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Web application to track fuel usage of cars: Drive-Greener

Bachelor's Thesis (9 ECTS)

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Web application to track fuel usage of cars: DriveGreener

Abstract:

Due to the ongoing global energy crisis, more and more people are trying to cut costs, especially regarding fueling their vehicles. Current web applications for fuel consumption tracking on the market are outdated, do not display enough appropriate information and statistics and are uncomfortable to use. DriveGreener aims to solve that problem by helping users save money and see their usage habits and vehicle spending. DriveGreener is a modern web application built using Java, Spring Boot and AngularJS.

Keywords:

Web Application, Java, AngularJS, PostgreSQL, fuel consumption, vehicles

CERCS: P175 Informatics, systems theory

Sõidukite kütusekulu jälgimise veebirakendus DriveGreener

Lühikokkuvõte:

Energiakriisi tõttu on inimestel ja ettevõtetel läinud aina olulisemaks kulude säästmine, eriti sõiduvahendite puhul. Turul olevad rakendused on kas aegunud, ei kuva kasutajale piisavalt vajalikku statistikat, ning on ebamugavad kasutada. Selleks on veebirakendus DriveGreener, mis võimaldab kasutajal säästa raha, näha täpsemalt oma kasutusharjumusi ning kulutusi sõidukitele. Tegemist on veebirakendusega, mis on loodud kasutades Javat, Spring Booti ja AngularJS'i.

Võtmesõnad:

Veebirakendus, Java, AngularJS, PostgreSQL, kütusekulu, sõidukid

CERCS: P175 Informaatika, süsteemiteooria

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1 Introduction

In 2021 energy prices started to rise due to the COVID-19 pandemic and other factors. After the Russian invasion of Ukraine at the beginning of 2022, a global energy crisis followed. The energy prices reached record highs, and it started to increase inflation. Increased inflation has sent people into poverty, changed the production rates of factories and slowed economic growth. [1]

Households in Europe, on average, spent 13.2% of their total expenses on transport in 2018. After housing expenses, transport is a household's second most significant expense. [2] It is one of the most significant expense articles in a household budget. Fuel is a part of the expenditure and can be directly affected by the user's driving habits, meaning it is possible to save money by changing the habits of a user.

This thesis aims to develop a web application DriveGreener to inform people about their vehicle's energy or fuel usage and, in turn, save them money. The application collects data from the user, which the users insert into the application from the user interface. The data collected by the web application is analysed, consolidated and displayed to the user in a way that helps the user understand how different ways of driving affect the user's energy consumption and wallet. DriveGreener helps users to drive smarter and aims to reduce energy and fuel usage in passenger vehicles, which also helps to reduce CO_2 levels in the atmosphere.

The rest of the thesis is structured as follows; Section 2 discusses the background of different fuel consumption factors in vehicles with detailed explanations. Section 3 compares and discusses the applications that directly compete with DriveGreener and how the developed application is superior. After that, section 4 establishes the functional and non-functional requirements for the application, development tools and software used to create the application. The last part, section 5, introduces the results with an in-depth description of the DriveGreener application, including requirements validation. Section 5 also mentions the application's possible future plans, ideas, and developments.

2 Vehicle fuel consumption factors

In the first chapter, background information about the fuel consumption of vehicles and factors influencing vehicle fuel consumption is introduced.

2.1 The effect of speed and road type on the fuel consumption of a personal vehicle

Internal combustion engine cars have significantly higher fuel consumption at higher constant speeds than slower ones. At higher speeds, the airflow increases on the car's body panels, which uses more fuel. For instance, only a 4% increase in speed could mean an almost 40% increase in fuel consumption [5:182-183].

According to a study by Tim Jonas et al. [3:9], temperature and the type of road on which the vehicle is driven are the most significant factors in the energy consumption of battery-powered electric vehicles. These have the most significant impact on vehicle energy consumption. For example, major interstate highways have the highest energy consumption when the outside temperature is 20C. When driving on this type of road, the average electricity consumption is 14.7kWh/100km. Driving on all other types of roads increases the efficiency of electric cars. The lowest energy consumption was on collection roads, with an average consumption of 7.9kWh/100km.

