similarly, the phone application keeps the white header and a navigation bar in the bottom with the top-level categories. Moreover, some other sub-tab are also kept from Volvo standards, as the overview/preferences tab in figure 33. No specific guidelines were found for onboard devices, however, only similar elements were utilised in the interface development, as shown in the figure 32.

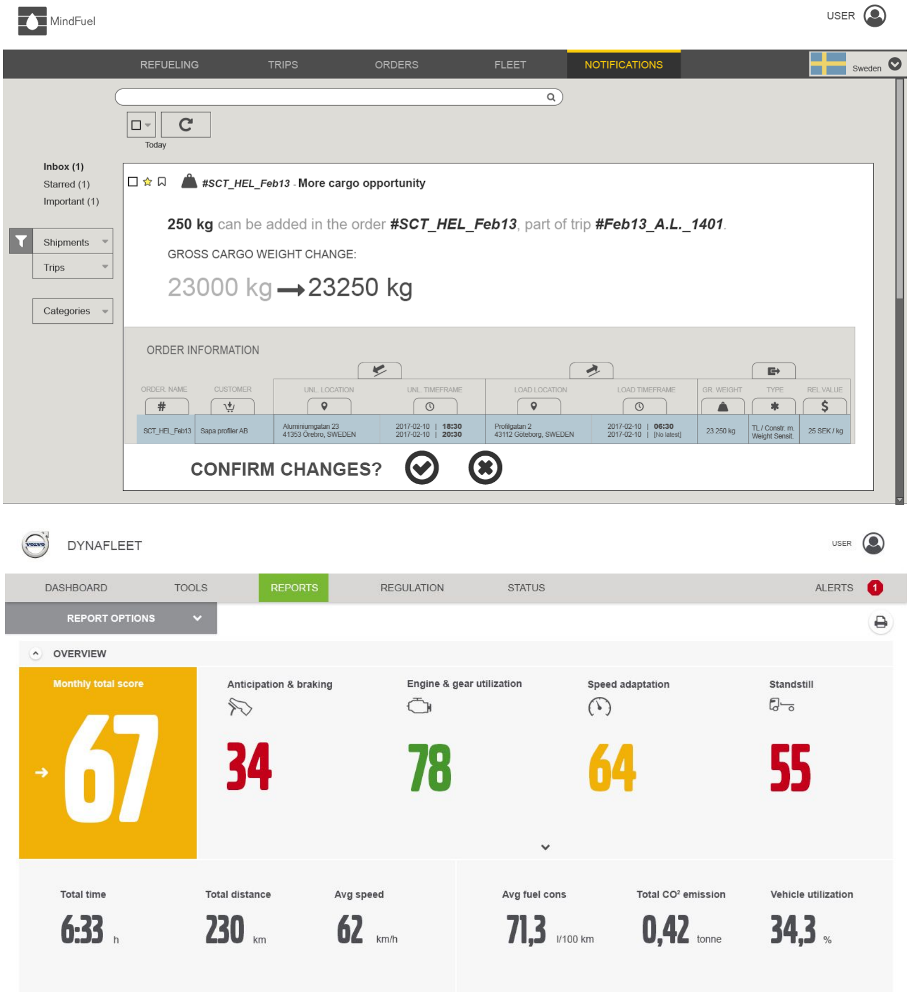


Figure 31: MindFuel and Dynafleet desktop screens.

Figure 32: MindFuel and Dynafleet onboard screens.

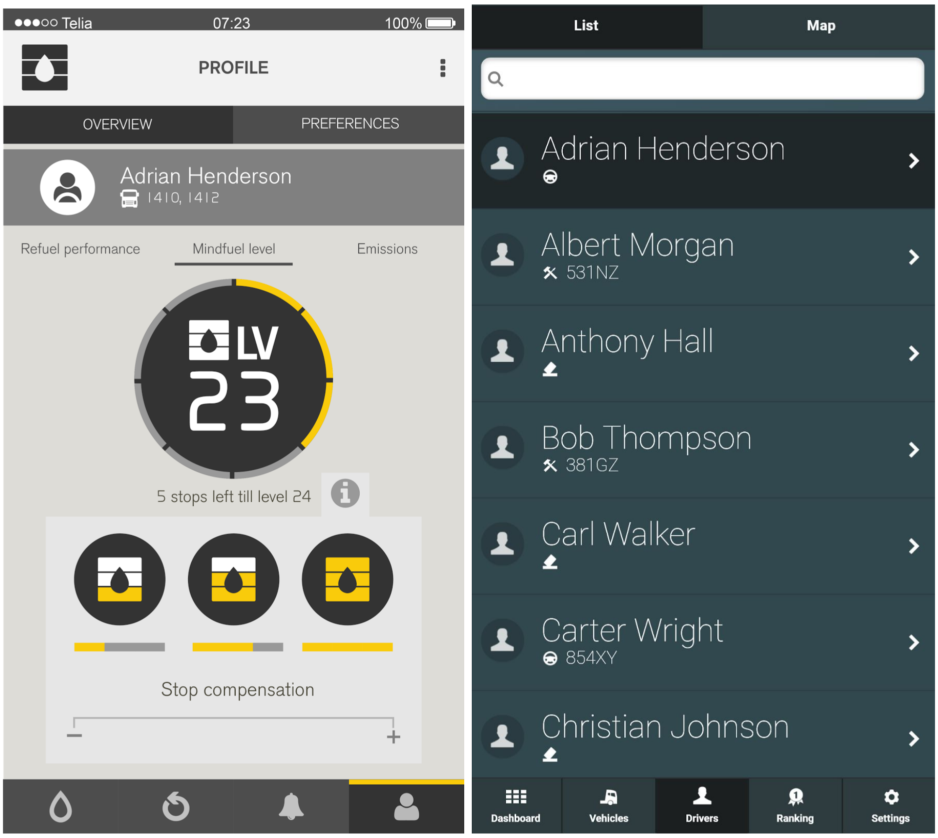


Figure 33: MindFuel and Dynafleet mobile phone screens.

4.2.2 Logo, corporate colors and greenness

Logo ideation and final logo

MindFuel can be defined as a tool to optimize truck drivers' refueling behaviors in order to match the priorities of the fleet. For that reason, elements such as fuel icons and symbols as well as the characteristic division and analysis of the fuel tank in different sectors (refill quantity, refill capacity, optimizable, used, not used etc.) were the main concepts utilised in the logo ideation, as shown in figure 34. Figure 35 shows the final logo design which consists of a fuel drop symbolic icon, the characteristic feature of a fuel tank divided in the three main section (used, unused and optimizable fuel capacity). The final logo was chosen due to its simplicity and effective communication of MindFuel function, as well as for the opportunity the shapes give to also visualize optimal stops.

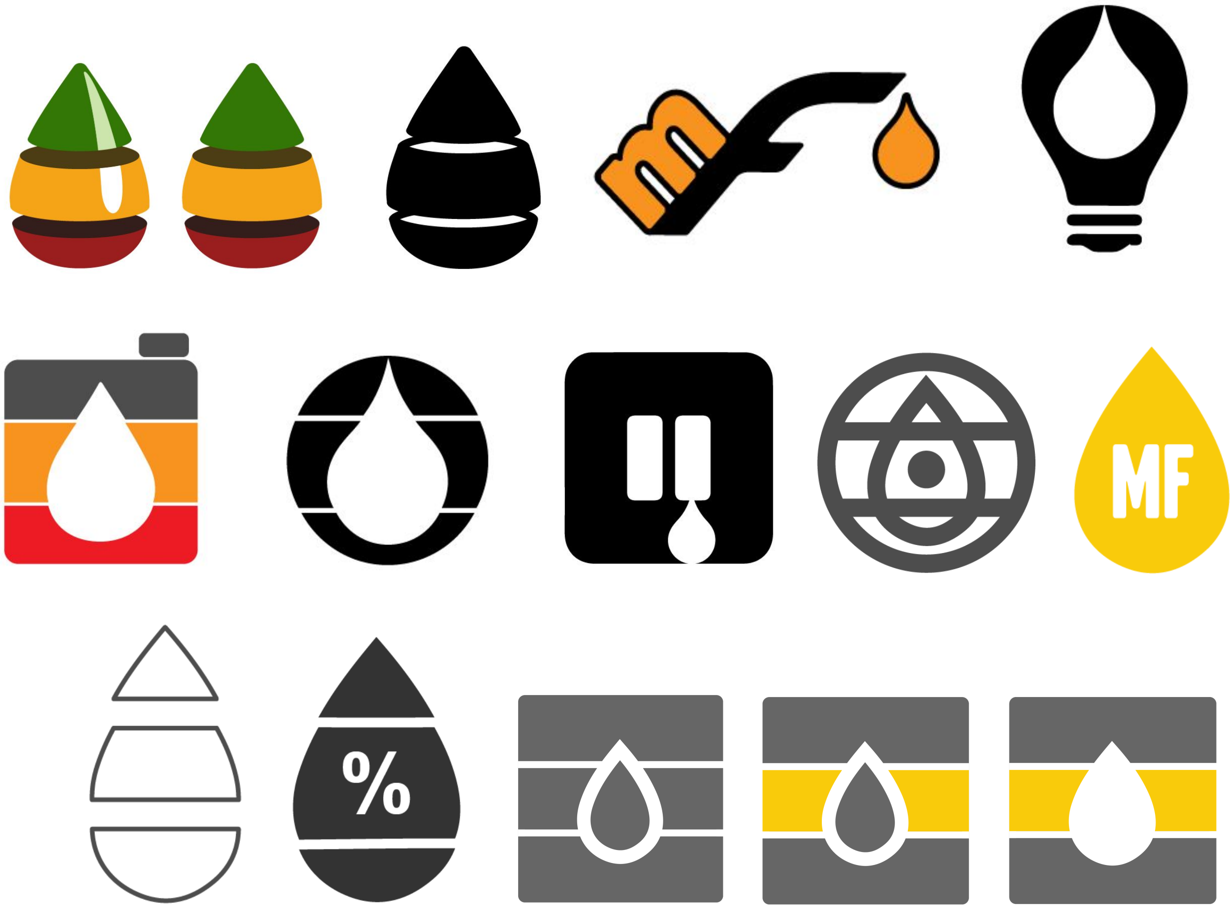


Figure 34: Logo ideation.

Figure 35: Final logo design.

MindFuel corporate color

Moreover, Supernova Yellow (name by ww.chir.arg, also can be found as Pantone 123, shown in figure 37) was selected as MindFuel's corporate color due to several reasons. Firstly, there was the objective of finding a trade-off between selecting a color that differentiating color that at the same time matches Volvo Brand Guidelines (shown in figure 36). As a matter of fact, a different color from other Volvo products (which usually tend to go for more dark blue, green and grey tonalities) due to the uniqueness of the product was selected, without forgetting its modeless nature (as specified in the requirements section, 3.5).

Greenness

What is more, although the product contains several visualizations in order to transmit awareness and encourage environmentally-friendly practices, it was clear that MindFuel was not a green product in its core. For this reason, following suggestions from Danciu (2015) in order to avoid "Green Washing" (meaning superficially transmit green values or characteristics) the product focuses on transmit added value to the user, in this case, enhanced planning, incentives for the drivers, positive impact in savings and revenue among other reasons. These thoughts are captured in the visual identity by avoiding green colors that are usually related to green products, and instead choosing a more distinctive color which is more coherent with the actual purpose of MindFuel: optimizing refueling behaviors to match the priorities of the fleet, which among them there are the environmental impact.

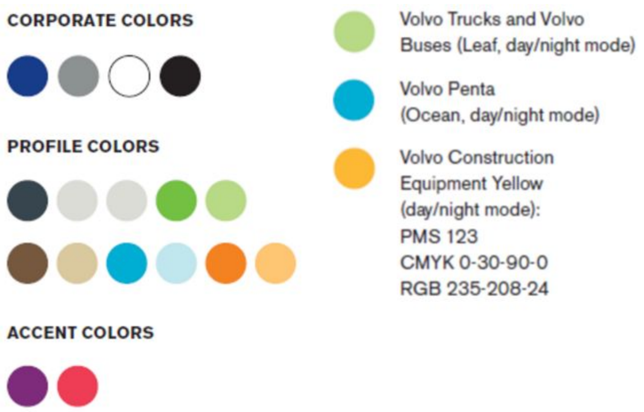


Figure 36: Volvo Brand Identity Colors from Volvo Brand Mobile App Handbook (2015).

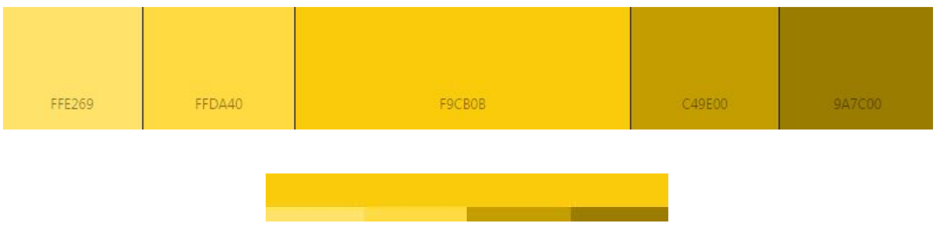


Figure 37: Supernova Yellow (ww.chir.arg), Pantone 123. Color variations.

5 Final concept

5.1 Design specifications

As it is explained in section 3.5, requirements of this project can themselves be considered as an outcome of this work, not only for future refinement, but also as considerable results for any work or product that shall be developed in the area.

5.2 User Interface

This section covers an overview of the phases regarding the final user interface development, conducted later in the ideation/refinement phase.

5.2.1 Concept development

From the early sketches, through all the discussion and decisions that took part in defining the interface concept, there was not a clear line that divided different concepts or radical decisions, but an array of incremental development decisions and small iterations that led to the final concept, displayed and explained in the next section. To have a more accurate idea of how the final concept development happened, it could be said that entailed user feedback explained in the last section, and desktop design principles from Cooper (2014) or Google (2017) usability guidelines for android.

5.2.2 User tests and evaluation

User tests

Displays, icons, labeling and other interface elements were briefly evaluated and updated. Most of the workflow and suggested keypaths were found logical and almost no problems arose. However, lacking a working prototype, some aspects could not be tested as there was some sort of keypath conditioning.

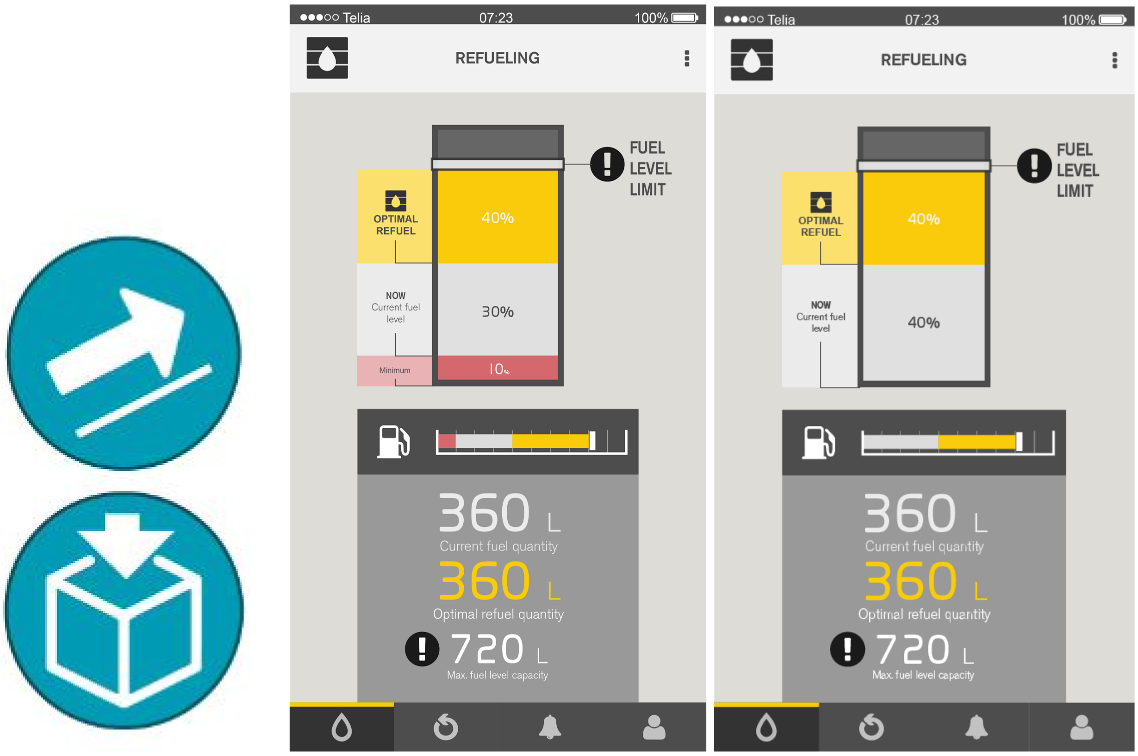


Figure 38: previous and final load icons and refuel (tank) visualizations.

Meetings with users led to iterations in visualization elements, icons and symbols such as load and unload ones. Similarly, adjustments in the fuel tank visualizations were made, e.g. showing just the current fuel level and the optimal refill, instead of also showing the minimum fuel capacity as it is shown in figure 38.

Evaluation against requirements

In this case, requirements were not used to choose between substantially different pre-concepts due to the nature of the project. Instead, these are used as a validation mechanism. Likewise, many requirements could require a whole project only to be analyzed in their complexity, as it was mentioned in the requirements section. Moreover, most of these are quite qualitative, so it is found more useful to explain to what extent (how) they are fulfilled, or if there are any major flaws (a comment is attached to each requirement title). In some cases, requirements are very useful for an actual development of the app (a good example is R0b), but it was found that from the interface part it is just about limiting showed content or similar. For this reason, it did not add anything to the interface design to address it graphically. Thus, these cases will be commented after the sentence “internal functioning requirement for developers”. Full description of each requirement can be revised at the requirements section.

GENERAL REQUIREMENTS

W0 Integration & Discretion: most of the information is integrated within Dynafleet, and the onboard part could also be within the Dynafleet app. Regarding effort, there was a thorough intent in reducing the input time and effort by adding taylormade import functions and labeling, as well as the grouping of elements and general structure. When it comes to the driver part, discretion is applied in considering as few modal, disturbing or distracting feedback as possible. The driver app is also proactive and the dispatcher app has different smart functions for suggesting optimal trucks and identifying import elements.

Multiple level solution

R0a Adaptation to roles: a multi-platform solution was delivered only requesting input that the user should have at hand or know instantly.

R0b Relevance: “internal functioning requirement for developers”.

R0c Optimal setting structure: the combination of driving profiles (including preferences and compatibility), trucks and trailers, and the system making the trips and importing the shipments was thought to agglutinate the information in such a way that can be accessed in biggest relevant chunks with the least edition.

SPECIFIC REQUIREMENTS

Customer desirability

W1 Greenness: all the different solutions (desktop, phone, onboard) visualize the fuel consumption decrease due to MindFuel optimization, the subsequent kilograms of emissions saved as well as tasks with equivalent impact to help to create awareness among the users. Green washing was avoided in the visual and functional styles.

R1 Credibility & Trustworthiness: the desktop interface shows to fleet managers the impact on the business case of each of the alternatives, including the initial business case (current expenditure prior to implementing MindFuel) to allow the users to make an effective comparison. Cases where optimization cannot be done or are not suitable are restricted. However, more could be done in a future real implementation to convey this background actions for user trustworthiness.

Adaptability to user and context

R2 Flexibility: MindFuel provides three different optimization alternatives from which the drivers can choose the one that suits them the best.

R3 Optionality: “internal functioning requirement for developers”. However, an option should be added in the profile to set these preferences (which are quite standard to any software).

R4 Integration of freedom: a specific visualization and adaptation to the points system was designed for cases where the driver stops in a non indicated station, and this does not penalize driver proactiveness for the same cause as the recommendations of MindFuel pursue.

R5 Legality: legal issues were considered in the trucking area including, speed limits, compulsory breaks and cargo weight limits

R6 *Reward system:* a simple point and level system was developed, which both motivates the driver (points) and shows a general cumulative compliance indicator (level). The point system did not have any monetary units not to create conflicts; the actual compensation currency remains to the owner to decide.

R7a *Distribution of data input; invasiveness:* Most of the manual data, including planning and trips and shipments specifications will be provided by dispatcher. On the other hand, the driver would only introduce and adjust preferences.

R7b *Minimization and convenience of data input; invasiveness:* from the dispatchers side, the shipments / orders distinction helps integrating MindFuel in their workflow at the right moment. Timing convenience is further aided by all the features explained in the comment after R0c above. In the case of the drivers, the system is designed to not bother the user and work proactively despite not having the user following its instructions (e.g., reacting to and aiding an unexpected stop for the system, arbitrarily decided by user).

R7c *Optimization of feedback; invasiveness:* the phone application gives drivers pre-trip information of optimal refueling stops and other events. On-board notifications are given just for the refueling stops and can be easily avoided by the driver.

W2 *Anticipation to driver actions:* notifications onboard can easily be dismissed and any decision can be cancelled (undo option). However, as if a driver stops in a place while still having fuel for the target , probably having taken a detour, warning the user that it is not necessary to stop there cannot be done before the detour is taken. For this reason, two negative reactions would happen: a) making the user feel stupid or angry at the system, which goes against the interaction design guidelines described by (Cooper, 2014); and b) actually losing time if the detour was for nothing and a refill is not done. For these reasons, and having found no means of such anticipation, it was decided not to include any discouraging message when this happens.

W3 *Driver workday friendliness:* MindFuel would give suggestions accommodated to driver preferences, especially regarding time (e.g. user is able to choose “few stops as possible”).

User motivation

W4 *Ideal compensation:* this idea was dismissed since the surveys showed almost unanimously a preference for monetary compensation that could compromise R5 if the solution implemented it by default in the GUI.

W5 *Assistant & environment oppositor comprehensive*: this was not explicitly showcased, but the design contemplates small actions of which, if a selection was developed, could pop up exclusively among all functions. For example, the suggestion of refuel amount in a completely user-decided stop.

Optimization and priorities

R9a *General optimization:* MindFuel allows the fleet manager to configure default settings in the profile section. In this section, the fleet managers can order eco, cargo and time optimization alternatives in terms of prioritization.

R9b *Back up alternative:* following the prioritization of alternatives previously done by the user, the system would provide sub-optimization alternatives according to the needs of the user in case higher-priority alternatives cannot be applied.

W6 Dynamic adaptiveness: optimal refueling locations would be updated according to the circumstances of the trip. In case the proposed alternative is not applicable anymore, other suggestions would be proposed. Similarly, the required fuel fill quantity would be updated for every refueling event. More complex algorithms to anticipate tight DTC situations remain for the software development.