The result of Tim Jonas et al. also supported by the research of Sokratis Mamarikas et al. [3:5], where it was found that at low speeds in the city, the energy consumption of electric vehicles is low. However, at higher speeds and on highways, it is significantly higher. The rationale was that electric cars have lower energy consumption in the city and at low speeds, as electric vehicles can use regenerative braking, which returns energy to the battery. This kind of energy recovery does not have a significant effect on highways because the traffic there moves more evenly. Therefore, the battery level cannot be restored as there are few sudden braking on highways.

In a study by Tim Jonas et al. [4:9], it was found that it is possible to save energy by avoiding certain road types. For example, avoiding major highways by driving on any other type of road saves at least 12% energy per kilometer. Electric vehicles save up to 46% of energy when driving in the city compared to the highways.

2.2 The effect of car weight on fuel consumption

According to the study of M. Al-Moman et al. [5:183], the more people there are in the car, the higher the fuel consumption. There are two contributing factors. One of them is the increased mass in the car, so the engine has to do more work to move the car forward. Secondly, the roll resistance of the tires on the road increases because the mass of the car increases, but the contact patch with the road remains the same.

2.3 The effect of car usage conditions on fuel consumption

According to Sakno, O et al. [6], adequate car maintenance significantly affects fuel consumption. A study found that the newer vehicles had the lowest fuel consumption of all the cars tested. Walid. M. Al-Momani et al. [5:183] also achieved comparable results. It was found that the fuel consumption of a car in good condition and well-maintained is significantly lower. They also found that fuel quality directly affects energy usage - using higher-quality fuel reduced consumption by up to 10% at higher speeds. It turned out that fuel consumption was also affected by air conditioner usage. Regardless of speed, fuel consumption was consistently higher when driving with air conditioning. On average, air conditioning is 5% less energy-efficient than driving without air conditioning.

2.4 Fuel consumption factors in relation to the DriveGreener application

DriveGreener aims to help users reduce their costs and ecological footprint by using the factors described in the previous paragraphs. By showing the user different factors and data, it is possible to influence how users think, drive and decide about vehicles. The driver of a vehicle can influence how much these different factors affect fuel consumption by changing driving style and habits. The application will display these factors to the user in valuable graphs, which are generated using the data inserted by the user.

One of the factors is the road type - differentiation between different road types is made by splitting the amount of driving done in the city and on rural roads. The differentiation was made because it is tough to differentiate between all types of roads outside the city, and generally, cars use more fuel in stop-and-go traffic than outside of the city on a rural road. All the data is combined on a graph with the fuel consumption related to the percentage of city driving. For example – a user drives most of the drives in the city, rarely on rural roads; this causes the fuel consumption to be very high in the city but relatively low outside the city. With that data, the users can make a decision to use the car less in the city and instead ride a bus. Alternatively, users can invest in a vehicle, which is a much more efficient vehicle in the city than the previous one.

Another crucial data point will be used in DriveGreener – vehicle weight. The application collects on each fill-up the vehicle load using three categories – empty, half load and full load. Fuel consumption for each category is calculated, and a graph is displayed to the user. This helps the user to understand whether their vehicle is economical with a bigger load and helps them to understand their vehicle better for more savings.

3 Analysis of competing applications

There are many different fuel consumption monitoring applications on the market. In this thesis, two of the largest and most popular applications were analysed: Fuelly and Spritmonitor.

3.1 Spritmonitor

Spritmonitor [7] is a prevalent online fuel consumption monitoring web application with over 700,000 users and over a million unique vehicles entered. In Spritmonitor, users can add several cars to track and monitor their fuel consumption individually. When adding a car, the user must specify the car's manufacturer, engine details, gearbox, and fuel type. Specifying various engine configurations, for example, electric, diesel, petrol, and petrol-LPG, is possible.

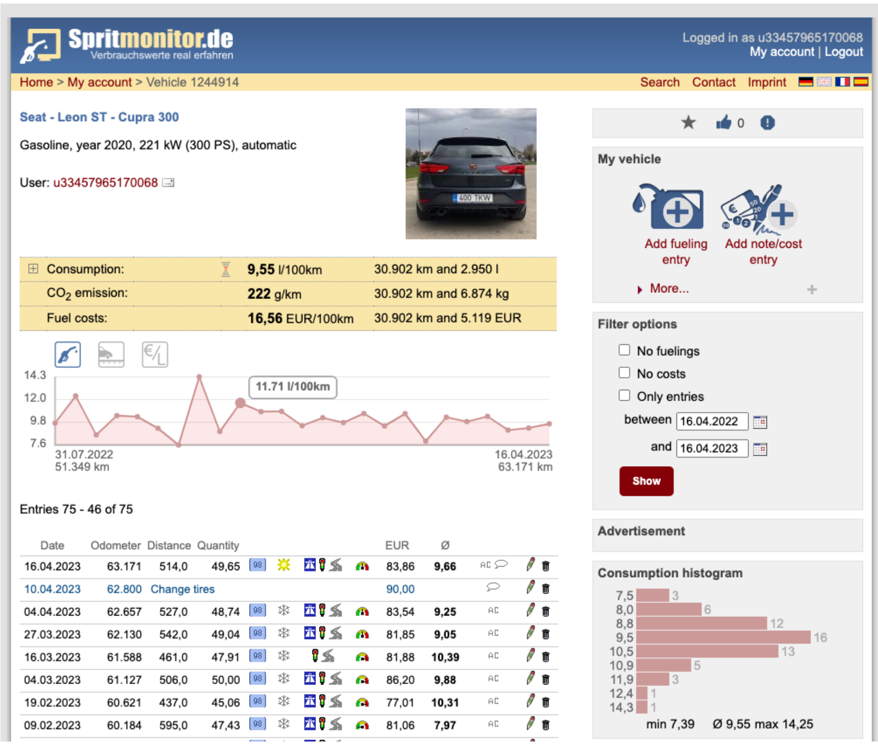

Figure 1 – Spritmonitor vehicle page [7].

Most of the tracking is done by collecting different data from the user when refuelling. The user must enter the fuel amount, fill-up total price, and the distance travelled. In addition, it is possible to determine the type of fuel filled, gas station, driving style and various parameters such as the use of the air conditioner, the use of a trailer and the type of roads driven.

The application calculates the fuel consumption of the vehicle's fuel tank each time the vehicle is refuelled. The obtained data is used to calculate the average fuel consumption of the car for the entire time, CO_2 emissions, and the price of travelling 100 km.

In the author's opinion, the functionality part of this app is excellent. However, one of the most significant downsides of the app is its outdated design and confusing and complicated user interface, where it is hard to find valuable information. It is also difficult for companies in Estonia to use it, as the application does not support Estonian license plates, which can be used to identify a specific car from many very similar cars quickly in a business setting, where there are, in many cases, more than 10 similar cars. There is also no option to add time notifications to the email. The most potent part of Spritmonitor is the view of graphs. Graphs can display many data types and are very clear, for example, a view of consumption or fuel price over time. These graphs inform the user about the expenses and consumption under different conditions, which helps the user to adjust their driving style and car usage.

3.2 Fuelly

With over 600,000 users and a million unique vehicles, Fuelly [8] is also one of the most popular online applications through which it is possible to track a vehicle's fuel consumption. The basic functionality is similar to Spritmonitor, but only vehicles with internal combustion engines can be added. Similarly, to Spritmonitor, when adding a fuel consumption entry, the user will be asked for the price, distance travelled, and fuel amount. In addition, it is possible to specify what percentage of the distance was covered in the city, the type of fuel used, gas station and tire pressures in detail. Apart from fuel consumption tracking, one of the extra features is the possibility to add various notifications about upcoming maintenance and inspections.