Display implementation & infrastructure

R11 Dynafleet context: the solution was implemented in the Dynafleet environment in all cases that was relevant.

W7 Navigation systems: considered by integrating the tomtom navigation available. Other than that, it is about "internal functioning requirement for developers"

R12 Truck implementation: two alternatives are proposed for the onboard interface; for new trucks, an onboard screen interface that covers best all the functions, and a similar (or same) interface for a standing smartphone replacing the onboard screen, which was not visualized as it would be basically the same (do not confuse with the smartphone version for planning, which was visualized).

Privacy

R13 Configurable privacy: "internal functioning requirement for developers" and standard preferences controls that could be implemented together with notification preferences.

Responsibility and critical weights

R14 Responsibility conveying

> *R14a weight limit compliance:* warnings are designed for the driver (which is responsible for the weight distribution) and notifications for dispatchers are thought accordingly .
>
> *R14b allocation of responsibility for weight distribution:* a specific interface (load distribution tool) was not designed due to the specificity of the task for the dispatcher and since the final responsibility lies on the driver. Several backend solution to limit this and keep it simple could be implemented "internal functioning requirement for developers".
>
> *R14c limitation of OA2 for trailers:* MindFuel would automatically remove OA two (cargo) when extra cargo would be loaded in the trailer, since it will not be possible to add extra kilograms without surpassing the overweight limit per axle "internal functioning requirement for developers".

5.2.3 Final concept

Desktop

Among the five tabs the interface contains, ‘refueling’ is where the optimization and refuel planning actions, preferences and performance overview happen; ‘trips’ contains tools to organize and visualize the trips (made of shipments); ‘orders’ entails a database of incoming importable orders, and ‘fleet’ (Figure 39) shows the different databases of trucks, trailers and drivers, including driver preferences (e.g. refueling preferences) and general fleet preferences (e.g. fuel supplier, frequent cargo or default refuel optim. alternative). Multiple ‘fleets’ can be entered to make groups of similar characteristics of trucks/trailers/route types. Finally, ‘notifications’ shows different messages about important driver events, optimization possibilities and other warnings.

In the orders tab (figure 40), users can visualize, filter, sort and assign orders to a trip or shipments (agreed orders with a customer), as well as past shipments tagged as favorites for future templates. Spreadsheets can also be easily imported to the system by assigning labels to the different columns using the taylormade functions in the right panel (upper screen of figure 40).

Figure 41 shows how the user can visualize trips both in list mode or timeline/calendar mode (allowing a visual planning overview) in the lower screen-half. The selected trip details are shown in the upper half (details+map) of a selected order (upper central box). A full (separate) prototype shows how it looks when the selected order is shifted: the yellow segment in the map switches accordingly. Figure 42 (lower screenshot) depicts a specific snapshot of the process of setting a trip. The different keypaths that arise when setting a trip are described in text (and graphically in the separate prototype) as figure 42 suffices to explain most part of the interface for these steps.

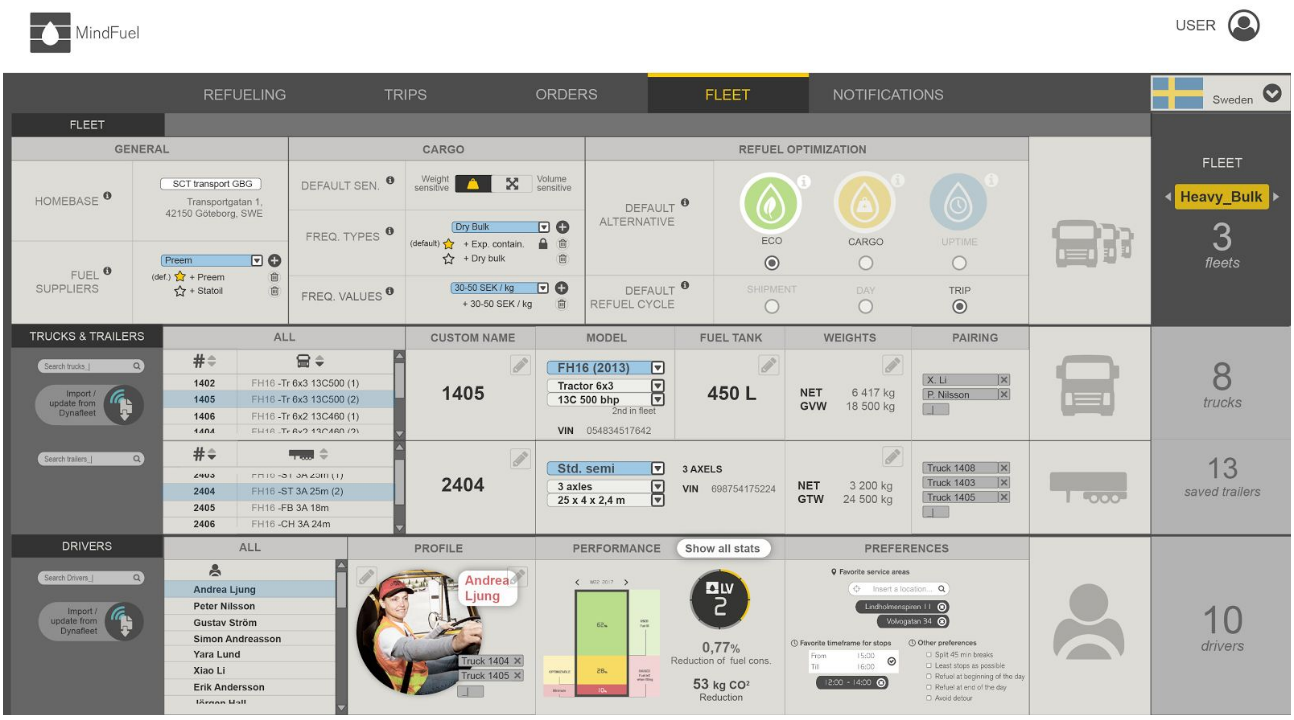


Figure 38: desktop version; fleet tab.

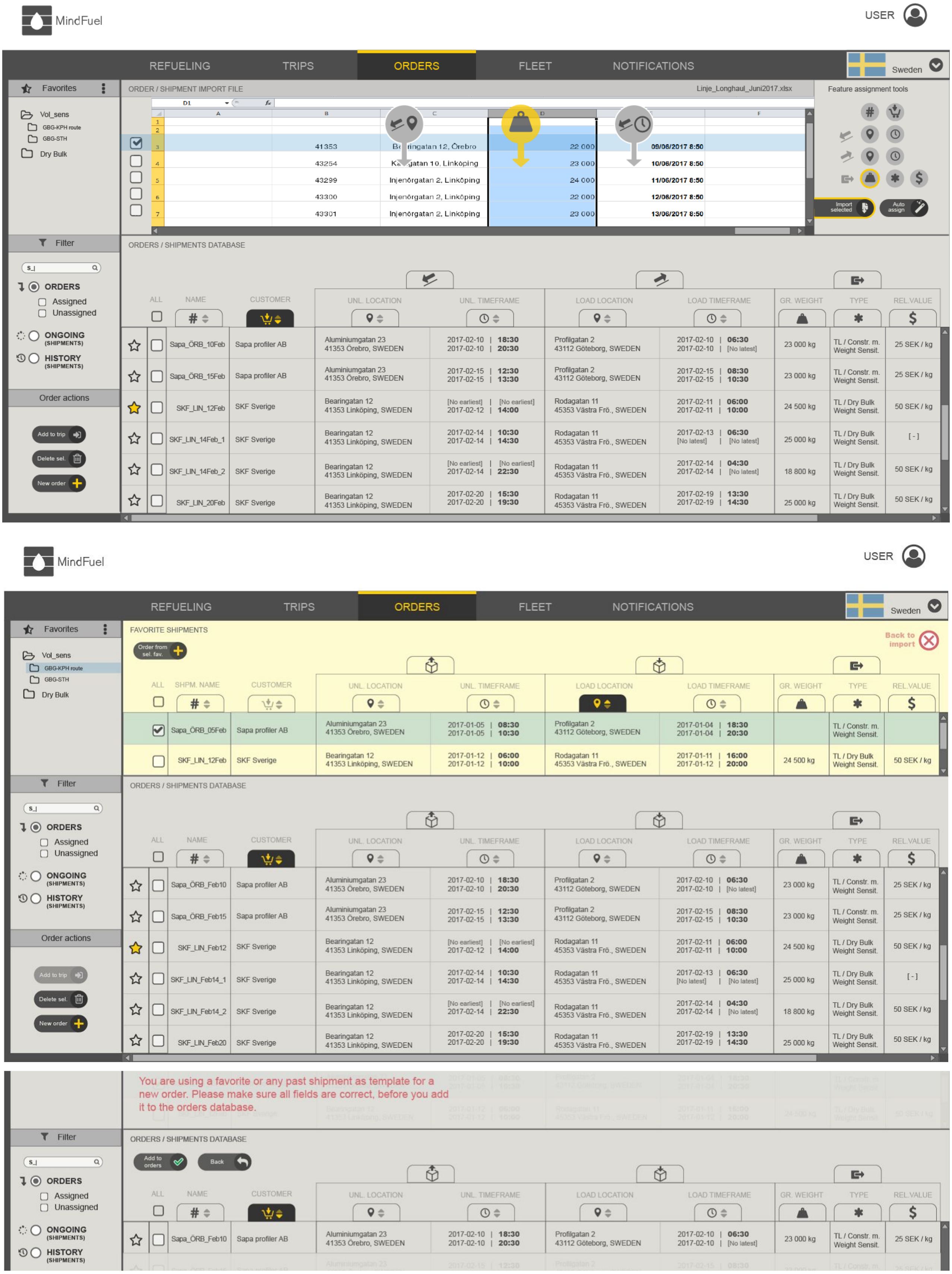


Figure 40: desktop ver.; import orders (1), edit orders, shipments and favorites (2), add from favorites (3).

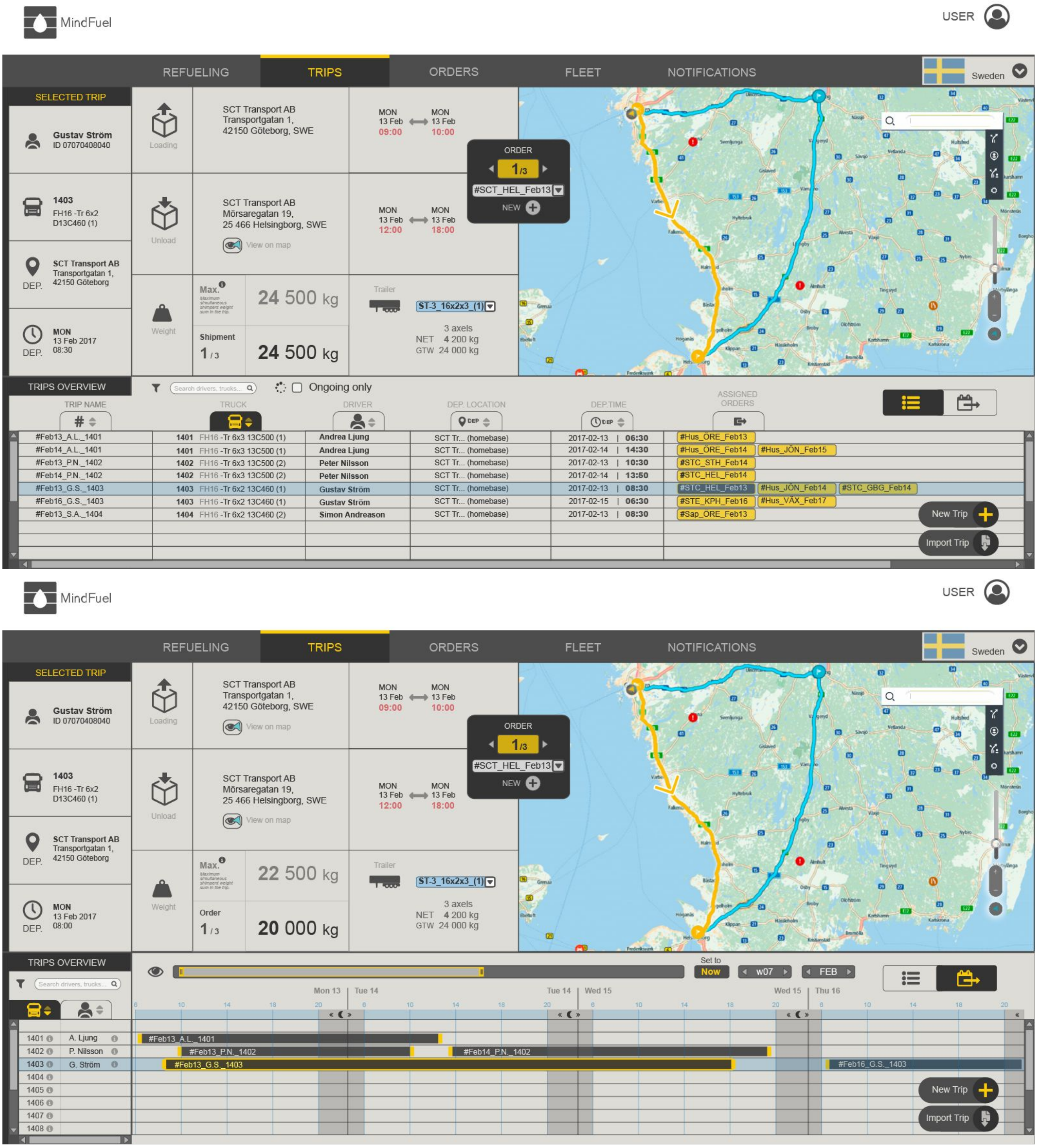
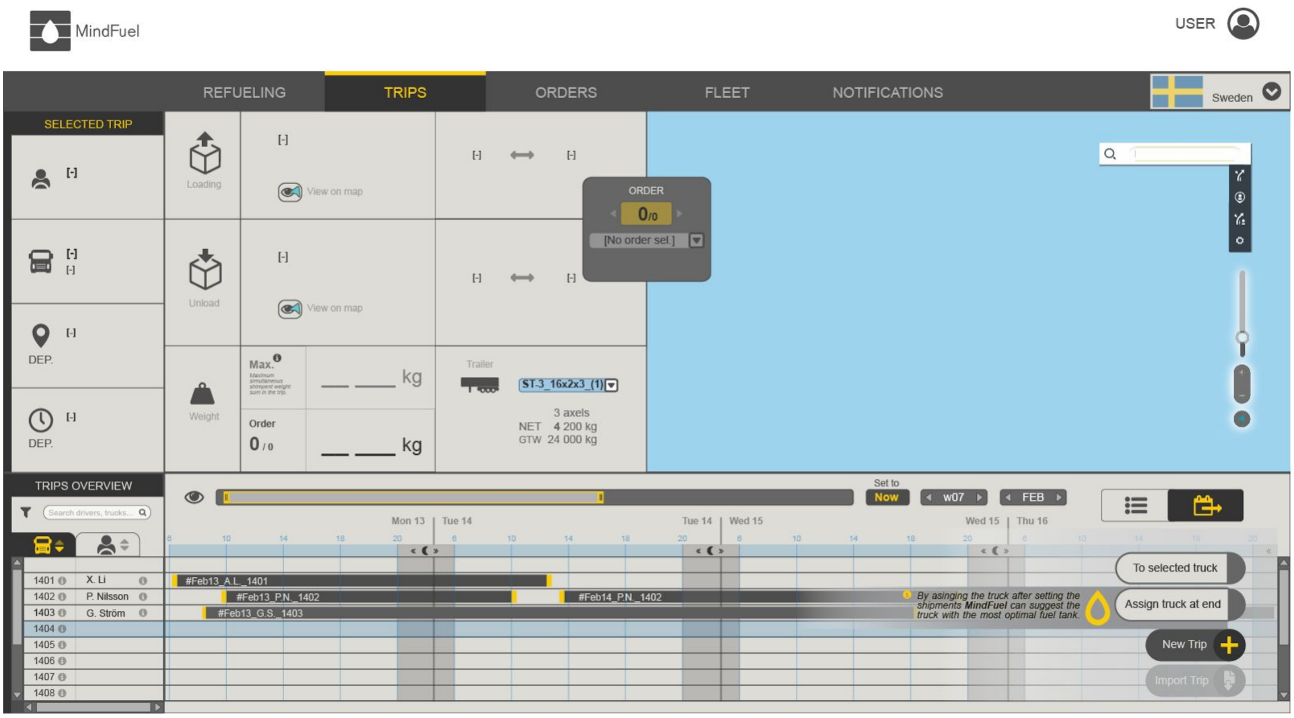


Figure 41: desktop version; trip view modes.



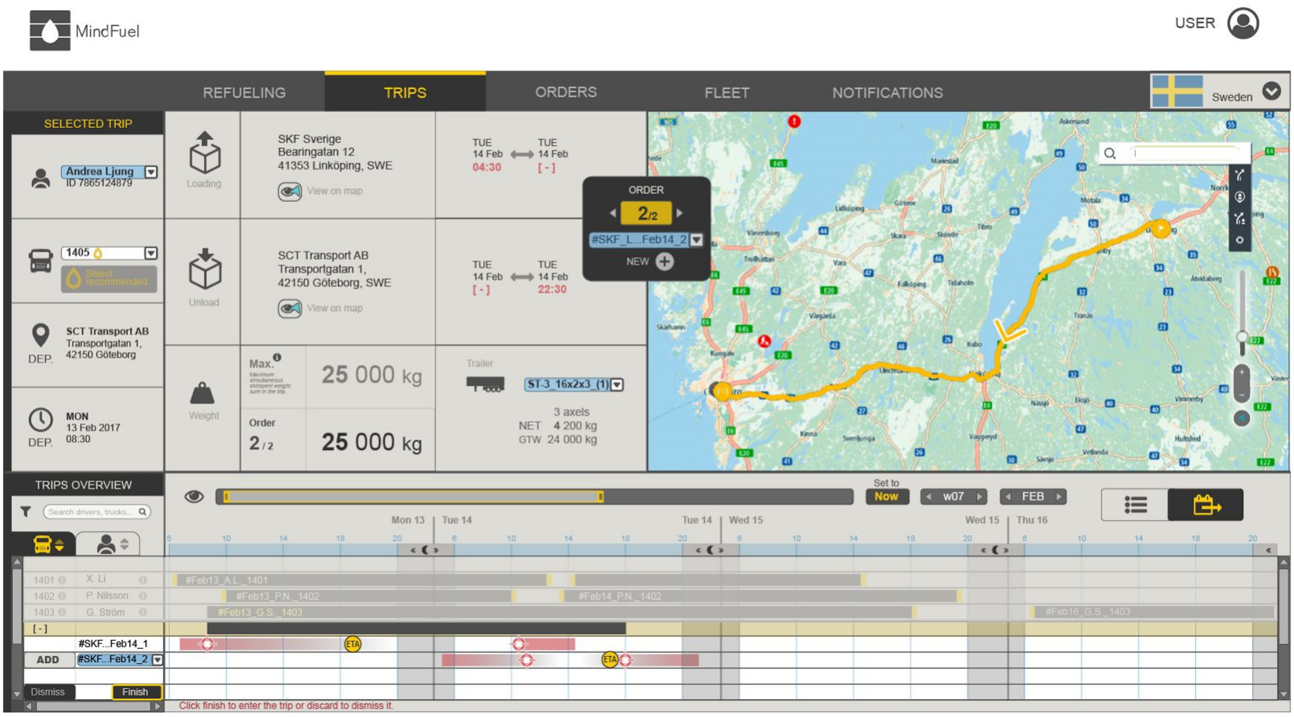


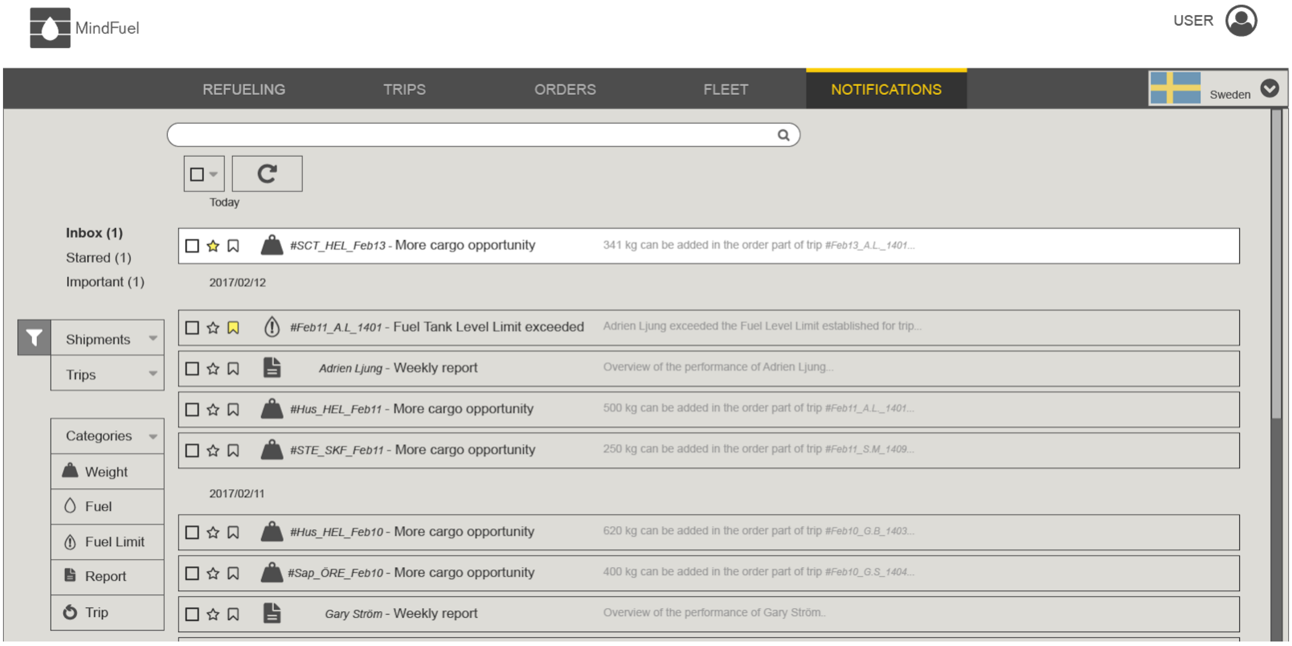
Figure 42: desktop version; adding a trip.