The author believes this application's user interface has slowly become obsolete. The actions, which should be the most straightforward, easy to find, are small, blend in and difficult to find. The user interfaces present a lot of the and because of that look very cluttered. The design is beautiful but slowly shows its age on the user experience side. The biggest problem with this app is that there is no way to add electric cars. In addition, the statistics that the app gets in the form of graphs are very minimal. The most outstanding feature of Fuelly is the ability to add how much distance was covered in the city and highway. It gives the user much useful additional information to estimate fuel consumption.

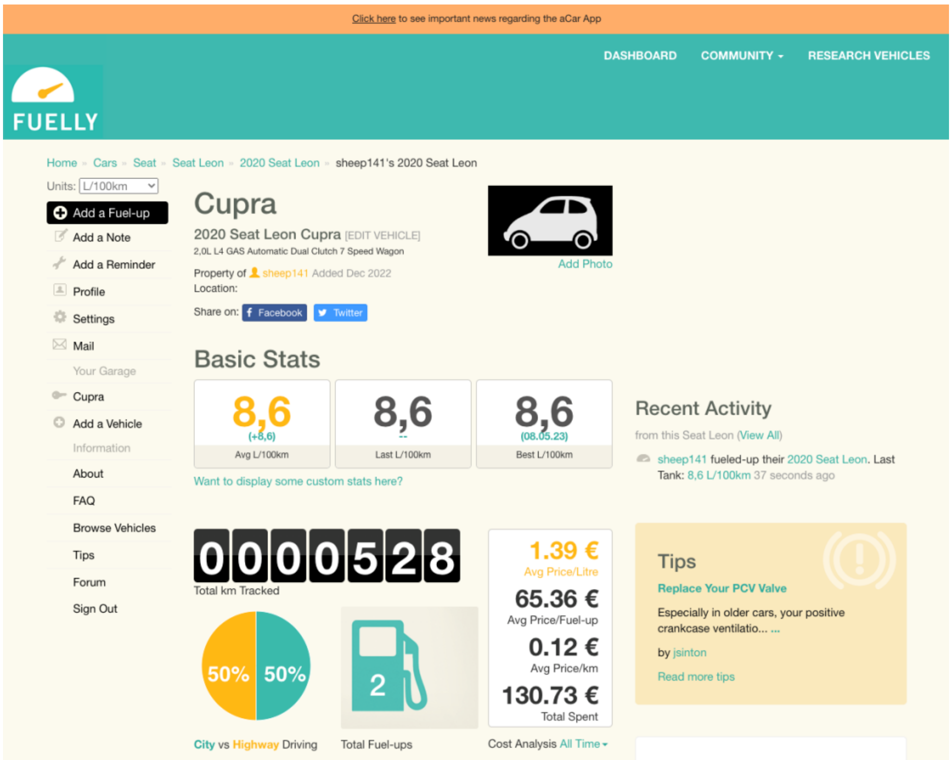

Figure 2: Fuelly Vehicle page [8].

3.3 How DriveGreener advances existing applications

Neither Fuelly nor Spritmonitor is perfect, and both have flaws in different areas. However, both of them have many positive aspects. DriveGreener aims to combine the best parts of both of these applications while modernising many parts of these applications. Table 1 presents a comparison between DriveGreener, Spiritmonitor, and Fuelly focusing on their key aspects. The DriveGreener application intends to be much less cluttered, modern looking and much easier to use by having main actions and views easy to find and use. The data shown to the user as graphs will be simple and easy to understand, with detailed views. One of the features crucial features of modern times, support for electric vehicles, which is missing from Fuelly, will be supported by the developed solution. The application will have features inspired by the competition, namely the driving style, city driving percentage and tire type. These features will be used for graphs and calculations to show the user why to change their habits and what are the biggest factors in their expenses.