Regardless of the path, the user will add an order from the dropdown list to the trip (lower left corner). Once the order is plotted in the time axis, the system shows the quickest estimated time of arrival, and two aim shaped drags to define an optional target pickup and unload times within given delivery timeframes, thus aiding combining several orders. Once all orders are added and adjusted, the user can finish the trip as long as a driver and a truck are assigned (only compatible showed).The interface differences in the two different paths explained below are described next:

a) The user selects a truck to assign orders to: it is the first option after clicking on 'add trip' (upper screenshot in Figure 42). The orders are assigned to a truck from the beginning.

b) The user combines orders and assigns a truck in the end, thus allowing a MindFuel recommendation (second option). Once all orders are added, MindFuel suggests an optimal truck for the trip —not feasible until a confirmation of all desired order placement.

Figure 43 and 44 visualize the notifications tab, where users get messages concerning topics such as additional cargo opportunities in a certain shipment due to optimized refueling, alarm messages in the unlikely case a drivers exceeds the fuel tank level limit in a refill, or weekly report updates of drivers. The user will be able to sort and filter notification messages down to categories (weight, fuel, fuel limit, reports and assigned/unassigned trips), as shown in figure 43. Additionally, figure 44 shows a opportunity-notification for adding more cargo for an ongoing input order that shall be negotiated to become a shipment, where the user can directly see all the information of the shipment in the screen as well as confirm the changes.



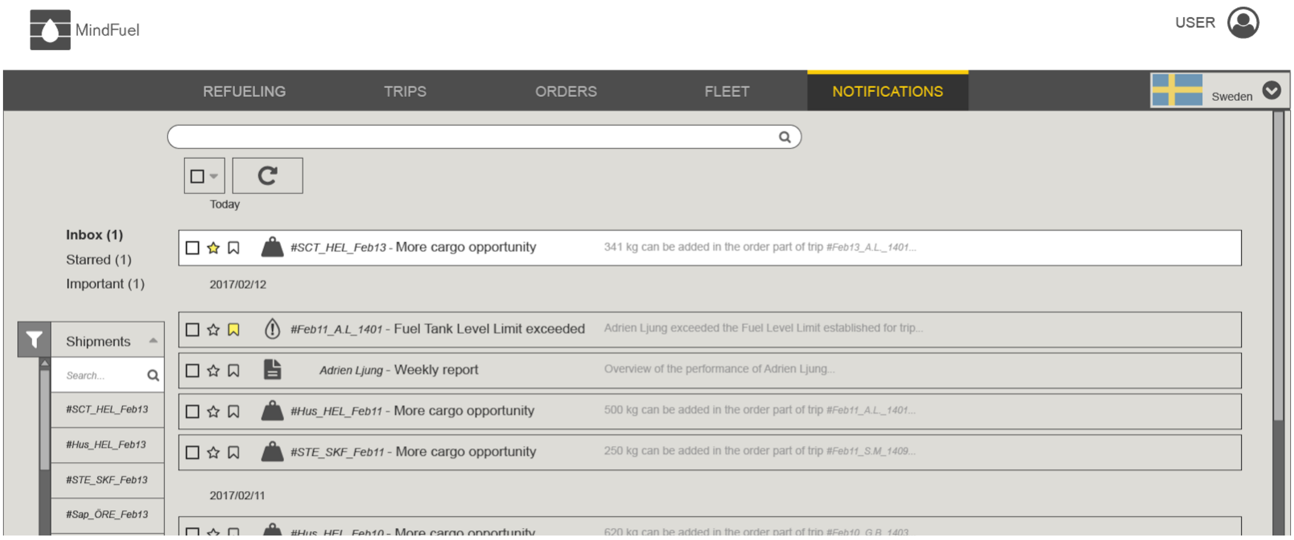


Figure 43: desktop version; notifications, categories sorting (1) and filtering (2).

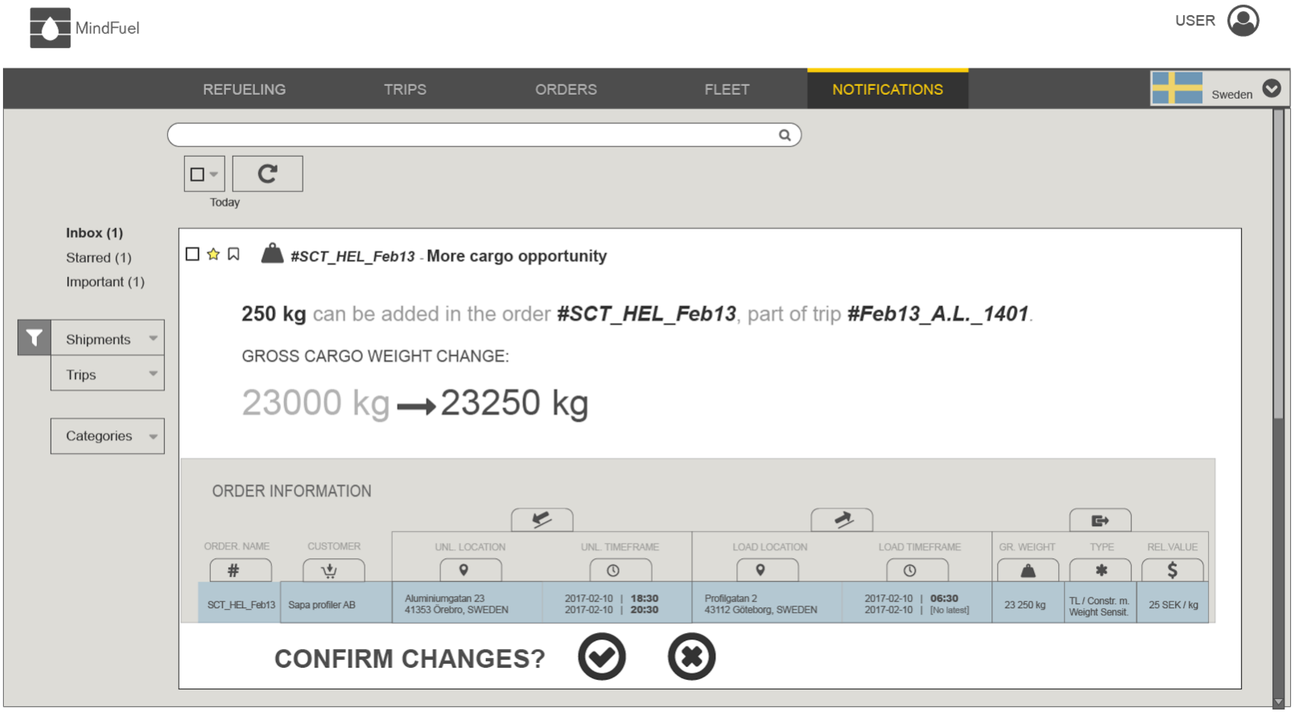


Figure 44: desktop version; notifications, opened notification.

Figure 45 shows two examples of the refueling tab screen. On the top-left part, there is the upcoming trips section, where the user can select a previously planned trip. The fleet manager can sort the trip list by departure date, truck and driver.

Moreover, there is a search bar and two categories were the user can filter the trips down to total (all the trips currently planned) and not reviewed (where the system has automatically assigned a refueling behavior according to the preferences previously selected but the user has not revised).

On the right of the upcoming trips section, there is the fuel tank utilization visualization board. Above the tank there is the capacity in liters of the tank, below there is the amount of refills the trip will have and the current refill visualized. Moreover, the user will be able to adjust the refill strategy; so they will be able to choose to refill in each event what is needed for optimize a shipment, a day or a trip. More regarding the tank, red sector refers to the optimal refill level (fuel level the truck would ideally have when arriving to the refueling location), which in the case coincides with the minimum fuel level, when the warning lamp of the fuel gauge lights. Green part refers to the fuel fill quantity, on the left part of the tank is visualized the amount that will be needed for the trip while the capacity in the tank refers to the quantity chosen for the refill in the selected event (shipment, day or trip). In grey, there is the empty and thus optimizable capacity, displayed in percentage, liters and kilograms. What is more, the fuel tank level limit is visualized with a yellow line. On the right side of the board, the user can select the optimization alternative desired for the selected case.

On the top right, there is an adapted TomTom (2017) navigation visualization of the selected trip. Navigation screens visualizes load, unload, suggested breaks and refueling events.

On the bottom-left there is a trip vs consumption graph that displays the estimated consumption of the vehicle, so cargo opportunities (in case OA two, cargo, is selected) when fuel level is below the fuel level limit.

On the bottom-right, the user has an overview of MindFuel's impact on the business case as well as on emissions. This section contains the annual business case (income and expenditures) regarding the factors MindFuel can affect as well as its actual impact with concrete numbers. On the right part there is also a visualization of the total kilograms of emissions reduced as well as the quantity of tree seedlings and incandescent lamps switched to LEDs that would have been needed to retrieve/reduce the same quantity of emissions. Furthermore, when the user switches from different optimization alternatives and refill strategies, the impact of those actions in the business case will be shown with arrow icons pointing up in green (positive) and down in red (negative) as shown in 46 (left bottom part). Figure 46 shows an example of the visualization of two different cargo alternatives (only the refueling visualization and timeline), one for a day and one for the trip with the same trip selected. Figure 47 shows an example of OA one application (eco) in the first screen while the second screen shows one of the OA three (time).

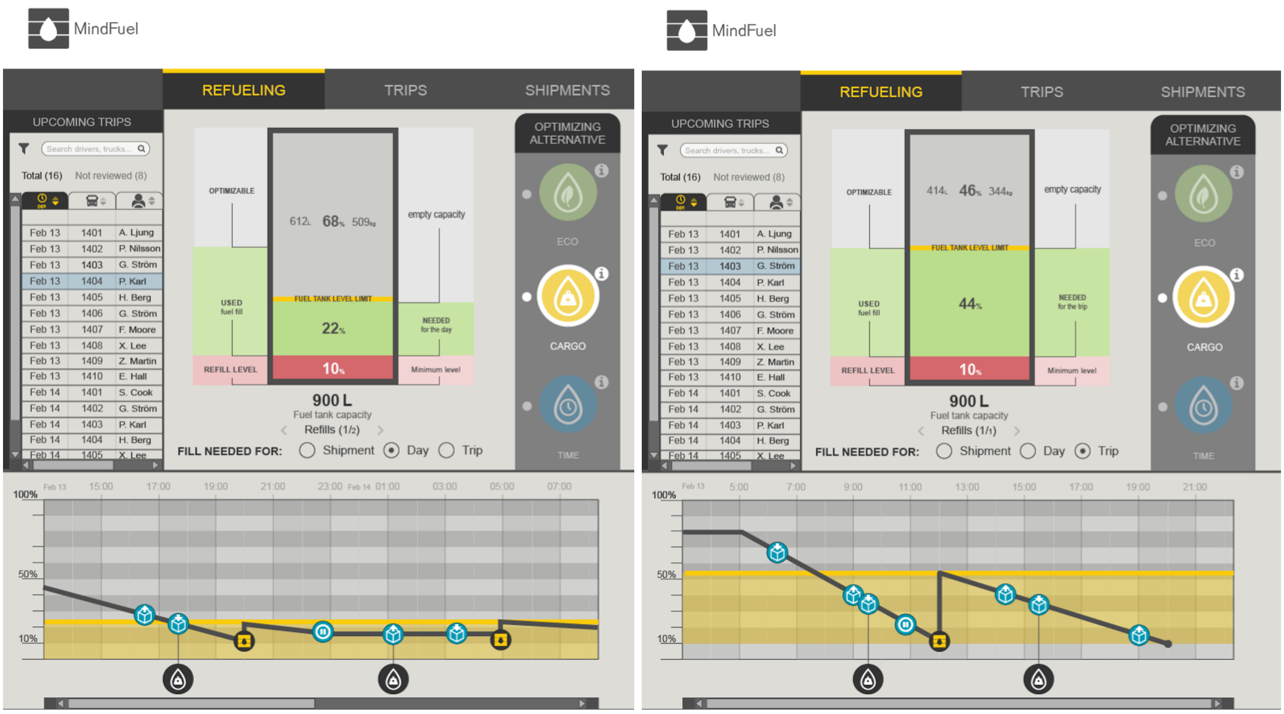


Figure 45: desktop version; refueling.

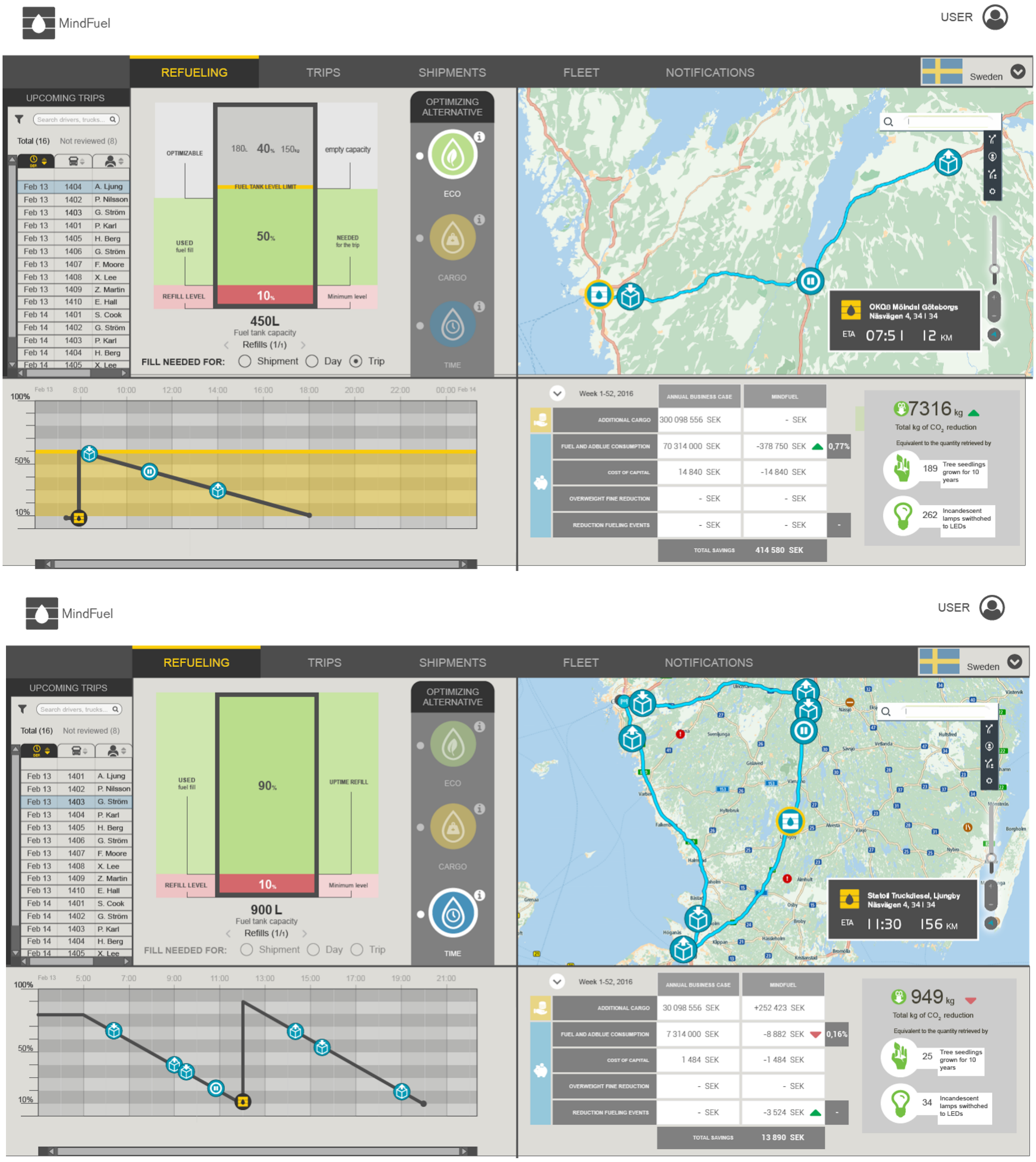


Figure 46: desktop version; refueling (2).

Mobile

The mobile version allows drivers to check the route plan and MindFuel recommended gas stations on the way at a glance before departure, as well as managing their preferences and tracking their performance regarding refueling.

Figure 47 displays both launch and login screens. This transition follows one of the alternatives suggested in Volvo Brand Mobile App Handbook, having a launch image that becomes the background of the login screen afterwards.

The refuelling screen (figure 48), supports the driver indicating the optimal quantity in each refueling stop. The screen contains a visualization of the fuel tank utilization, the fuel tank bar chart currently used in Volvo Trucks dashboard displays, and the exact amount of liters to be refilled. The current fuel quantity is visualized in white (same as in the dashboard display) while the optimal refuel quantity is displayed in supernova yellow (MindFuel yellow). What is more, the fuel level limit is shown and remarked in order to ensure the driver is aware of no surpassing it.

The bottom bar navigation in figure 49 contains tabs with the four main categories: refueling, trips, notifications and profile. On top, the white headline shows the name of the selected tab from the bottom line, the logo of the application on the left and a settings icon on the right; this pattern follows Volvo Brand Mobile App Handbook guidelines. Moreover, figure 50 shows the trip timeline visualization in which the driver can see loads, unloads, suggested refueling stops and breaks. By tapping one time in each icon, the user would be able to see the name of the event. On the left, there user can select each of the three refueling stops the system will suggest and how the route and sequence of events changes in each case.

On the screen in figure 49, when an event is selected, the board on top of the timeline visualizes the Estimated Time of Arrival and the kilometres left for the selected event. If no event is selected, the board by default will show the data of the final destination. Additionally, on the bottom-left part of the screen, the user will be able to change between days, in the cases the trip consists of more than one day. Moreover, on the top-left part of the screen, the user will be able to switch to map view (second screen in figure 50) adapted from TomTom navigation (TomTom, 2017).

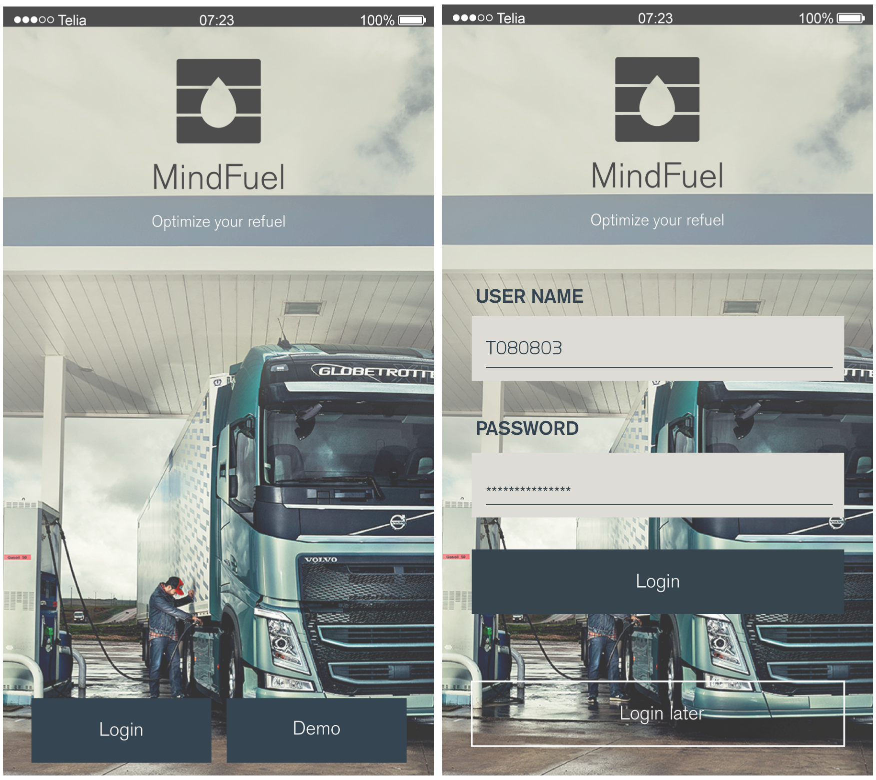


Figure 47: mobile version; launch and login screens.

Figure 48: mobile version; refueling screens.

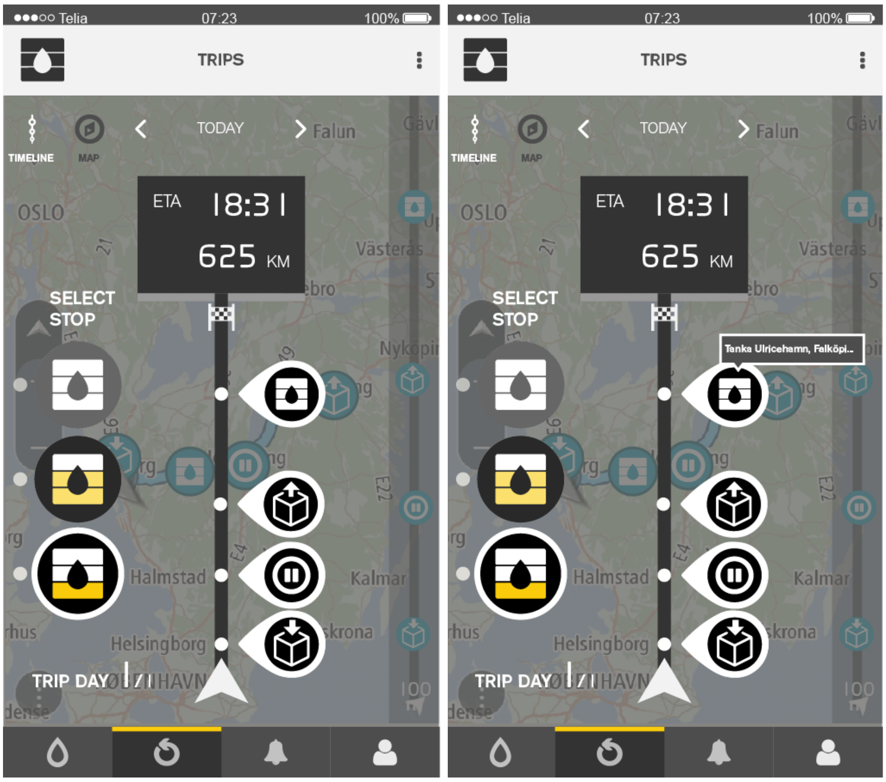


Figure 49: mobile version; trip timeline screens.