DriveGreener improves the functionality of Fuelly and Spritmonitor with some new, never seen features. DriveGreener collects data about the load of the vehicle to display to the user how load changes fuel consumption, which is not found in either of the applications.

Table 1: Feature comparison between Spritmonitor, Fuelly and DriveGreener.

Feature	**Spritmoni-tor**	**Fuelly**	**Drive-Greener**
Electric vehicle support	X		X
Monthly consumption graphs	X		X
Detailed consumption graphs (trip, consumption, price, unit price per filling)	X		X
Vehicle load/weight data			X
Modern Design		X	X
Easy to use			X
CO2 emission calculation	X		X
City vs Highway percentage selection		X	X
Consumption calculation for different city percentages			X
Amount of data visualisation	Medium	Low	High
Application supports mobile phones	X		X

4 Application Requirements

This section will discuss the different requirements, which were identified for the application before development, focusing on key requirements that were considered to compete with Fuelly and Spritmonitor.

4.1 Functional Requirements (FR)

FR1: The system must support a user account system.

The reasons behind this requirement are that without an account and user functionality, the concept of the application does not work, as there is no way to connect a car to a person and store private data.

FR2: The system must allow users to add at least one vehicle to their account.

Part of the essential functionality is to track fuel consumption. Many families and companies have multiple cars, which need to be tracked individually for the expenses and statistics to be calculated.

FR3: The user must be able to specify the detailed specifications of the vehicle.

This includes the vehicle manufacturer, model, trim, fuel type, and drivetrain. This is necessary to identify the vehicle from other vehicles and to store crucial data about the vehicle itself.

FR4: The user must be able to add fill-ups to the vehicle.

This is the most important data of the application on which everything else is based. With the fill-ups, the user must be able to specify the fuel used, odometer and price.

FR5: The system must calculate and display the statistics of every fill-up

Every time after user has filled up their vehicle, system must calculate statistics – fuel consumption, total price, trip and also display these calculated statistics. This is necessary for the user to see instantly the statistics for the previous trip.

FR6: The user must have the ability to create fill-ups that are not full fill-ups

When a user does not refuel or charge the vehicle completely, then it still must be possible for the user to track the fuel consumption. When the tank is not filled completely, the consumption calculation will wait until full fuel-up.

FR7: The user must be able to see consolidated graphs of different parameters of filling statistics

The graphs are a necessary functionality of the application. Without the graphs, it is impossible to show the user exactly how fuel consumption has been changing throughout fill-ups and what parameters affect the expenses the most.

4.2 Non-Functional Requirements (NFR)

NFR1: The Application interface shall look modern and clean.

This makes the application easier for the eye because modern design principles are pleasant to look at and easier to understand for the user.

NFR2: The Application has to be simple and easy to use.

Usability is very important; it distinguishes different applications with somewhat similar functionalities from each other. When an application is difficult to use, users might get frustrated and not use the application because of the bad experience.

NFR3: The Application has to be simple to be used on mobile.

When people fill up their vehicles, they usually want to add the fill-up data right away from their mobile phones. Because of this, the application has to look nice and be simple to use on mobile and add a fill-up easily.

4.3 Development platforms

DriveGreener is a web application, which means it needs front-end and back-end solutions for the application to work how the requirements state. As the functional requirements state, the user data must be stored indefinitely, meaning the application needs a database. The author chose Angular front-end, Java with Spring Boot back-end and the PostgreSQL database.

Angular

Angular [9, 11] is a powerful single-page application design framework based on Typescript. It is designed by Google and used on many enterprise-level solutions. Google themselves also use it on their Cloud Platform [10].

The author chose Angular as it is an enterprise-level application with powerful features, which means that in the future, it is possible to scale the application to work as a business solution on a much bigger scale. For the development itself, Angular 15 was chosen as it is the latest version available at the time.