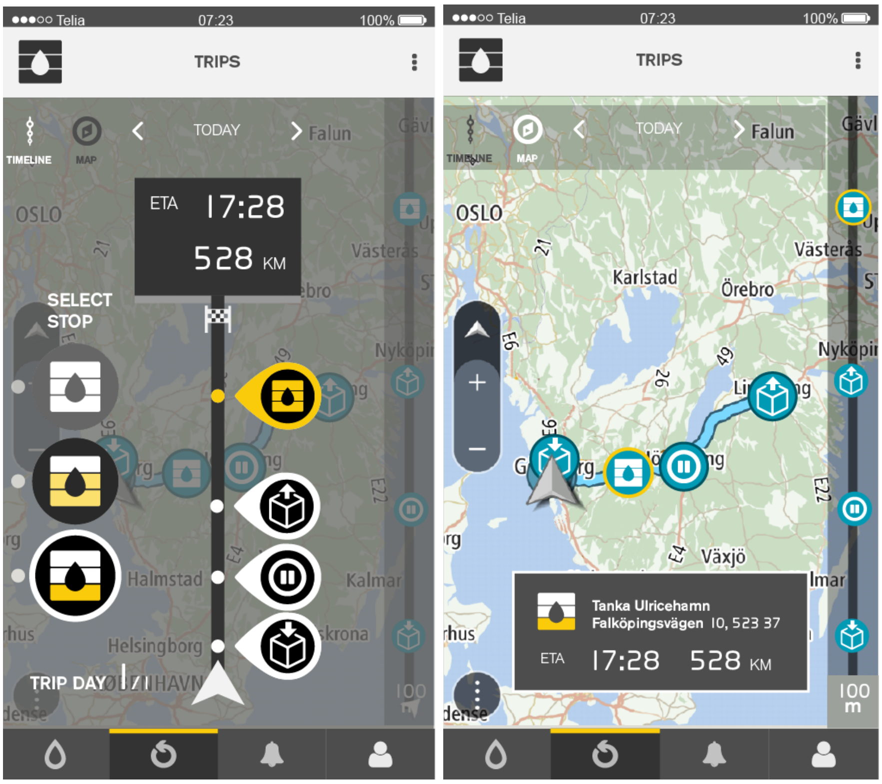


Figure 50: mobile version; transition from trip timeline to map view.

Figure 51: mobile version; profile, overview, refuel performance and MindFuel level.

Figure 52 shows some of the post-trip information the driver will be able to visualize in the overview section within the profile tab. On top, a stack contains the drivers name, profile picture and vehicles driven will be displayed; feature that will remain through all the screens within the profile tab. Profile tab contains two sub-tabs: overview and preferences. Within overview three sub-tabs are available to visualize refuel performance, MindFuel level and emissions.

Refuel performance shows a visualization of the average fuel tank visualization. In red, the minimum fuel fill capacity, the most optimum fuel capacity left the drivers should refill with, is displayed in red. In yellow, the fuel amount that could be optimized is visualized. Consequently, both quantities conform the “unused capacity” or fuel left when filling. Also, the average fuel fill or “used” is shown in green. MindFuel level (second screen in figure 51) visualizes user’s current MindFuel level according to the number of optimal stops he/she has performed. The system will provide three different stops; providing one, two and three points respectively. The amount of points corresponds to how optimal the stop is, the more points the more optimization. Each time the driver completes a circle (8 stops) he/she achieves a new level. The screen provides a visualization of the current level and an information tab explaining the stops score system.

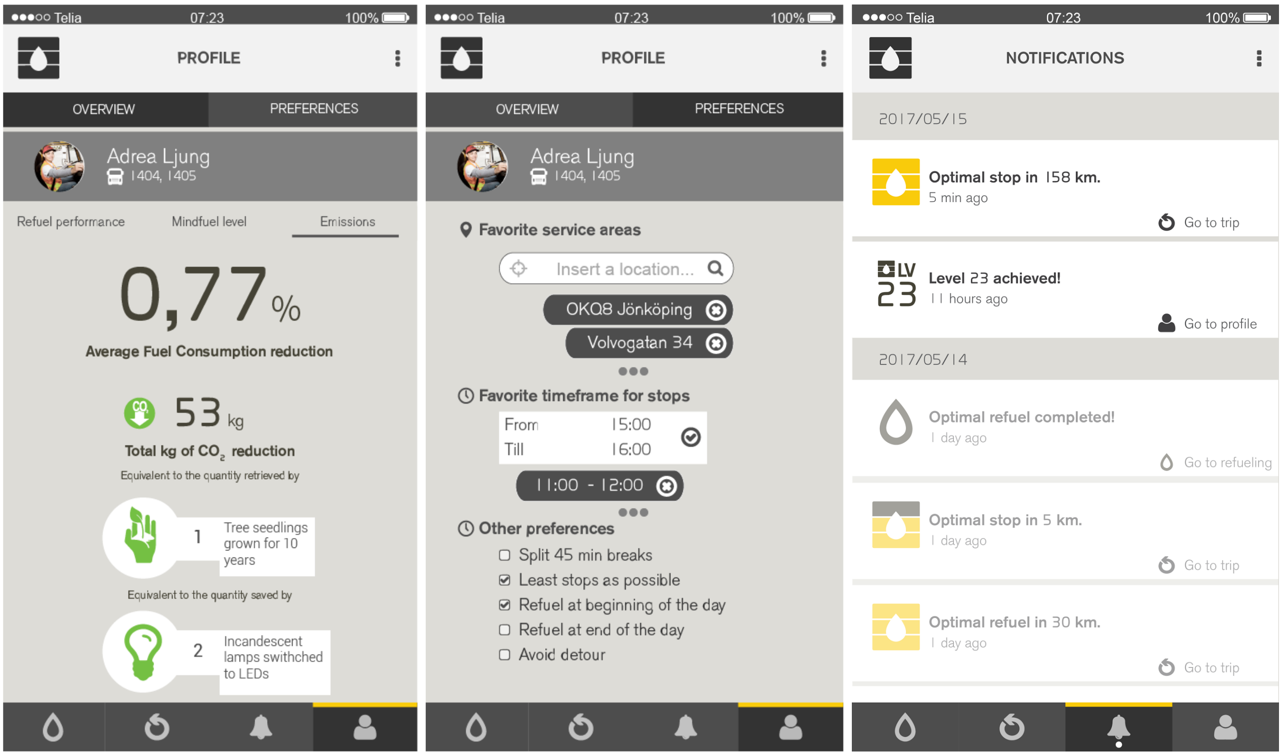


Figure 52: mobile version; profile-overview-emissions, profile-preferences and notifications.

Figure 52 shows the profile-overview display and notifications (right). In the left screen, the average fuel consumption reduction as a result of using MindFuel is depicted, as well as the amount of kilograms of emissions reduced, also translated into tree seedlings grown for 10 years or the equivalent amount of incandescent lamps switched to LEDs. On the other hand, the preferences display (central screen in the same figure) would use a tag system for introducing favourite locations and timeframes (following Google standards; Google, 2017), as well as checkboxes for quickly adjust fixed preferences.

Onboard

The onboard version is designed for truck integrated screens, aiming for minimal driver distraction and minimal confusion. As the informative screens suggest in figure 53, the onboard system shows the most optimal recommended refueling stop (last of the three recommended), optional backup stop to avoid driver concerns about fleet card issues or running out of fuel (figure 54) and options for skipping the most optimal stop in advance, thus showing the second most optimal and if this is skipped beforehand too, the most optimal is shown (figure 55). These three degrees of optimality correspond to three, two or one MindFuel points award respectively, and are shown by greying out none, one or the two upper bits of the MindFuel logo, respectively. In case the driver does not stop at any suggested stop, if the principles behind MindFuel are respected, the driver shall be announced a point reward accordingly. Screens show stop name and address, distance left, detour time (excl. refueling time), option to notify the system for a desired earlier stop (skip most optimal in beforehand) and MindFuel point reward. When the time to stop arrives, the system displays the amount of fuel to be refilled and any warning message if the current optimization alternative involves extra cargo. A more complete approach can be seen in the prototype available separately.

Note that in the last example, (figure 55, right), there is an undo button. This allows going back to the previous option. This screen would also appear when the first suggestion (Ljungby, 3 MF points) is skipped and the second appears, only that in this case the undo would have a countdown so the next skip option is available (both buttons share screen location). If the target (active) stop was missed, the screen in figure 58 at the end of the section would appear.

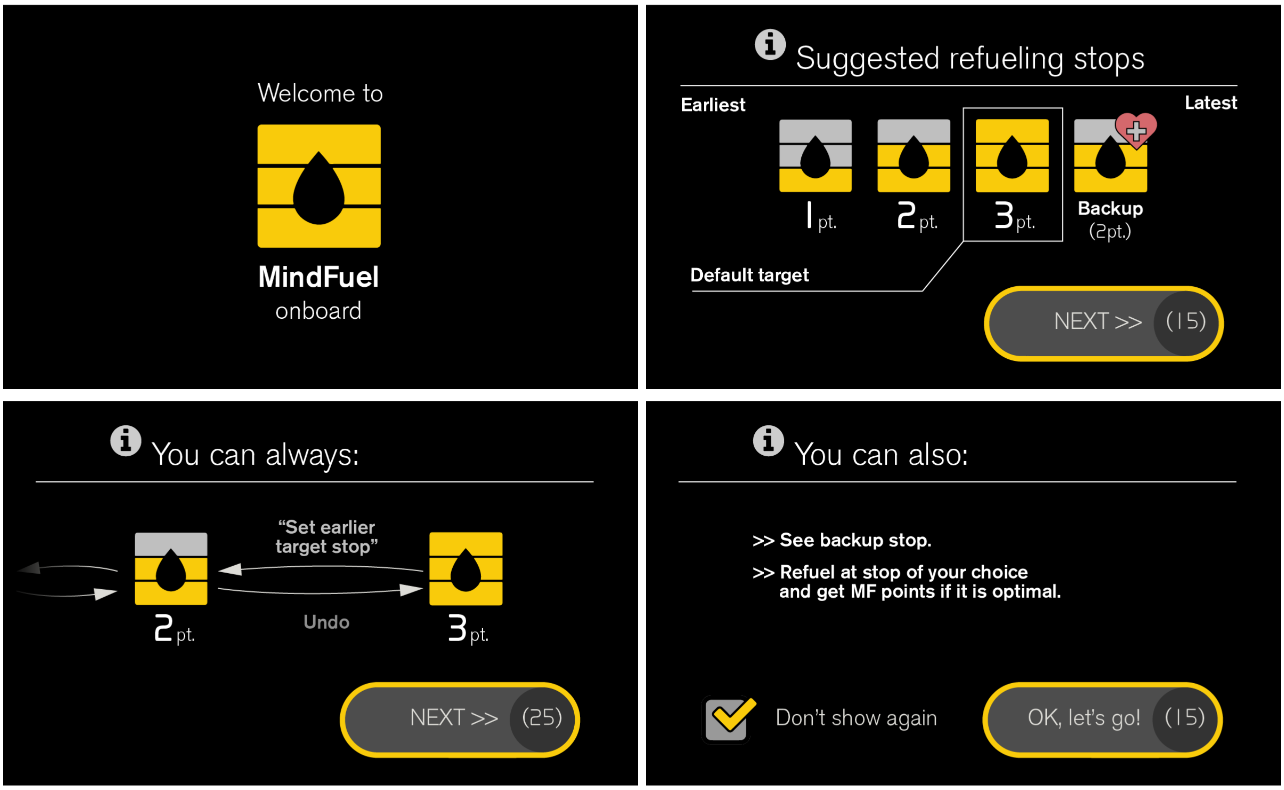


Figure 53: onboard version; information screens.

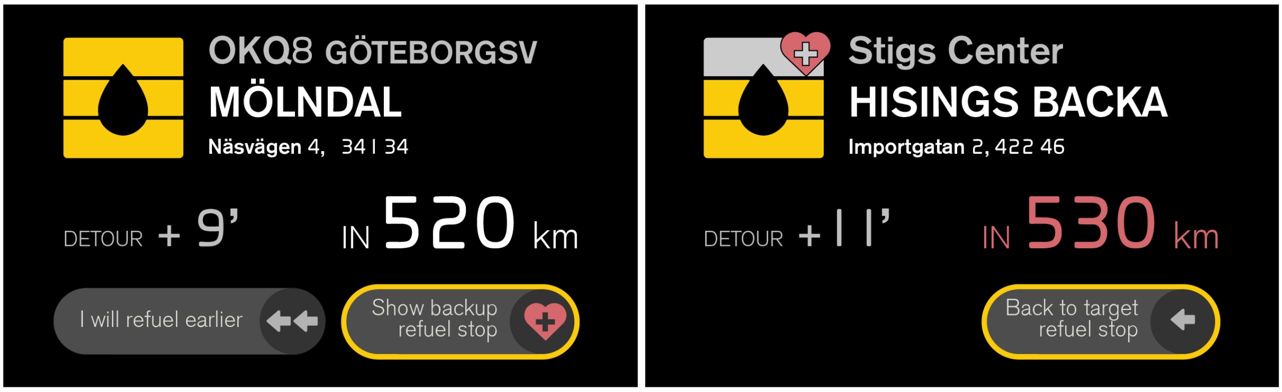


Figure 54: onboard version; optimal stop and backup stop.

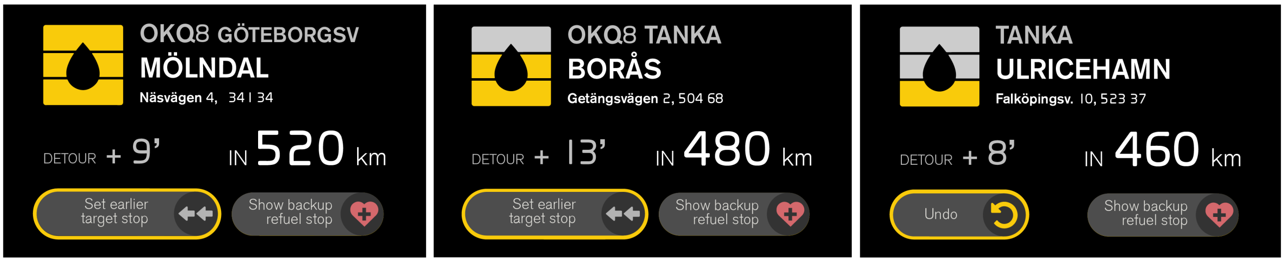


Figure 55: onboard version; setting earlier target (less optimal) stops by driver early notification.

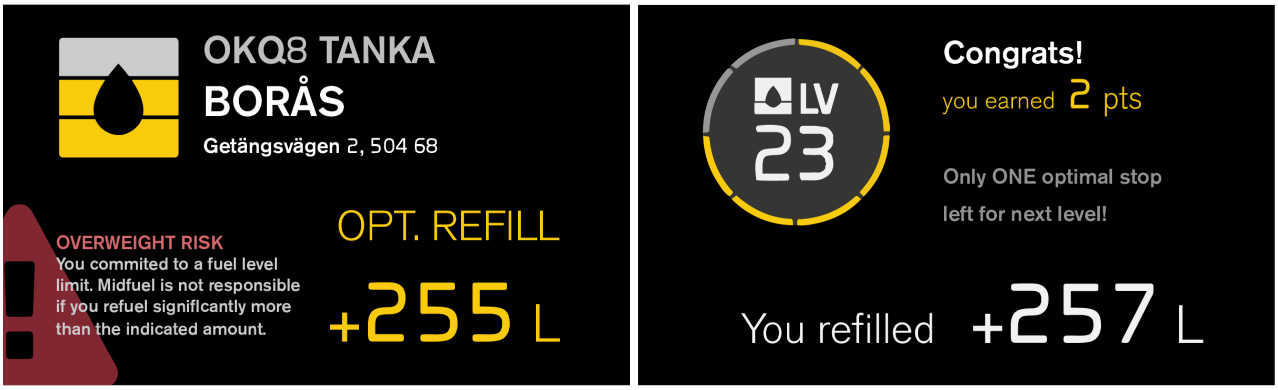


Figure 56: onboard version; refueling time screens.

Figure 57: onboard version; user (arbitrarily) selected stop confirmation.

Bear in mind the screen on the left of figure 56 has the additional message that appears when extra cargo alternative is active, due to responsibility issues. This screen would be available few kilometers before the stop so the drivers have the number of Liters in their head. The screen on the right of this figure would appear after the refueling is complete via tank sensors, fuel card sync or other sensor of higher accuracy if available.

In figure 57, it can be appreciated that the user went to another stop close to the suggested second most optimal stop. When the system detects a possible detour towards a gas station within a potential refuel timeframe, as soon as it gets close to a gas station and especially if the truck is going to stop, the system asks for confirmation, and shows a greyed out preview of the points that would be earned if the stop was done (figure 57, left). Confirmation would lead to the screen on the left part of the same figure and dismissal or ignoring it for a while would result in returning to the target stop. Figure 58 shows the settings for pop-up screen frequency and approach anticipation, as well as an option for MindFuel to be even more in the background, adapting to freely-selected stops.

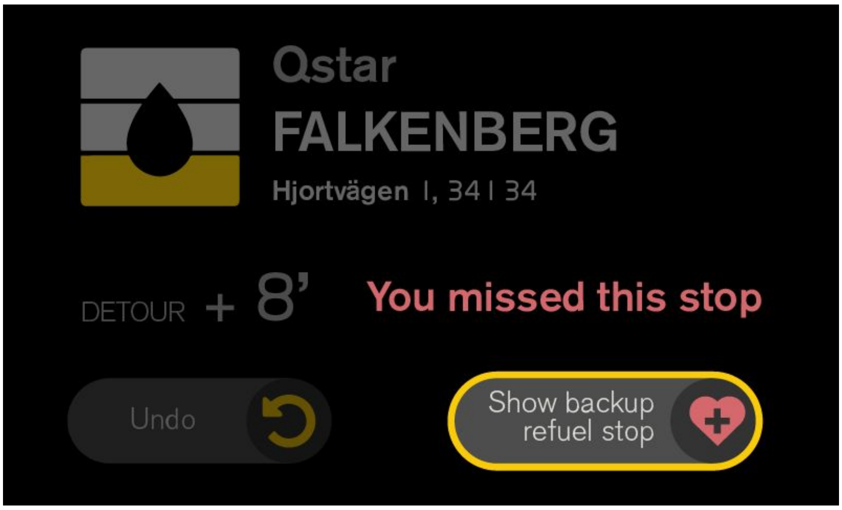


Figure 58: onboard version; target (active, selected) stop missed.

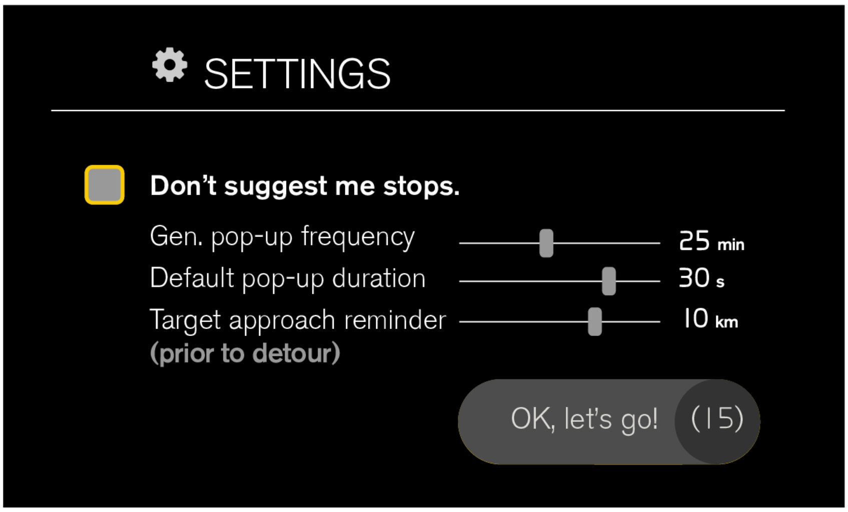


Figure 59: onboard version; settings.

6 Discussion

6.1 Project outcome, initial goals and methods

When restating the initial goals of the project, several factors delimited the results of the research. Even though the literature review provided a bigger picture of the different research areas, the lack of specific material regarding truck driver behaviors and motivations for refueling practices led to rely more on the user studies and fieldwork. Moreover, the singularity of the idea and consequent lack of direct competition led to take a more holistic approach for the market analysis. The market analysis served as a source of inspiration, triggering different ways for providing feedback.

On the other hand, the user studies and fieldwork ended providing most of the insights regarding truck driver behavior later used for problem areas definition and requirements. The user studies highlighted the existing huge diversity of fleets, cargo and delivery types. These findings remarked the need to aim for a solution that accommodates to every type of fleet, allowing to adjust all the features while requiring minimum input at the same time. Although drivers from different backgrounds and fleets answered the survey, only part of a single fleet was interviewed as a whole, which limited the problem exploration to some concrete use cases and again a lot of assumptions were made.

Similarly, the team had access to very few fleet and transport managers that could potentially give a more complete understanding of problems that could arise as a result of the implementation of the product. Nevertheless, the trip scenarios ended up being an efficient tool for identifying situations not described by the respondents in the surveys and interviews and help to improve them in later iterations, as well as an overview of which variables were critical or relevant in the different situations, which was not apparent or obvious without putting those together related to each other. What is more, discussing with experts topics such as fuel, truck sales or Human Machine Interaction within Volvo provided a bigger picture understanding of the needs of all the stakeholders of the project.

To finalize, “suitable forms of reward and incentives for the drivers” stated in the requirements, was found out of the scope of the project. In fact, no incentive suggestions were given apart for setting the framework for introducing gamification (MindFuel level, section 5.2.3 in “Final concept”) since it was assumed that the variety of companies and its policies would make the proposals too shallow; and most importantly, generate potential issues between drivers and owners.

6.2 Societal, ethical & eco aspects

An implementation of MindFuel can bring primary users closer to the fleet owners in understanding each other's drives and sharing common business objectives and values. If design solutions do not consider needs of each stakeholder in a balanced manner, this could end with unwanted compromises, especially from the primary user side which is in a more vulnerable position. For this reason, MindFuel's multi-platform approach allows the system to gather data from both stakeholders and suggest efficient alternatives for each particular case (see section 4.1.3, functional groups and hierarchy).

The level of privacy of drivers in respect to fleet owners could harm the dignity of pilots and this should be carefully considered when analyzing user needs and implementing solutions. For example, data of truck drivers acting in a very inefficient way revealed to the owners that they could both call drivers out, ridiculing them, and making them feel their are being overcontrolled and thus lead them to reject the system. Consequently, only data previously agreed with the drivers should be gathered and utilised.

The MindFuel business case does by all means reduces environmental impact of an existing of fossil fuel consumer sector-truck logistics, if employed coherently. Moreover, the principle behind MindFuel is adding value (monetary and environmental impact savings, together with increased transport capacity) with low material and monetary investment. For this reason, any product-service system that will implement MindFuel should keep this investment low in the mentioned aspects.