Spring Boot and Java

Spring Boot [12] is a Framework that is used to create Spring-based applications. It is an opinionated view of the Spring framework, and it makes creating Spring applications simple. Spring and Spring Boot are the most widely used web frameworks [13]. Spring Boot applications require Java to work [14]. Java is a programming language and computing first released in 1995, and currently, it is one of the biggest platforms and programming languages in the world [15].

Spring Boot and Java both were chosen by the author because they are the most popular web application development platforms in the world. One of the other reasons for choosing Java and Spring Boot is that the author has a lot of experience using them on enterprise-level solutions. Because Java and Spring are so widely used, they have a lot of support and information available. That makes the development process much simpler and faster for the developer. In the DriveGreener application, Java JDK version 19 is used with Spring Boot version 2.7.9.

PostgreSQL

PostgreSQL [16] is an open-source relational database system that supports SQL standards. It originates from the University of California with a project named POSTGRES from the year 1986. In the application, PostgreSQL version 14.1 is used.

5 The DriveGreener Application

This section provides an in depth discussion about the application DriveGreener, which was developed for this thesis work. The user authentication and login functionality in Angular and Java with Spring Boot was developed using a guide made by Bezkoder [17]. The application's source code with instructions on installing the application is available at GitHub: https://github.com/kaurvali/DriveGreener.

5.1 Architecture diagram of the application

Figure 3 is a diagram that describes the application's basic architecture. This is simplified and does not contain all small data transport objects. However, it gives a good overview of how the application works and data flows.

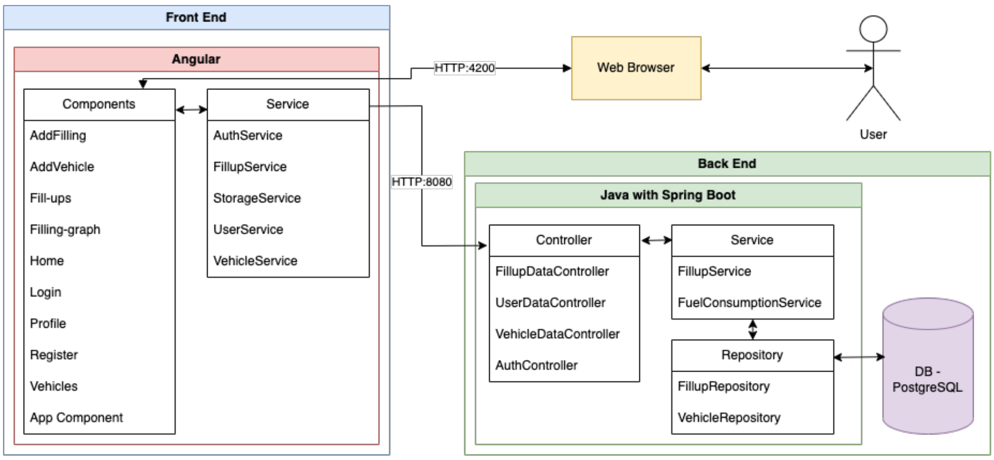

Figure 3 – DriveGreener architecture diagramm.

As mentioned, the application is developed using Angular 15, which serves the front-end to the user, who accesses the application via a web browser. Angular itself consists of components, which communicate with services. The Angular services communicate with the back-end server via API calls over HTTP. The back-end server is created using Java 19 with Spring Boot 2.7.9. Data is sent in the form of JSON and secured by JSON Web Tokens to controllers in the back-end application. In there, controllers get information from services that contain the logic to calculate fuel consumption, CO_2, etc. The services get data from the repositories, which communicate with the PostgreSQL database.

5.2 Application in depth

In this section, the specific views of the application are described. This includes explaining how the application works, how the fuel consumption es calculated, and what kind of graphs are shown to the user.

Landing page

This is the first page the user interacts with when the application is opened. This page is only displayed when the user is not logged in. It describes to the user the application's basic functionality, how to use it, and what are the calculated statistics. This page also includes information about the source code and who is the author of the application.