6.3 Further research and development

On the first place, as mentioned before, the vast diversity of truck fleets, delivery and cargo types together with the limited resources of the team limited the problem exploration phase and led to several assumptions. For this reason, based on the knowledge brought by the current research, a concrete reality-check with different fleets, having various cargo and delivery types should be conducted in order to identify fleet niches that would —a priori—get the most benefit from the concept proposal. Therefore, some well oriented pilot studies could be conducted so as to test the real impact of MindFuel on the fuel consumption, revenue and emissions, as well as user acceptance within the different targeted fleet contexts. Related to this topic, types of cargo and their applicability to the detail (profit per extra tonne) was found out of the scope of the project. What is more, due to the unreliability of the existing weight sensors, weight per axle and related overweight was not considered. Therefore, more development work of these sensors would enhance the security and trustworthiness of the proposed product.

Moreover, as it was found in the literature review (section 3.1.4), the refueling cannot be solved separately from routing and planning, since the refueling location would directly affect the route. However, route, planning and transport management systems were considered as a completely separated initiatives that could not be covered effectively in this project. What is more, Volvo Group currently did not have any route or transport management optimization tool, apart from an agreement with TomTom navigation (2017) so no conflicts or incompatibilities with the concept proposed were found. However, in order to to successfully implement MindFuel, some research in the area of route optimization should be done. This would lead to further investigation in adaptation of third party companies software, or eventually developing a separate solution for route and transport optimization.

In addition, fuel prices were not considered due to the target of the project, long hauling trips within Sweden, as there is a low fluctuation of prices between refueling locations in an optimal refueling threshold area. Additionally, as respondents acknowledged using fuel cards, agreements of fleets with fuel providers minimise the opportunities of optimization in that field.

Finally, regarding future steps for developing the conceptual product, customer desirability studies (usually fleet owners and managers) should be developed from the marketing perspective, once again considering all the existing spectrum of truck fleets and delivery types by making use of the knowledge contextualized throughout this project. Furthermore, all the skills necessary to develop the product further such as programming, data analysis, machine learning and artificial intelligence among others would be required.

7 Conclusions

The current project was triggered from a business case idea that focused on optimizing unused fuel by avoiding drivers' premature refueling. Furthermore, it proposed three different optimization alternatives which aimed to match and enhance the priority areas of fleets (consumption, cargo and time). The current MindFuel project not only conceives a conceptual proposal for implementing the mentioned idea but also optimizes the used fuel, allowing trip planning in order to use the most optimum tank capacity in each case and providing optimization in terms of consumption, cargo or time. In this way, MindFuel sets the framework for further developing route planning tools, adding variables such as the weight along the trip, since weight data currently gathered from the TGW sensors is unreliable. This knowledge would enhance fuel consumption data, and opens up for further implementation fields such as Machine Learning and artificial intelligence for tracking, which would allow to record, analyse and suggest the most optimal routes. Overall, MindFuel pursues the maximization of fuel optimization, smoothing the transition till the establishment of autonomous vehicles. The requirement list provided in this project can serve as the foundation for further development as well as trigger similar initiatives.

On balance, MindFuel is a concept proposal that aims to provide a refuel optimization tool which allows fleets to maximize their priority business areas, enhancing the awareness of fleet performance as well as the planning of trips and shipments. On the other hand, truck drivers can benefit from MindFuel, since it provides a platform for improving trucking performance without being intrusive as well as keeping drivers' freedom. Additionally, it provides means for drivers to maximize income through a compensation system for achievements.

From the research phase several insights are apparent: first and foremost, there is a huge diversity of fleet, cargo and delivery types as well as different negotiation options and company policies that certainly shape the way in which MindFuel can optimize resources as well as to which extent. In general, it was observed that truck drivers are unaware of the impact of optimized refueling as they showed certain skepticism about the overall idea, which challenged users acceptance. Among the concerns that influenced the implementation the most, not only the most frequent "spending as little time as possible" was present, but also fleet cards not working in a certain stop of their supplier or not having refuel stops available when needed. The trip scenario simulations pinpointed the possibility of optimizing a relevant margin of the fuel tank for several optimization alternatives. Moreover, the market analysis remarked the uniqueness of the product and is subsequent lack of direct competitors.

Overall, it is necessary to understand that MindFuel has potential for real implementation within the Volvo services context with a humble investment, considering the existing hardware and service infrastructures. All the previous emphasis in customer desirability, accurate niching and pilot studies also lay in facts like fleet owners and managers only caring for their business model type and specific circumstances, their priorities (e.g. delivery time compliance over fuel savings) or their mental models about truck trip allocation, routing and other factors. Throughout this research it was suggested how driver concerns and fleet manager and owner concerns are often somehow opposite, so tradeoffs are required to deal with customer desirability versus end user acceptance in a real implementation of the MindFuel product-service concept.

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9 Appendix

9.1 Sources of data for Business Case

A theoretical concept application was developed based on the data of the total population of Dynafleet, Volvo Truck's fleet management system.

Subsequently, a specific fleet was selected to validate some assumptions. The selected fleet comprised of 12 vehicles operating in Germany and Denmark. During the study for MindFuel, weekly and daily reports were generated from Dynafleet from 30th May till 26th of June 2016 (4 weeks), considering data such as time, location, driver name, driver activity, odometer and fuel level. These studies allowed to confirm the inefficient fueling behaviors of the drivers as well as to identify different route patterns that had different fuel consumption. This opened up for the possibility of allocating the most suitable truck and route to conform the optimal trip.

Moreover, Dynafleet provided most of the data needed for elaborate a business case for an specific fleet; such as when, where and with which level drivers refuel that allowed to determined the unused and optimizable capacity. These facts lead to proposal of combining potential service with the already mentioned existing application.

As mentioned before, by focusing on the number of pickups (load/unload events) and the distance driven, 4 trip types (go-back to the homebase) were differentiated, each of those with different fuel consumption. Knowing the fuel consumption of each truck and being able to forecast the consumption of the different types of trips allows to determine how much fuel is needed and how much is disposable in the tank of each vehicle. Therefore, since the trucks did not follow any trend regarding trips performed, there was a big potential in giving recommendation regarding trucks-to-trips allocation. Thus, for instance by having one week as a framework, it was possible to give a suggestion which of the trucks were more optimal for a week pattern. Different trips and certain fuel consumption (longer trips, more fuel consumption and hence bigger tanks) were taken into consideration. Additionally, it was possible to identify the most optimal tank for a certain weekly pattern (set of trip types) in case of truck renewal.

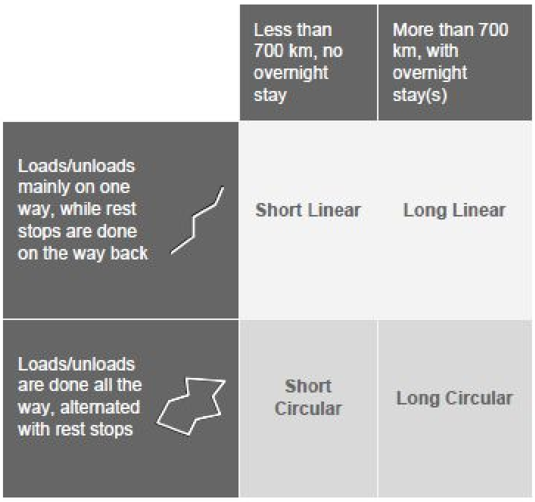


Figure 61: MTR fleet route patterns.

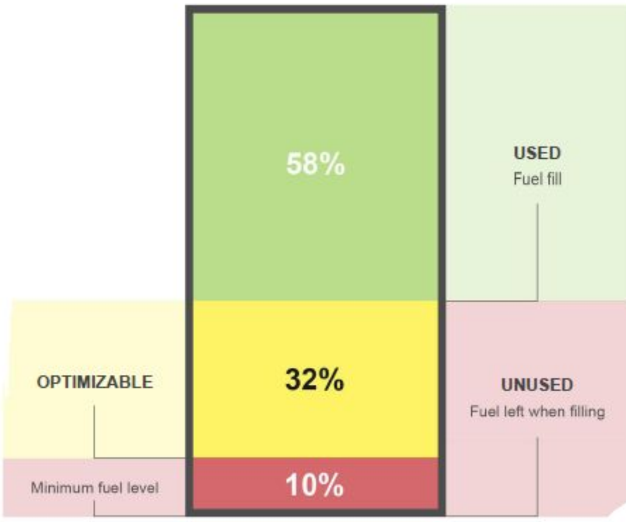


Figure 62: Selected fleet fueling behavior (Week 22, 2016 (30th May- 3rd June).

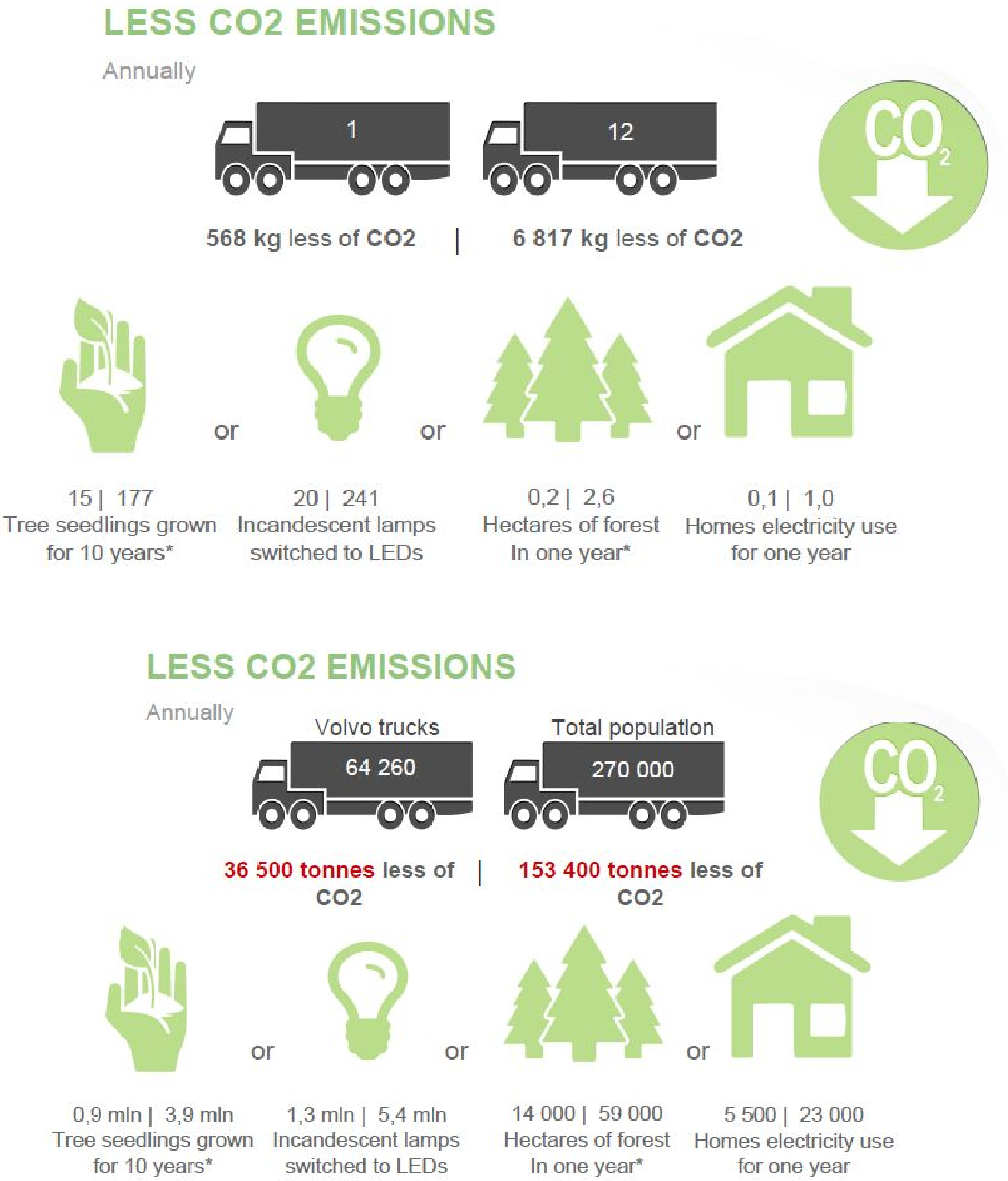
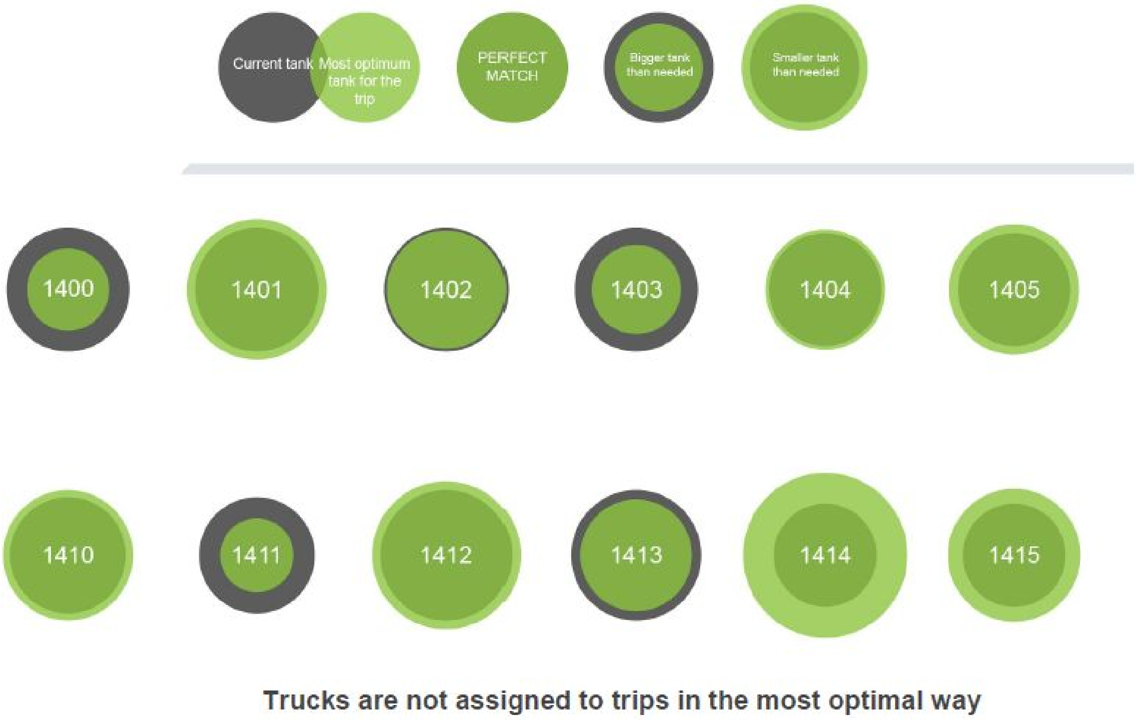


Figure 63: MindFuel impact on emissions.



Scenario 3	**300** fueling events saved per year*	**50** working hours **
Reassigned trucks	**355** fueling events saved per year	**60** working hours

Figure 64: Tank sizes versus Fuel needed for a trip AFTER reallocation. Each number represents a different truck.

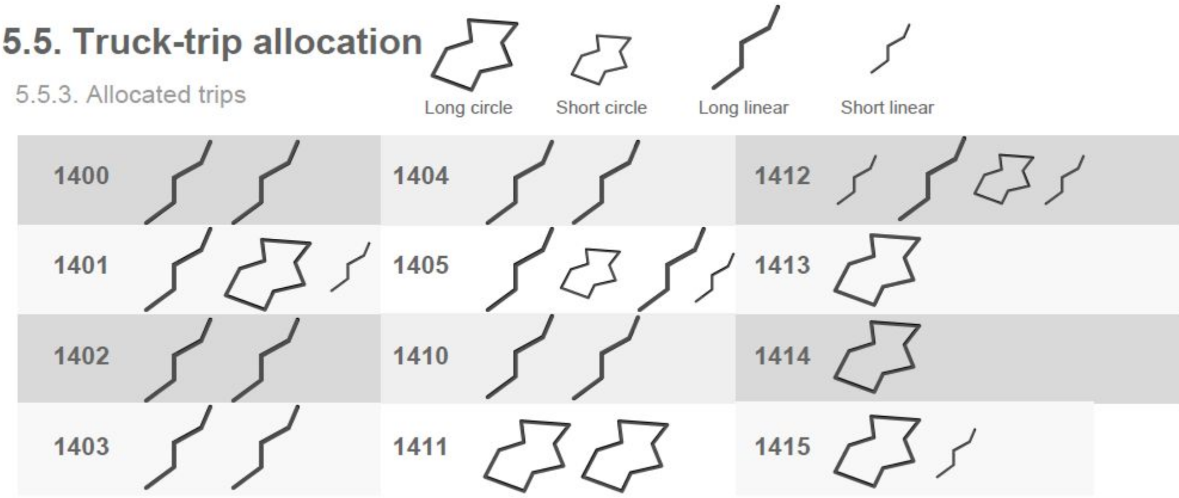


Figure 65: Suggestion of the most optimal trips for each vehicle. Each number represent a different truck.

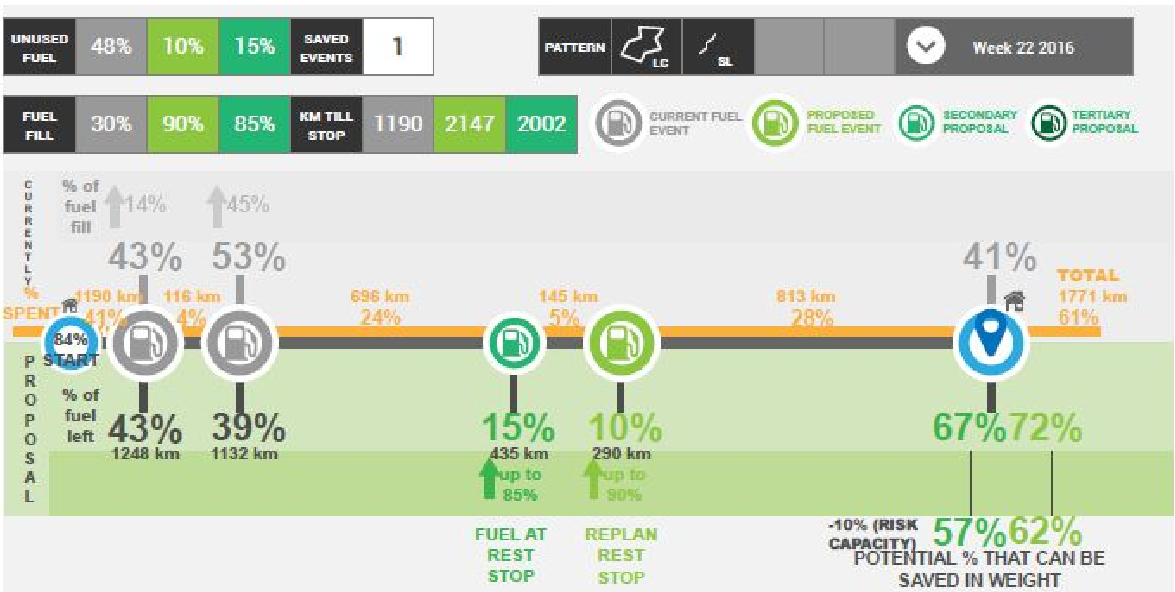


Figure 66: Suggestion for the most optimal stops.

9.2 Simulation scenarios' details

9.2.1 Initial conditions

USE CASE 1 | Single delivery - Linear return overnight - 900L tank, start at 35% | INITIAL CONDITIONS:			
TRUCK			
	Model	**Weights & permitted max.**	**Other details**
Truck	FH 16 4x2 Tractor - Low - Full Air Suspension FH 42 T6LA WB Wheel base 3800	Net weight: 7300 kg GVWR: 18 000 kg Driver + AdBlue + belongings + other: 300 kg	Maximum fuel volume is 1480 litres for a 4x2 tractor. (2 x 700) **Truck for scenario has 2 x 450 L**
Trailer:	Kögel Shuifzeil schuifdak 3 axle	Net weight: 6300 kg Load capacity: 35670 kg Gross allowed: 42 000 kg	
Gross weight excl. fuel & cargo →	**13 900 kg**		
GCWR (max of road) →	**44 000 kg**	**Max. fuel + cargo →**	**30 100 kg**
Initial fuel tank level →	**35%**	315 L	
ROUTE			
	Location	**Load / unload weight**	**Pick / drop windows**
Starting location (A)	Malmö Lastbilcentral AB		5:50 Start time
Pickup stop (B)	Malmö Mertz Transport AB	Load	6:00 - 7:00
Pickup stop (C)	Uppsala	Unload	18:00 - 20:00
Pickup stop (D)	Uppsala	Load	5:30 - 7:00
Finish location (Z)	Malmö	Unload	17:30 - 19:00
PRE-TRIP FIXED VARIABLES			
Type of cargo	Weight sensitive		
Trip length	1400-1500 km (long), 2 days		
Trip shape	Linear		
Pick-ups	Single delivery		
Deadline delivery time	Narrow (around 2 hours)		
Order combinability	Non combinable		

Figure 67: Initial conditions for scenario 1.

USE CASE 2 | Multiple delivery - Circular overnight - 1480 L tank, start at 12% | INITIAL CONDITIONS:			
TRUCK			
	Model	**Weights & permitted max.**	**Other details**
Truck	FH 16 4x2 Tractor - Low - Full Air Suspension FH 42 T6LA WB Wheel base 3800	Net weight: 7300 kg GVWR: 18 000 kg Driver + AdBlue + belongings + other: 300 kg	Maximum fuel volume is 1480 litres for a 4x2 tractor. (**2 x 740 L in this use case**)
Trailer:	Kögel Shuifzeil schuifdak 3 axle	Net weight: 6300 kg Load capacity: 35670 kg Gross allowed: 42 000 kg	
Gross weight excl. fuel & cargo →	**13 900 kg**		
GCWR (max of road) →	**44 000 kg**	**Max. fuel + cargo →**	**30 100 kg**
Initial fuel tank level →	**12%**	177 L	
ROUTE			
	Location	**Load / unload weight**	**Pick / drop windows**
Starting location (A)	Stockholm	(loaded)	Mon 6:25
Pickup stop (B)	Oslo	Unload // Load	Mon 13:00 - 17:00 // Mon 14:00 - 17:00
Pickup stop (C)	Malmö	Unload	Before Tuesday at 13:00
Pickup stop (D)	Copenhagen	Load	Tuesday
Finish location (Z)	Stockholm	Unload	Wednesday 14:00 -15:30
PRE-TRIP FIXED VARIABLES			
Type of cargo	Weight sensitive		
Trip length	1800 km (long), 2-3 days		
Trip shape	Circular		
Pick-ups	Multiple delivery		
Deadline delivery time	Combined (narrow, medium and broad)		
Order combinability	Non combinable		

Figure 68: Initial conditions for scenario 2.

USE CASE 3 | Multiple delivery - Circular one day - 450 L tank, start at 68% | INITIAL CONDITIONS:			
TRUCK			
	Model	**Weights & permitted max.**	**Other details**
Truck	FH 16 4x2 Tractor - Low - Full Air Suspension FH 42 T6LA WB Wheel base 3800	Net weight: 7300 kg GVWR: 18 000 kg Driver + AdBlue + belongings + other: 300 kg	Maximum fuel volume is 1480 litres for a 4×2 tractor. (**2 x 740 L in this use case**)
Trailer:	Kögel Shuifzeil schuifdak 3 axle	Net weight: 6300 kg Load capacity: **35670 kg** Gross allowed: 42 000 kg	
Gross weight excl. fuel & cargo →	**13 900 kg**		
GCWR (max of road) →	**44 000 kg**	**Max. fuel + cargo →**	**30 100 kg**
Initial fuel tank level →	**68%**	306 L	
ROUTE			
	Location	**Load / unload weight**	**Pick / drop windows**
Starting location (A)	Göteborg		Wed 7:00
Pickup stop (B)	Göteborg	Load	Wed 7:00 - 9:00
Pickup stop (C)	Skövde	Unload	Wed 11:00 - 13:00
Pickup stop (D)	Örebro	Load	Wed 15:00 - 17:00
	Linköping	Unload	Wed 18:00 - 20:00
	Jönköping	Load	Thu 10:00 - 12:00
	Värnamo	Unload/Load	Thu 12:00 - 14:00
	Göteborg	Unload	Thu 17:00 - 19:00
Finish location (Z)	Göteborg		
PRE-TRIP FIXED VARIABLES			
Type of cargo	Weight sensitive		
Trip length	788 km (short), 1 days		
Trip shape	Circular		
Pick-ups	Multiple delivery		
Deadline delivery time	Combined (narrow, medium and broad)		
Order combinability	Non combinable		

Figure 69: Initial conditions for scenario 3.

USE CASE 4 | Single delivery - Long linear one day - 450 L tank, start at 45 % | INITIAL CONDITIONS:			
TRUCK			
	Model	**Weights & permitted max.**	**Other details**
Truck	FH 16 4x2 Tractor - Low - Full Air Suspension FH 42 T6LA WB Wheel base 3800	Net weight: 7300 kg GVWR: 18 000 kg Driver + AdBlue + belongings + other: 300 kg	Maximum fuel volume is 450 litres for a 4×2 tractor.
Trailer:	Kögel Shuifzeil schuifdak 3 axle	Net weight: 6300 kg Load capacity: **35670 kg** Gross allowed: 42 000 kg	
Gross weight excl. fuel & cargo →	**13 900 kg**		
GCWR (max of road) →	**44 000 kg**	**Max. fuel + cargo →**	**30 100 kg**
Initial fuel tank level →	**45%**	202,5 L	
ROUTE			
	Location	**Load / unload weight**	**Pick / drop windows**
Starting location (A)	Göteborg		Thu 5:00
Pickup stop (B)	Göteborg	Load	Thu 5:00 - 7:00
Pickup stop (C)	Helsingborg	Unload	Thu 8:00 - 10:00
Pickup stop (D)	Helsingborg	Load	Thu 9:00 - 11:00
Pickup stop (E)	Göteborg	Unload	Thu 11:00 - 13:00
Finish location (Z)	Göteborg		
PRE-TRIP FIXED VARIABLES			
Type of cargo	Weight sensitive		
Trip length	438 km (short), 1 days		
Trip shape	Linear		
Pick-ups	Single delivery		
Deadline delivery time	Narrow		
Order combinability	-		

Figure 70: Initial conditions for scenario 4.

9.2.2 Simulation spreadsheets

Scenario 1

https://docs.google.com/spreadsheets/d/1GFtriwqvutIMG8jTBghWBp3SlKurkkmApwBYeI8h_c4/edit?usp=sharing

Scenario 2

https://docs.google.com/spreadsheets/d/1luWi8oYJfzzjwEdVvdFgKVIyeKHOZpVjIM_guW3NtUI/edit?usp=sharing

Scenario 3

https://docs.google.com/spreadsheets/d/1d_n456joEVIVBA0YVzxWtSqm0PS6JqEJfKl1HHVByLE/edit?usp=sharing

Scenario 4

https://docs.google.com/spreadsheets/d/1dFgBaPSBeeUNZwKsuX5964ymhQ-13zFz8QbScr1srf8/edit?usp=sharing

9.3 Personas used in presentation

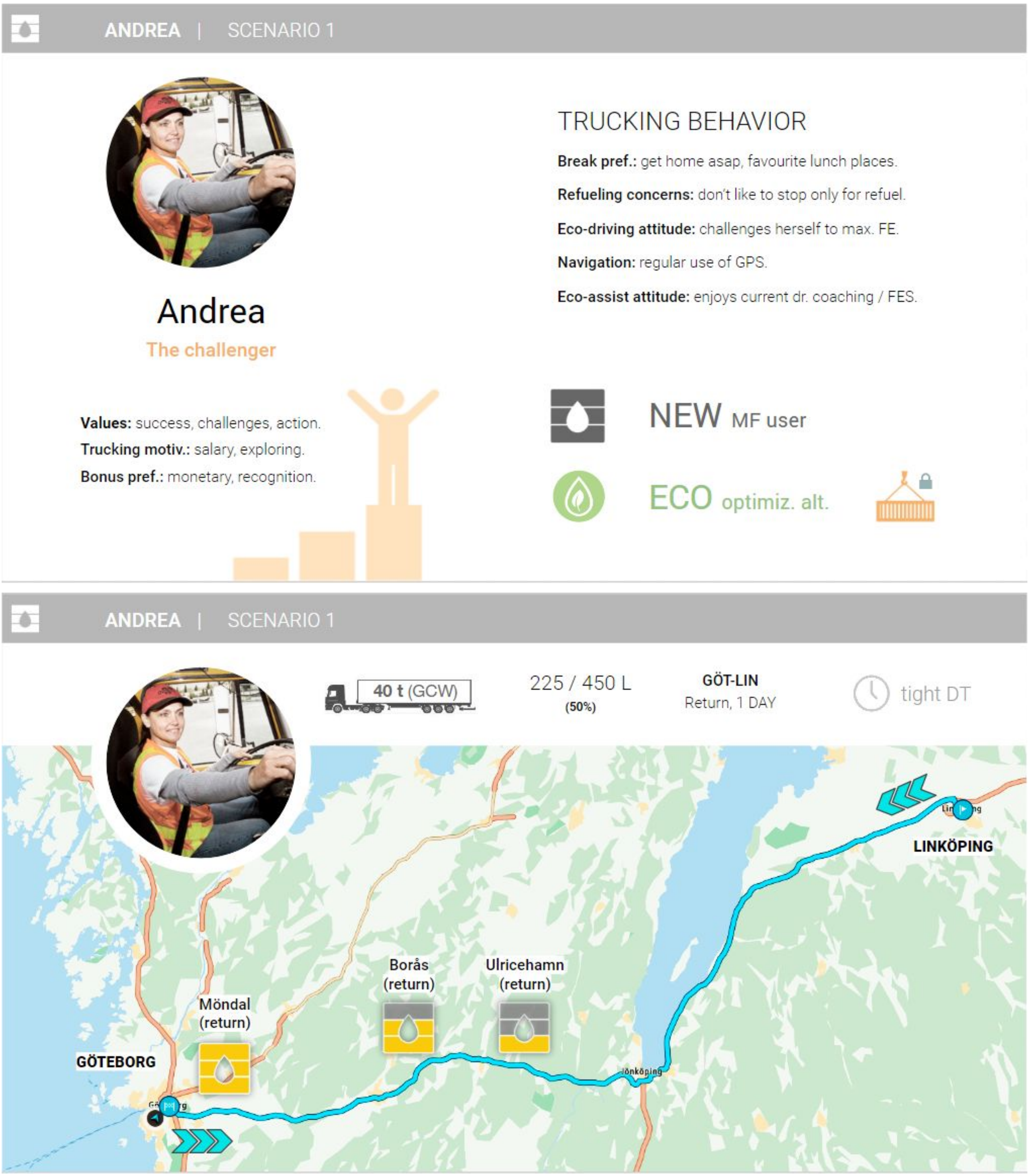
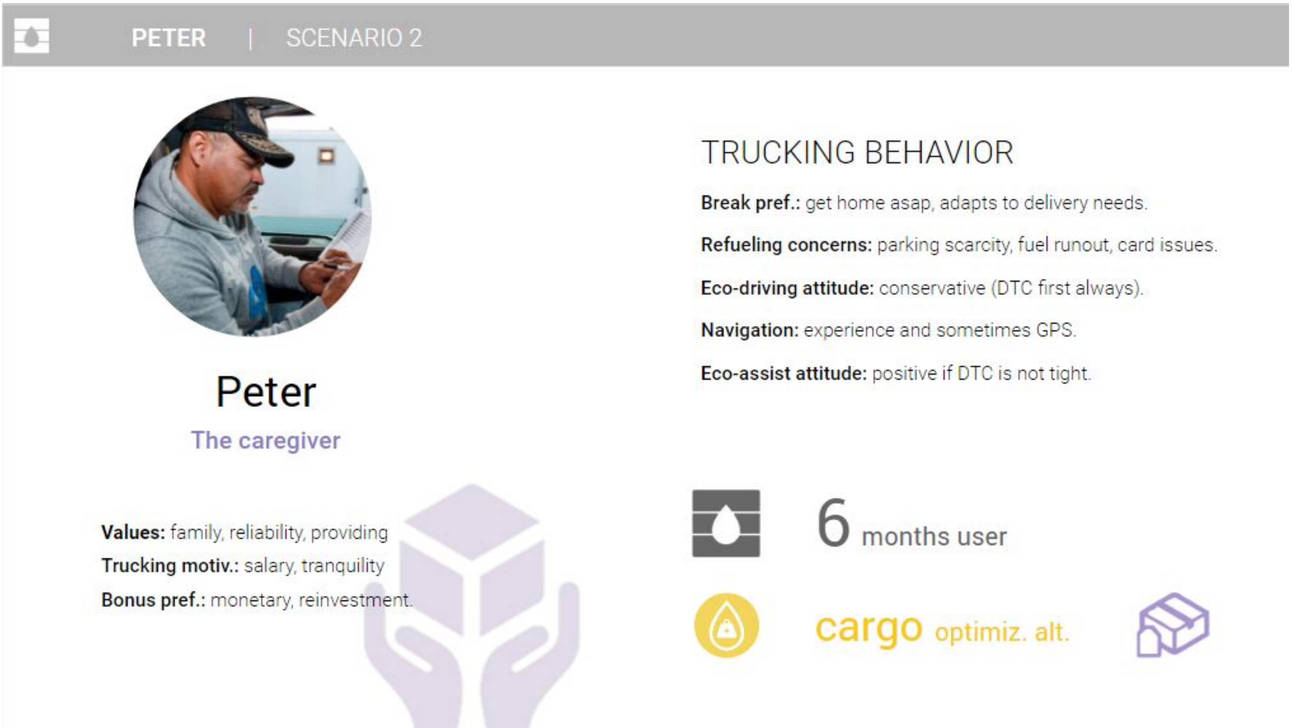


Figure 71: presentation persona/scenario 1: Andrea.



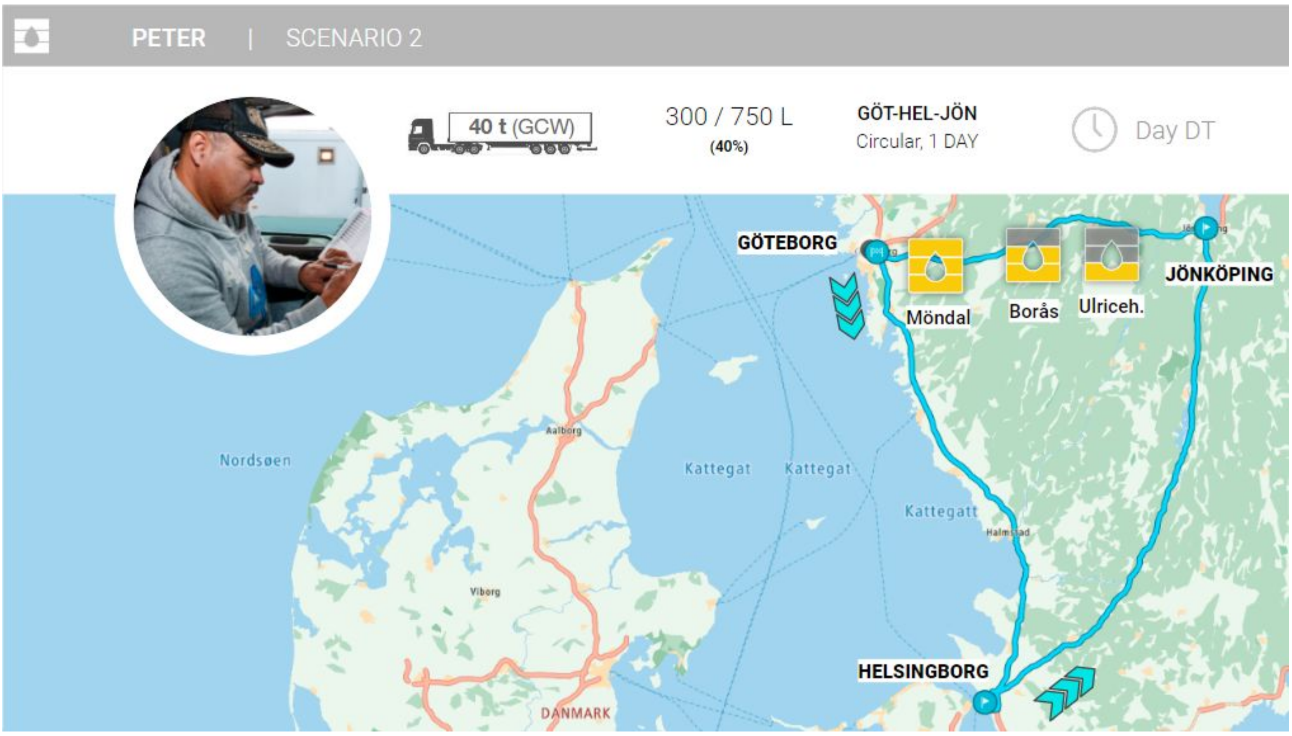
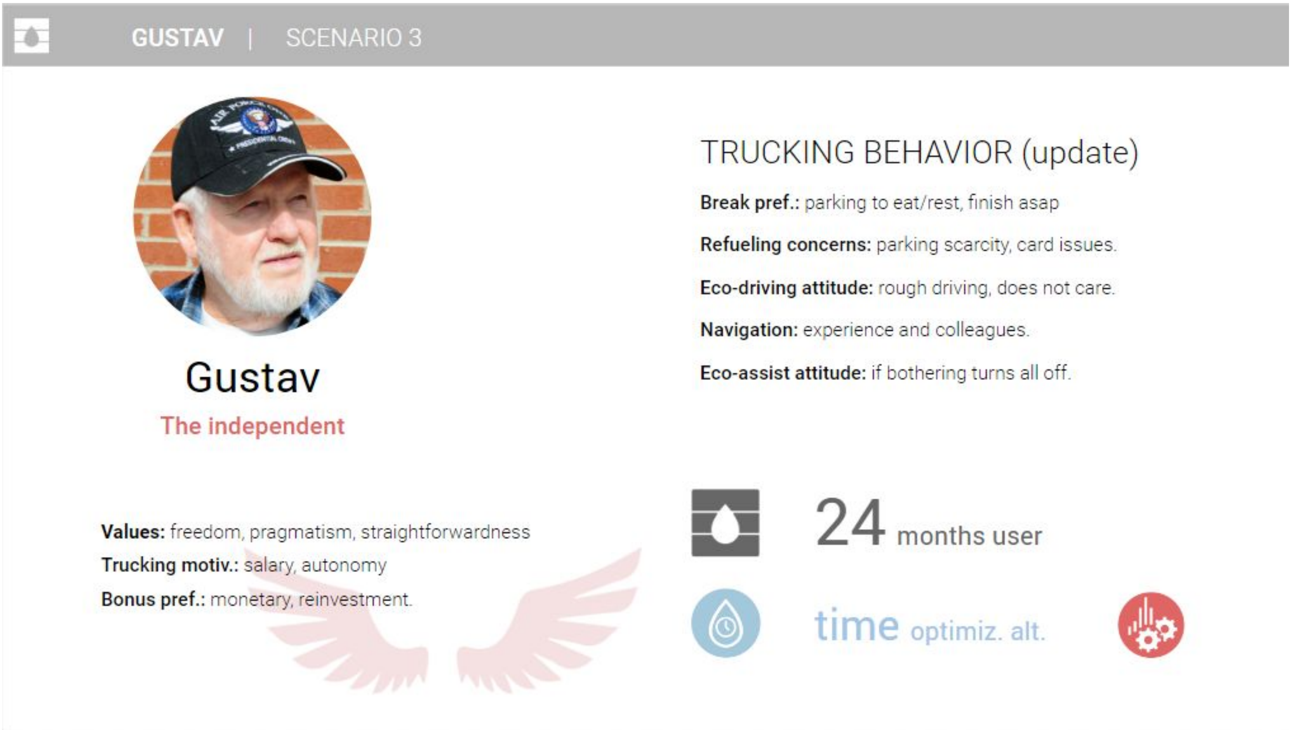


Figure 72: presentation persona/scenario 2: Peter.



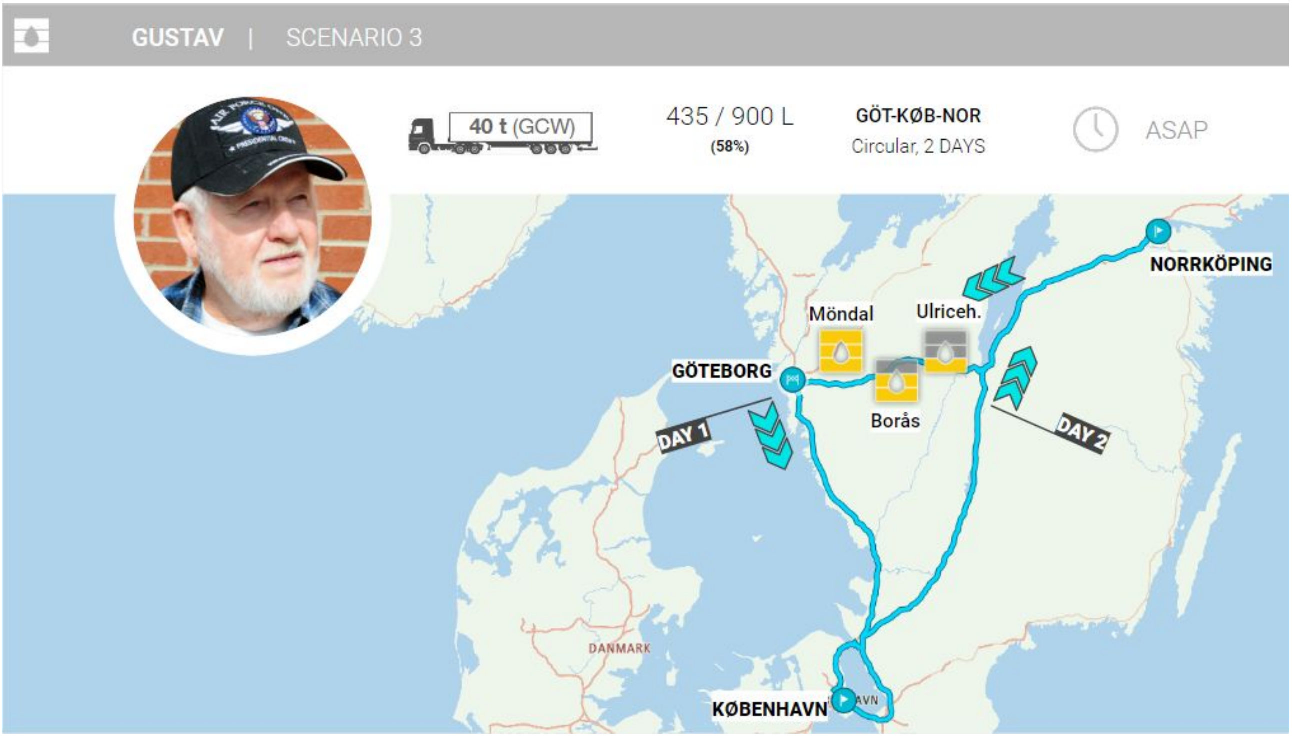


Figure 73: presentation persona/scenario 3: Gustav.

9.4 Questionnaires

9.4.1 Truck drivers

REFUELING HABITS / TANKA RUTINER

Hi! We are Industrial Design Engineering students from Chalmers University of Technology. We are collaborating in a project related to the impact of fuel overload in consumption. We would like to know from your experience as a truck driver your refuelling practice decisions, and what motivates you when it comes to eco-practices. Bear in mind, this survey is anonymous. Your participation is highly appreciated. Share your experience, it will take just a few minutes, thank you!

Your country of origin

Your answer

Nationality of the fleet

Your answer

Type of truck

Distribution

Long haul

Do you own the truck you drive?

Yes, it's my own truck.

No, the truck is owned by the fleet.

How long have you been driving trucks?

Less than 1 year

1-3 years

3-5 years

More than 5 years

What is the size of your truck's fuel tank?

	Less than 450 L	450-600 L	600-750 L	750-900 L	900-1050 L	More than 1050 L	I don't have/use this tank
Tank 1	○	○	○	○	○	○	○
Tank 2	○	○	○	○	○	○	○

What is your most common delivery window (time span)?

Very small: less than 1 h

Small: 1-2 h

Medium: 2-4 h

Large: 4-12 h

Very large: 1 day or more

YOUR REFUELING PRACTICES

Do you have any concerns (oro, bekymmer) when you think of refueling?

I have NO concerns at all.

I sometimes fear running out of fuel (maybe a past experience involved).

I don't want to be making calculations on fuel, just be on the safe side.

I just need to be as quick as possible (time pressure, delivery).

Being unsure of the fuel prices when I am going through or to different countries.

Other:

When do you usually refuel?

Beginning of the trip.

End of the trip.

Only when low in fuel.

Together with short breaks (<45 min).

When there is time available.

I always stop at the same time.

I often stop only to refuel.

Other:

Where do you refuel?

At the homebase.

Cheapest place.

Gas stations I know.

Where I am going/want to sleep.

In a gas station within the network of my fuel card.

I always stop at the same station.

Other:

At what gauge level do you usually refill?

Not any in particular.

Less than 10% (red warning light)

10-30%

30-50 %

50-70%

70-90%

How much do you usually refuel?

Usually till the max.

It depends on the price.

The amount I need between stops.

Enough to return to the home base.

What I need for the day.

What I need for the week.

I usually fill up the same amount of liters.

Other:

Choose 4 other factors that influence your refueling place choice the most.

None / I don't care

Better food

Showers

Well supplied store

Good entertainment

Lower price of services

Extensive parking areas for rest and sleep

Safety: fuel theft, cargo, personal safety, while sleeping...

Wi-fi connection

Other:

How do you pay for your fuel?

I pay with my own credit card.

I use a regular fuel card or loyalty card.

I use a fleet fuel card or corporate card.

I don't use any fuel card.

Other:

In case you use fuel card(s), how many do you own?

1

2

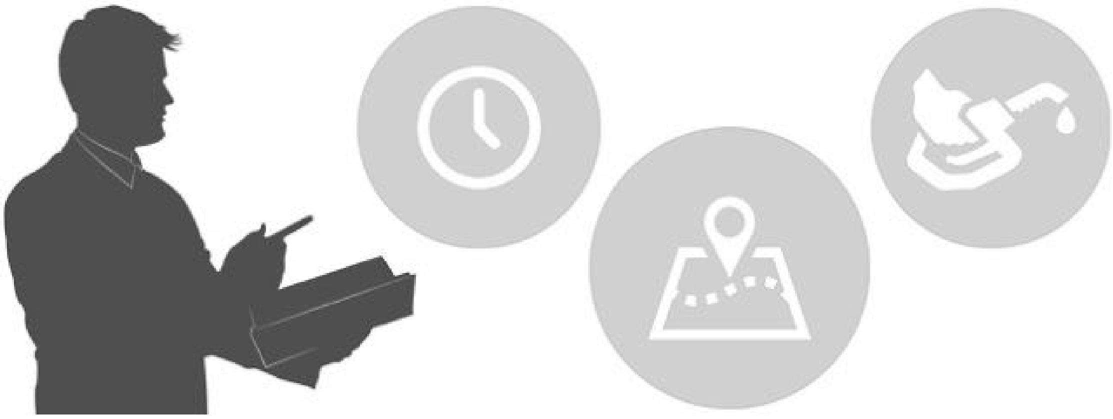
3

Other:

If so, how do you know where the stations of your loyalty card are located?

Your answer

Do you get any tips or requests from your fleet manager on how you should refuel?



Not at all.

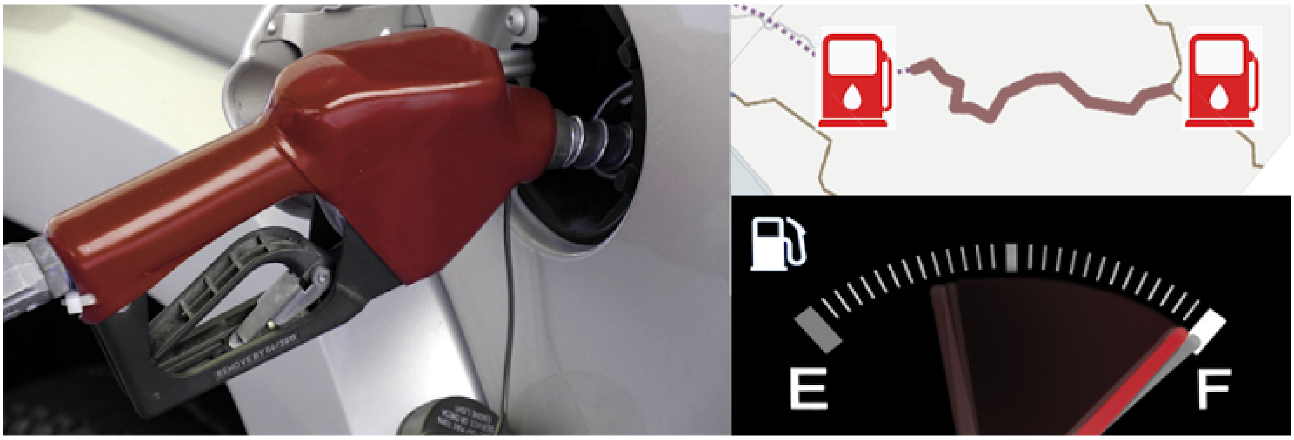
Some vague, obvious requests like "as cheap diesel as possible".

They tell me to refuel not much more than what I am going to use between two fill up stops.

Other:

CAN PLANNING REFUEL SAVE FUEL?

Did you ever wonder if the way you refuel (when, how much) affects your fuel consumption meaningfully?



No, I never questioned this.

I might have thought of it, but never thought it could be important.

I have questioned this, but I don’t know how much it affects nor how to deal with it practically.

Yes, and I try to practically implement this.

If you responded “Yes...” how do you plan your strategy?

Your answer

How much you think refueling strategy affects fuel consumption compared to eco-driving?

Basically nothing, it’s certainly negligible.

It is probably negligible comparing to what I could save by eco-driving.

It is probably much less than what I can save by eco-driving.

I could gain meaningful savings.

Other:

Do you plan refueling to save fuel (tanka för att spara bränsle)?

	1	2	3	4	5	
No / I think it doesn't make a difference	○	○	○	○	○	A lot, I try to optimize fuel weight all I can

What is the effort that you make for eco-driving (not necessarily performance)?

	1	2	3	4	5	
None, only I drive naturally	○	○	○	○	○	I take big effort to eco-drive thoroughly

If you planned your refueling strategy, would you appreciate having assisting technology?

No, I would prefer to do my own calculations, even if I had to do it during in my breaks.

Probably yes.

MOTIVATIONS

What motivates you for eco-driving/eco-practices?

Reduction of emissions (miljöhänsyn)

	1	2	3	4	5	
Don't care	○	○	○	○	○	It's important

Potential compensations from fleet owners

	1	2	3	4	5	
Don't care	○	○	○	○	○	It's important

COMPENSATIONS FOR OPTIMAL REFUELING

If you had any compensation for saving fuel either by eco-driving or eco-refueling, how much would you be motivated by the following compensations?

Monetary compensation (money)

	1	2	3	4	5	
Wouldn't appreciate	○	○	○	○	○	I'd love this!

Be on top the ranking of best drivers

	1	2	3	4	5	
Wouldn't appreciate	○	○	○	○	○	I'd love this!

Higher responsibility/prestige cargo (viktigare, värdefullare frakt)

	1	2	3	4	5	
Wouldn't appreciate	○	○	○	○	○	I'd love this!

Deliveries closer to my home

	1	2	3	4	5	
Wouldn't appreciate	○	○	○	○	○	I'd love this!

Choose what deliveries I am assigned

	1	2	3	4	5	
Wouldn't appreciate	○	○	○	○	○	I'd love this!

Presents, trips, exchangeable points...

	1	2	3	4	5	
Wouldn't appreciate	○	○	○	○	○	I'd love this!

Reinvestment/upgrades on my truck and related premium services

	1	2	3	4	5	
Wouldn't appreciate	○	○	○	○	○	I'd love this!

We'd love to know any other thing you'd really appreciate as compensation!

Your answer

Do you currently get any sort of compensation for efficient practices?

No

Monetary compensation

Promotion, visibility or reccomendation

Choosing my assignments (closer to home, better cargo)

Presents, trips, exchangeable points

Reinvestment on my truck

Other:

CURRENT ASSISTING SOLUTIONS

Do you use any method for planning routes and stops?

No, I don't

I do my own calculations

I use a Fuel Management System app or platform (truck in-built)

I use a Fuel Management System app or platform (external, 3rd party)

I check fuel prices of different stations in the way on my own

I get all the instructions from the fleet owner/dispatcher

Other:

Do you follow any method for consumption or eco-driving?

No, I don't.

I do my own calculations.

I use a dedicated app or service (in-built by the manufacturer).

I use a dedicated app or service (external, third-party).

Do you get any feedback on your driving?

Yes

No

If yes, what kind of feedback, and by whom?

Your answer

SUPPORTING DEVICES

Visualization devices available in your tuck:

GPS device screen

Smartphone

Smartwatch

Tablet

Integrated truck screen

Other:

What device would you prefer for getting refueling strategy assistance?

1. Smartphone (app)

2. Tablet (app)

3. Smartwatch (app)

4. Intelligent voice assistant

5. Heads up display (HUD)

Integrated truck screen

SERVICE PRIVACY

If a refueling strategy assistant technology required tracking the following data, what level of privacy would you consider acceptable?

	OPEN: visible identity and data for Fleet Owner	PARTIAL: anonymous data available for Fleet Owner.	MANUFACTURER: anonymous data for Manufacturer/Service Provider	CLOSED: data is only handled by the software for the service.
Truck location	○	○	○	○
Fuel consumption	○	○	○	○
Fuel tank level	○	○	○	○
Video while driving (in cabin)	○	○	○	○
Video while driving (exterior)	○	○	○	○

PLACE & COMMENTS

Place where this survey was filled

Your answer

Comments you'd like to add

9.4.2 Fleet managers

REFUELING & ECO-DRIVING

Hi! We are students from Chalmers University of Technology.

We are researching on refuelling and fuel consumption for our Master Thesis project. We are collaborating in a project related to the impact of fuel overload in consumption. We would like to know about your practices as fleet manager regarding fuel management and refuelling strategies, and what motivates you when it comes to eco-practices. Bear in mind, this survey is anonymous. Your participation is highly appreciated. Share your experience, it will take just a few minutes, thank you!

* Required

Your country of origin

Your answer

Nationality of your fleet

Your answer

Type of trucks in your fleet

Distribution

Long haul

Both

Are you the fleet manager/dispatcher too?

No.

Yes.

Are you also an active truck driver?

Yes, I am an active driver of the fleet.

Yes, but I only drive occasionally.

No.

What is your link to carriers (logistics companies)?

Carriers hire my fleet services (I am a employer)

I'm part of a logistic company.

What is the size of your fleet?

1-5

5-10 vehicles

10-50 vehicles

50-100 vehicles

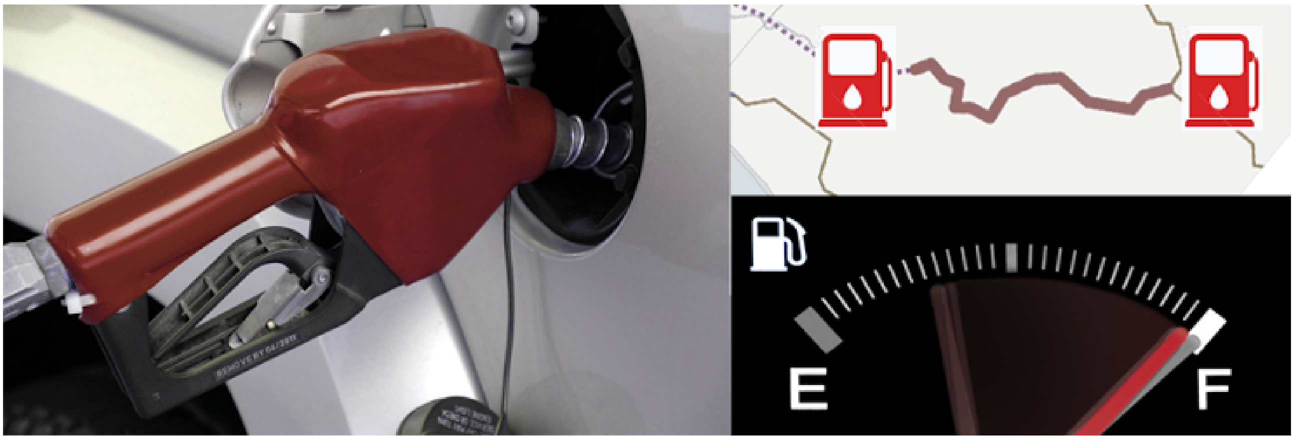
More than 100 vehicles

Rank 1(highest) to 5 (lowest) the priorities in your offered services.

	Competitive prices	Fast delivery	Flexibility (type of cargo, hours and delivery window spans)	Reliability (safety of freight, guarantee of sucess in time)	Safety (driver and vehicle)	Minimizing emissions
1	○	○	○	○	○	○
2	○	○	○	○	○	○
3	○	○	○	○	○	○
4	○	○	○	○	○	○
5	○	○	○	○	○	○
6	○	○	○	○	○	○

ON REFUELING STRATEGY

Did you ever wonder if truck drivers' refuelling practices (amount of diesel filled up, distance between refuelling stops...) affect your fuel consumption meaningfully?



No, I never questioned this myself.

I might have thought of it, but never thought it could be important.

I have questioned this, but I don’t know how much it affects nor how to deal with it practically.

Yes, and I try to practically implement this.

If you responded: “Yes, and I try to practically implement this” could you say how?

Your answer

So now that we asked, how much you think refuelling practices could affect fuel consumption?

Basically nothing, it’s certainly negligible.

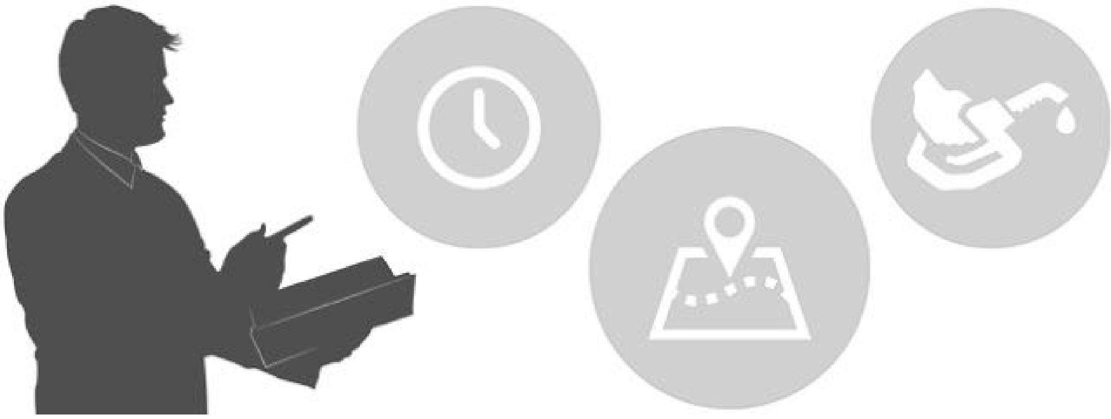
It is probably negligible comparing to what it could saved by eco-driving.

It is probably much less than what it can saved by eco-driving.

I could gain meaningful savings.

Other:

Do you provide any tips or requests to the drivers in your fleet on how they should refuel? *



Not at all.

Some vague, obvious requests like "as cheap diesel as possible".

I tell them to refuel not much more than what they are going to use between two fill up stops.

Other:

REFUELING PRACTICES IN YOUR FLEET

When do they usually refuel? *

At the beginning of the trip.

At the end of the trip.

Just when they are low in fuel.

They coordinate stops for short breaks (<45 mins.) and fueling.

Thet refuel where they sleep.

They often stop only to refuel (and perhaps buy something or go to the WC).

When there is time available.

They always stop at the same time (for example, tuesdays at lunch time).

I didn't think about it.

Other:

Where do they usually refuel? *

At the homebase.

They try to find the cheapest place.

In a gas station they have visited before.

Close to the location they want to take a resting, I guess.

I always stop at the same station.

In a gas station within the network of my fuel card.

I didn't think about it.

Other:

At what gauge level do they usually refill?

Not any in particular.

Less than 10% (red warning light)

10-30%

30-50%

50-70%

70-90%

I didn't think about it.

How much do they usually refuel? *

They fill up the truck till the max.

I guess they may calculate the amount of fuel they need for completing the trip.

Enough to go and come back to the home base.

What they need for a day.

What they need for the week.

They usually fill up the same amount (for example, 250 L)

I didn't think about it.

Other:

How do drivers pay for fuel?

They use their own credit own.

They use a regular fuel card or loyalty card.

They use a fleet fuel card or corporate card.

They don't use any fuel card.

In case they use fuel card(s), how many do they own?

1

2

3

If you planned your refueling strategy, would you appreciate having assisting technology?

No, I would prefer to do my own calculations, even if I had to do it during breaks.

Probably yes.

MOTIVATIONS FOR ECO-PRACTICES

How much affect these factors your decisions when it comes to planning the fleet's activity to reduce emissions?

Monetary savings in taxes/fines

	1	2	3	4	5	
Don't care	○	○	○	○	○	It's important

Reduction of emissions - care for environment

	1	2	3	4	5	
Don't care	○	○	○	○	○	It's important

Image of the company, company values

	1	2	3	4	5	
Don't care	○	○	○	○	○	It's important

Do you have to pay extra taxes/fines if you exceed certain carbon footprint?

Yes, only if the fleet activities exceed certain estimated footprint.

There is always a cost, proportional to the footprint.

No.

If it is the case, can you specify how do these taxes or penalties work?

Your answer

COMPENSATIONS

Do you compensate drivers for optimal performance?

No.

Yes, if they optimize fuel.

Yes, if they optimize time.

Other:

How do/would you compensate your drivers for eco-driving and optimization?

Your answer

Do you use any method for planning routes and stops? *

No, I don't

I do my own calculations

I use a Fuel Management System app or platform

I give all the instructions to the drivers

Do you follow any method for consumption or eco-driving?

No, I don't

I do my own calculations

I use a dedicated app or service

Do you provide your drivers with feedback about their driving?

Yes

No

In such case, what kind of feedback and how?

Your answer

SUPPORTING DEVICES

What devices do your drivers use during driving -for route aids, driving tips or statistics visualization?

GPS device screen

Smartphone

Smartwatch

Tablet

Truck in-built screen

Other:

What device would you prefer your drivers to have in order to make decisions in fueling events and receiving tips?

1. Smartphone (app)

2. Tablet (app)

3. Smartwatch (app)

4. Intelligent voice assistant

5. Heads up display

Skärm integrerad i lastbilen

Other:

Why did you select the chosen option the previous question?

Your answer

ACCESS TO DATA AND PRIVACY

In a possible service for refueling strategy driving and refueling data would need to be collected. What level of access as owner vs. driver privacy would you consider reasonable? *

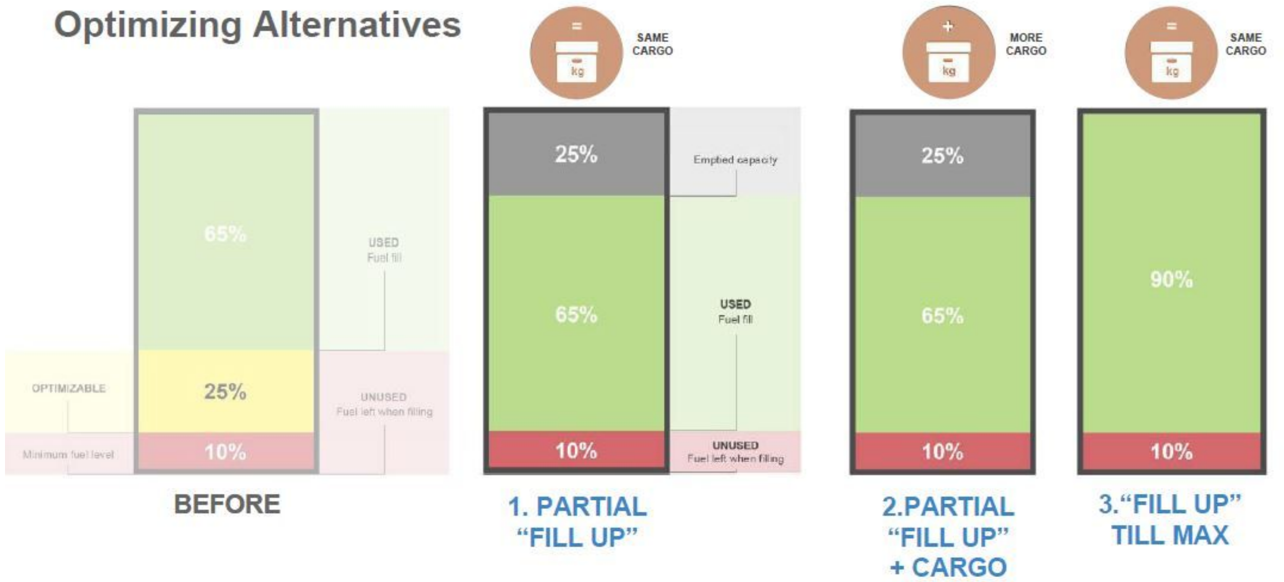
	OPEN: visible identity and data for Fleet Owner	PARTIAL: anonymous data available for Fleet Owner.	MANUFACTURER: anonymous data for Manufacturer/Service Provider	CLOSED: data is only handled by the software for the service.
Truck location	○	○	○	○
Fuel consumption	○	○	○	○
Fuel tank level	○	○	○	○
Video while driving (in cabin)	○	○	○	○
Video while driving (exterior only)	○	○	○	○

CONCEPT FOR OPTIMIZE REFUELING

We are collaborating in an initiative to optimize refueling based on the unused tank fuel potential. We would like to know what benefits and problems you see with the idea.

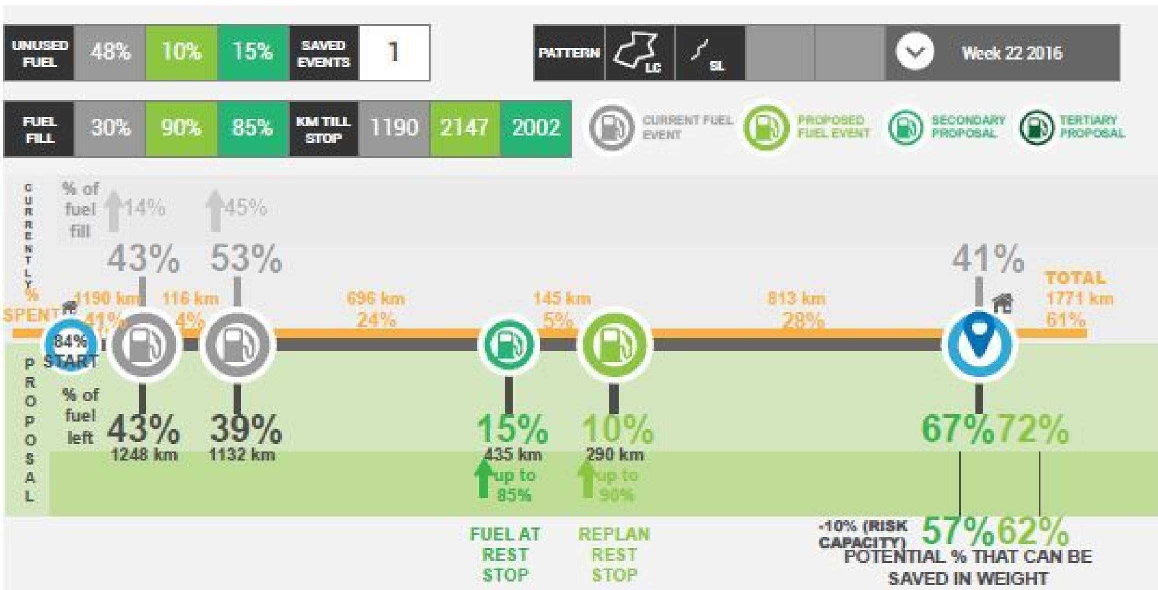
Three alternatives

In the concept, refueling can be optimized by PARTIAL FILLUP (1), where only the fuel to be used is filled (considering the 10% reserve). A second alternative would be replacing unused fuel with cargo PARTIAL FILLUP+CARGO (2). Finally, one could also FILL UP TILL MAX (3), where the gap between stops is big enough so all the fuel in the tank (till the 10% mark) is used.



The concept, at work

The assistant or service would propose a refuel event plan considering delivery stops, preferred fuel supplier and other desired input. Once the trip starts, it would keep track of the tank level, location and routing variability; the assistant would also come up with planned and updated suggestions for optimal refueling stop alternatives.



Can you identify any drawbacks in the assistant that may compromise your priorities (e.g., delivery windows)? Please elaborate which and how/why.

Your answer

Comments

9.5 Problem areas

TIMING

Compulsory breaks & driving hour limits

- Planning of breaks: *"Usually split when long-hauling, loads/unloads usually take 15 min". "When doing a distribution pattern, there is a 1 hour break for lunch"* (from truck driver interviews, section 3.3.3*) "They coordinate stops for short breaks, at least 15-30 min"* (from expert 2 interview, section 3.3.3*). "From the truckers side, don't force them to pass their favourite stop"* (from expert 4 interview, section 3.3.3*).*
- How they control or plan for not exceeding legal driving time: *"Own calculations and FMS"* (from truck driver interviews, section 3.3.3*)*
- How breaks are chosen and if they are given beforehand: Driver has freedom for managing the breaks and they are not given beforehand (from truck driver interviews, section 3.3.3*)*.

Time constraints & other commercial priorities

- Above refuel optimization and eco-practices: *"Only environmental attitudes if associated to low cost". "eco-driving is associated to costs". "drivers and owners usually care but have other commercial priorities"* (Höltl et al., 2012; from literature review section 3.1.6*).*
    - Mental models and priorities of dispatcher: what they consider essential to not risk and potentially more expensive in the long run. (From scenarios, section 3.3.6 scenarios*)*
    - Dispatcher instructions: info channel, flexibility, updatability (from scenarios, section 3.3.6*)*.

Units of planning

- Which chunks to consider (several trips? only per trip?) what is the time unit of consideration?(from scenarios, section 3.3.6*)*
- Can a day be a unit for planning fueling, perhaps a full return trip? what is the time unit of consideration?(from scenarios, section 3.3.6*)*
- Can a day be a unit for planning fueling?(from scenarios, section 3.3.6*)*
- Where can the driver accommodate a fueling stop between delivery routes to comply with the different pickup windows/days. Priorities: time (delivery span), consumption, flexibility. Worst case scenarios.(from scenarios, section 3.3.6*)*

DRIVER HABITS AND MOTIVATION

Motivations

- Emissions, awareness of eco-practices impact on society and operation costs
- *"Drivers usually have a lack of sensitivity towards environment"*(Dubey and Gunasekaran, 2015; from literature section, 3.1.6) "discrepancy between positive attitudes towards environment and actual environmentally conscious behavior"(Höltl et al., 2012; from

literature section, 3.1.6) ”fuel is the highest operational cost in truck fleets, taking around 30%”(Antich, 2013; from literature section, 3.1.2)”*tragedy of commons: individual benefits of polluting are instant noticeable while disadvantages become apparent way later*”(Höltl et al., 2012; from literature section, 3.1.6)

Compensations

- *“Monetary compensations such as cash incentives, gift cards or points”*(Fleet answers, 2014; from literature section, 3.1.6)”*competing situation, drivers should compete for the lowest FC*”(Höltl et al., 2012; from literature section, 3.1.6) ”*Incentives should be introduced slowly to maintain the positive effect*”(truck drivers interviews, from section, 3.3.3*)”Plain monetary compensation is the most appreciated one.* The compensation method of each fleet is sensitive to each fleet owner’s plan or interests. So it is on their behalf how to translate the compensation bonuses, like it is currently done with Dynafleet FES (Conclusion from meeting with expert 2, section 3.3.3). *Another type of compensation that rose up interest (either a lot or total rejection) is reinvestments on the driven truck”*(from truck drivers survey, section 3.3.2) *“Some drivers did not like rankings on the performance of the drivers, they used to have it at Halléns in the screens at the base”*(from truck drivers interviews, section 3.3.3)

“Confiscation” of driver freedom

- *“Drivers want to have freedom to choose where to stop for refueling, although they do not care about the fueling quantity and the timing”*(Suzuki, 2008; from literature section 3.1.6)”*Don’t make drivers skip their favourite stop*”(from interview with expert 4, section 3.3.3)”*Would bother him that someone tells him the amount of fuel he should be putting*”(from truck drivers interviews, section 3.3.3)
- Anticipating unnecessary refuels and reaction; an additional issue was found in a possible implementation of MindFuel: in the cases where a driver stops in a place while still having fuel for the target, probably having taken a detour, how to anticipate this or “minimize the damage”.

Refueling and related habits

- Concerns: *“Spending as little time as possible”, “fuel card not working and risking running out of fuel and time cost” and “Not having parking slots available when refueling, so it is not possible to combine it with a break”* (from truck drivers survey, section 3.3.2)
- When?: Mostly beginning or end of trips (from truck drivers survey, section 3.3.2), as well as when low in fuel.Fleet managers also say “*they coordinate refuel with short breaks”*(from fleet managers survey, section 3.3.2)*”Stop only to refuel if distribution pattern”*(from truck drivers interviews, section 3.3.3)”*Always refill at the end of the trip(at around 18:00), because the gas station he usually goes to is not open during the morning. (always same station)”*(from truck drivers interview, section 3.3.3)” *Most of them they don’t have a refueling spot in their homebase, they refuel afterwards.*”(from interviews with expert 2, section 3.3.3) There is a lot of variety and people that do not like at all (usually long haul trips) and others that do not mind stopping only to refuel (distribution patterns). Each driver/fleet usually has their own routines or patterns(from truck drivers interviews, section 3.3.3).

- Where?: Always same stop, gas station within network of their fuel card, known places. Sometimes also looking for the cheapest place possible (usually when doing international long-hauling)(from truck drivers survey, section 3.3.2).
- How much fuel left?:Usually 10-30% or even 30-50% (from truck drivers survey, section 3.3.2)*"When long-hauling, if he sees he has half of the tank before leaving he refuels so that he doesn't have to stop"*(from truck drivers interviews, section 3.3.3)
- How much refuel? Always till max (from truck drivers survey, section 3.3.2).
- Instructions from the fleet managers: Usually drivers do not get any tips (only refuel as cheap as possible in international long-hauling)(from truck drivers survey, section 3.3.2).
- Coordinate refuel with breaks?*"Not when doing a distribution pattern but yes in long haul"*(from truck drivers interviews, section 3.3.3)
- Does a stop for refueling alone bother you?*"No, usually a stop only for refuel does not bother me" (many actually refuel in stops only for most often.)*(from truck drivers interviews, section 3.3.3)
- Start the truck with warning lamp of the fuel gauge lighting would bother you? *"Yes, it would bother me (2 drivers answered this)"*(from truck drivers interviews, section 3.3.3)
- Does it bother to you to start the day with a refuel? *"Yes, will bother me a lot (2 drivers answered this). However, if fuel theft is a concern I would think about it"*(from truck drivers interviews, section 3.3.3)

Awareness

- Are drivers aware of the impact of eco-refueling? None of the respondents questioned that fueling behavior could affect consumption. The great majority think the consumption savings with optimal refueling behavior would be negligible compared to eco-driving (from truck drivers survey, section 3.3.2)
- Are fleet managers aware of the impact of eco-refueling? Same as drivers, none ever questioned it.(from fleet managers survey, section 3.3.2)
- Effort on eco-driving: The effort for eco driving is either quite high or very low. (from truck drivers survey, section 3.3.2)

CARGO RELATED VARIABLES

- Generally, driving with empty truck is avoided and it doesn't almost happen. (from interview with expert 2, section 3.3.3)However, in Halléns they drive back always with the empty truck. This limits the possibilities. (from fleet manager interviews, section 3.3.3)
- Cargo agreements with companies (with how much time in advance): how flexible they can be? (maximize the cargo transported) Always companies chasing more kg? *"Most orders are received for the day after, and some orders arrive several days beforehand."*(from fleet managers interviews, section 3.3.3)
- How is the cargo amount/weight ordered and dispatched?
    - E.g., only for one truck/not even, divide the cargo in multiple trucks / all you can fit in a certain number of trucks... *"Usually we send one truck full, the customers take*

into account how much they can have in a X dimensions truck."(from fleet managers interviews, section 3.3.3)

    - Can more cargo be fit in the last moment? if not, what would be the best option for a fixed limit of the deposit?*"Usually we send one truck full, the customers take into account how much they can have in a X dimensions truck."*(from fleet managers interviews, section 3.3.3)

- How is the max cargo capacity calculated? do you consider any OEM specifications? Are trucks weighed at the homebase?*"They order based in the container size, as Halléns tell their customers how much cargo they can carry (win-win). So usually, they ask for optimal (full capacity) deliveries for a certain container size."*"*Always full unload"*(from fleet managers interviews, section 3.3.3)

- Are overweight fines a problem in your company? Do you have any tolerances, what is the legal margin? *"They don't handle overweight fees because they don't load the cargo, other company is responsible for that in other countries and they come by ship. " "However, they have four trucks that they load themselves. If they load too much they have to go back to the factory and unload".* (from fleet managers interviews, section 3.3.3)

- What are the most common overweight fine types? How/when do they weigh trucks in controls.

"Usually trucks are weighed before leaving the homebase, most common type of overweight fine is caused by exceed Gross Combined Weight of the vehicle" "They weight in a weighbridge". (from fleet managers interviews, section 3.3.3)

- Percentage of cargo transported, fully or partially load (how full)?*"These are dedicated trucks that need to come back empty and be cleaned thoroughly for the next load."*"*They usually have trucks full in volume, they carry one truck usually per delivery."* (from fleet managers interviews, section 3.3.3)

FUEL RELATED VARIABLES

Tank size & fuel level (fleet manager)

- OA 2 (Cargo) with small tanks may not be optimal, as the small tanks are already 'optimized'. (from scenarios, section 3.3.6)
- Set a fixed tank limit for each delivery (to 'redefine available cargo' capacity of truck) or in general (for how long)…? What would it be acceptable for a fleet manager / driver? (from scenarios, section 3.3.6)
- If break, and time demands are flexible for a dispatch case, what is the optimal tank level or optimal consumption savings vs. refill driver time salary? (scenarios, section 3.3.6)

Fuel prices

- How much would MindFuel be saving in fuel price? fuel prices, prices may be quite local. more significant in different countries.(from interview with expert 4, section 3.3.3)

ROUTING, ALLOCATION & LINKING DELIVERIES

Transitions: between deliveries, days and/or drivers

- How are drivers assigned deliveries depending on your location of prior / posterior deliveries. (from scenarios, section 3.3.6)
- Do you drive the same truck always? *"Always the same"* (from truck drivers interviews, section 3.3.3)
- Do you put any thoughts for following deliveries or days in terms of planning for fuelling or timing? (from scenarios, section 3.3.6)
- In such case, how do you plan in terms of fuel between deliveries and days? *"refuel once a week (450L tank) everyday 15-16 trips (distribution pattern)"* (from truck drivers interviews, section 3.3.3)*"When long-hauling, if before starting the trip the tank is half empty, I fill it up till the top"* (from truck drivers interviews, section 3.3.3)
- How do you / can we communicate plans that affect transition between days (driver change) and deliveries? *"Changes in the plan are communicated through phone"* (from truck drivers interviews, section 3.3.3)
- Non reversible actions between days (bad planning): a filled up deposit affects the next day/delivery strategy, since
    - You may not be able to use +cargo option (if the deposit was full) (from scenarios, section 3.3.6)
    - Fuel theft risk/consequences increase (from scenarios, section 3.3.6)
- Order of priorities: fuel consumption/fuel theft, cargo, time: *"Number 1 priority is delivering in time. It is crucial, and the most expensive factor if not fulfilled. A dissatisfied customer is the highest cost a fleet owner faces.""Fuel is a means, the objective of the fleet owner is the delivery"* (from interviews with expert 3, section 3.3.3).

- Possible and impossible dynamic optimization alternatives:
    - Possible: multiple unload (distribution) allows
        - a) switch to fill up till max(incrementally) (from scenarios, section 3.3.6)
        - b) lower/optimize the FTLL due to higher fuel efficiency as a result of less weight (from scenarios, section 3.3.6)
    - Impossible:
        - Changing cargo orders in the moment, fitting more cargo within a delivery (from scenarios, section 3.3.6)

FUEL THEFT

"Fuel theft is undoubtedly a massive problem across the Continent. While telematics alone cannot solve the problem, it can certainly help through the installation of fuel level monitors linked to telematics reporting systems which provide alerts should a fuel tank begin to drain suddenly"(Plus gps, 2014; from literature section 3.1.5)*"Fuel theft accounted for nearly two-thirds (64%) of all thefts from LGVs last year with police recording 1,605 separate incidents in 2011."*(Centre tank, 2014; from literature section 3.1.5)

TRIP UNEXPECTED EVENTS

Changes during a trip and unexpected events

- What can change during a trip that can affect the established plan? In terms of, routing, timing (traffic jam, not arriving on time), refueling *"Usually, the only changes are regarding timing (traffic jam, not arriving in time etc)"*(from truck drivers interviews, section 3.3.3)

CUSTOMER AND TRIP PRIORITIES

Reliability: ensure they will get to the destination on time (Expert 2, section 3.3.3)

- Estimated time of arrival vs. ecodriving
    - In case of being late, DTC minimizes the damages? (scenarios, section 3.3.6)
    - The opportunity appears mainly in prolonged hilly trips, when a higher consumption within legal speed limit can result in considerable time savings. Some drivers mentioned having to ignore ecodriving when DTC is tight, but only when a compulsory break can be saved without the difference of consumption being critical for a need of an extra refuelling stop (scenarios, section 3.3.6).

CUSTOMER DESIRABILITY

Fleet owner / Dispatcher (main customer)

- They would appreciate assisting tech. for refuel (fleet managers survey, section 3.3.2)
- Reduction of emissions enhances company values? (fleet managers survey, section 3.3.2)
- Credibility, less fuel: don't think you would save fuel (interview with expert 2, section 3.3.3)
- Credibility, more cargo: the key is the cargo (from interview with expert 2, section 3.3.3)

Driver

- Most would appreciate an assisting technology for planning, if they had to plan (truck drivers interviews, section 3.3.3)
- None of the respondents use fuel man. systems (truck drivers interviews, section 3.3.3).
- None use assistance for eco-driving (from truck drivers interviews, section 3.3.3).
- None receive any feedback on their driving (from truck drivers interviews, section 3.3.3).

IMPLEMENTATION ENVIRONMENT & CONFLICTS

Dynafleet environment

- MindFuel not a consultancy service, but an operational tool. Hence it fits more in the Dynafleet context, supported by an app. For the driver needs to be mobile or nomadic device, ideally onboard. It could be good to have it as an extra service in Dynafleet (from interview with expert 4, section 3.3.3).

- No overlaps (contradicting instructions or interests) with Dynafleet, and there is also no service for route optimization in dynafleet (from interview with expert 4, section 3.3.3).

- The recommended fuel stops have to be sended to the gps (navigation application display) to make some sense. (from interview with expert 4, section 3.3.3).

Current assistance for Drivers

Currently none of the respondents use Fuel management systems. None use assistance for eco-driving. None of the respondents receives any sort of feedback on their driving. None plan their refueling. (from truck drivers survey, section 3.3.2).

Current assistance for Fleet managers

- No route support system (from fleet manager interviews, section 3.3.3)
- Knowledge from consumption and eco-driving performance from Dynafleet and fuel advice (from fleet manager interviews, section 3.3.3)
- Feedback given in the computer canteen (lunch room) and in the onboard screen. (from fleet manager interviews, section 3.3.3)

Current display solutions

- Current (from truck drivers survey, section 3.3.2):
  - Smartphone (1/10 did not have)
  - GPS device screen (most)
  - Tablet (few)
  - Integrated truck screen (half)

- Preferred for MindFuel (from truck drivers survey, section 3.3.2):
  - Smartphone and integrated truck screen most.Fleet managers also prefer them because they are already existing equipment
  - One respondent: Heads up display

Current driver coaching system

"Methods for eco-driving: real life coaching within dynafleet in the new trucks. data is renewed every 2 hours. Push notifications in the screen. Its within fuel and environment, not fuel advice. Problems with drivers because they could not turn it off so they had to took it of some trucks, now only about 10% of trucks have it." (from interview with expert 2, section 3.3.3)

INPUT, DISPLAY & INVASIVENESS

Having the minimum effort to put the input. Most experts agreed (and it was seen during interviews with drivers and transport managers in general) that the responsibles and managers for most of the data regarding trips are dispatchers. Also, drivers would generally not like to have to put more data into the system. Pre driving, during driving, break time, post (feedback), (from market analysis conclusions, section 3.2.3)

Data needed by the system

- Easy input before driving / breaks:
    - Cargo weight for each trip segment. (from scenarios, section 3.3.6)
- Coordination with navigation system

Experienced drivers often don't use GPS

- Force them to use navigation? (from truck drivers surveys, section 3.3.2)

PRIVACY

Truck drivers

- All drivers don't mind their fleet owners having access to their personal truck location, consumption and tank level data. (from truck drivers surveys, section 3.3.2)
- In cabin video only closed to software learning (from truck drivers surveys, section 3.3.2)
- Out-cabin video privacy tolerance spreads evenly. (from truck drivers surveys, section 3.3.2)

Fleet managers

- Open regarding truck location, fuel consumption, Fuel tank level (fleet managers surveys, section 3.3.2)

Manufacturer/Closed: video in cabin and exterior (fleet manager surveys, section 3.3.2)

9.6 Keypaths and alternative scenarios

Dispatcher - desktop

OA2, CARGO

1. Fleet: config & profiles truck trailer databases required)
    a. enter/import and/or config data
        i. homebase
        ii. supplier(s)/favorite
        iii. ...
    b. all done or available → skip "fleet"
    c. change a preference/ update databases

2. Prepare orders for trips
    a. First use → example shipment
    b. From favourites → New order OR New order → from fav.
    c. From last orders (history) → (Add to favourites) → Add order

d. Import → Add orders

3. Plan trip:
   a. First use (new user and/or empty software → example trip overview (existing or tutorial)
      i. Trip overview (chart view) with an order selected
      ii. Selected order specs and map
      iii. Trip overview (calendar view)
   b. Regular use
      i. Overview / check
         - check free compatible trucks and drivers
         - check compatible drivers
      ii. Add trip (new trip prior to a posterior already defined trip)
         a) To selected truck (***possible error if new trip happens prior to a posterior -already defined- trip and overlaps, both with truck trucks and drivers)
         b) Assign MindFuel suggested truck
      iii. Add one order (load/unload view and ETA)
      iv. Add another order
         1. Assign a truck
         2. Assign a recommended truck (truck-trip allocation)
      v. Confirm trip

      vi. Notifications → Inbox (Add more cargo)
      vii. Edit and check prior trips for refinement

4. Revise/ edit refueling plan
   a. First use → empty (notoriously sample) framework for pliancy and understanding (exploration)
   b. Normal use (link from notifications)
      i. Select OA and check that all makes sense
      Profit, select OK
      Want to switch alternative
      Impact of selection:
         extra cargo kg capacity, type(s)/value(s) of extra cargo
         impact on BC and emissions
5. Check notifications

   Opportunity to add cargo orders (done in 3-b-iv.)

   General (at any moment)
   Alerts of legal comply of agreed FTL limit
   Reports of drivers performance

   a. Inbox
   b. Open message → confirm add cargo

OA1, Eco & OA3, Time

Same as OA2.
Driver - mobile and onboard with voice interaction

MOBILE

1. Adjust preferences (first time or update)
2. Get assignment notification (optional)
3. Check trip (timeline & map)
    a. Current
        i. Preview a/b/c optimal stops and trip general, during all trip days
    b. Future

4. Start trip

5. Get push notification while driving on the integrated screen/voice feedback for a suggested optimal stop
    a. the driver can ignore a stop before so they get info about other alternatives (quick undo) and inform the system for higher quality recalculation (this action would also be able to be performed through voice interaction, ignoring the stop through voice input)
    b. The driver informs does not stop neither in a) nor b)
        i. app shows each new stop (feedback on each new stop would also be conducted through voice interaction, however, it would only continue with voice if driver answered by voice)

    b1 the driver stops in c) and gets one point

    b2 the driver continues → app shows a) again and same process follows

    c. The driver stops in the suggested stop (optimal a)
        i. passes stop c) → MindFuel shows reserve r) stop after a)
        ii. passes top b)
        iii. stops at a) App detects you have stopped → 3 points
        iv. Refuel amount adjusted to selected stop (also, through voice interaction, push notification of amount of fuel in this stop and alert of overweight risk and responsibility).
        v. gets 3 points
    d. The driver doesn't stop in the suggested stop and stops in r stop
        i. same process
    e. The driver stops in a stop which is not suggested by MindFuel
        i. App detects where you have stopped
        ii. Refuel amount adjusted to the selected stop
        iii. if suitable, MF calculates if driver deserves points
6. Performance overview
    a. Goes to profile
        i. Fuel tank utilization
        ii. MindFuel level