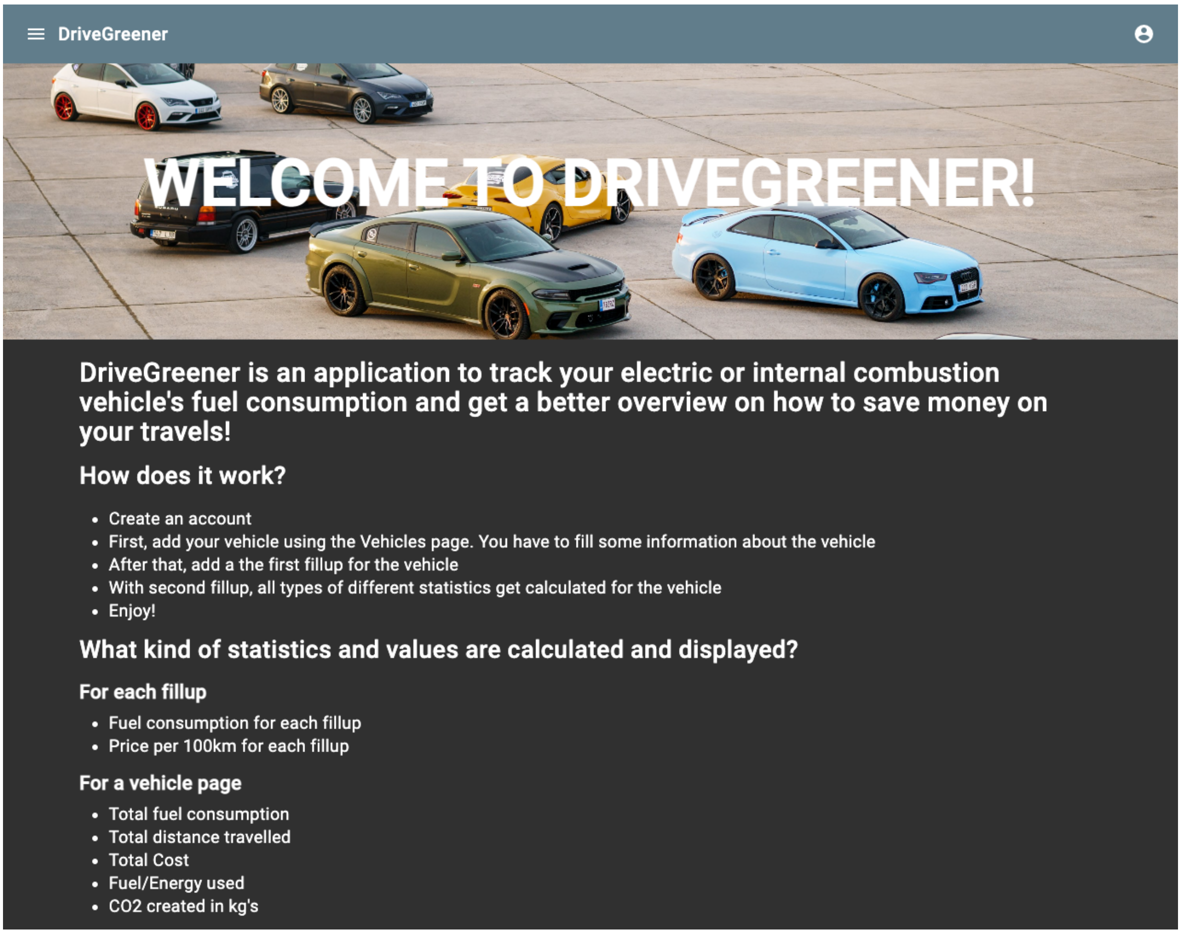

Figure 4 – DriveGreener landing page when user is not logged in.

Login and sign-up page

The user must log in to use all of the application's features. The log-in view is displayed in Figure 5. The login happens on the back-end side, where the user is processed and authenticated. This feature uses JSON Web Tokens to authenticate the user in the application.

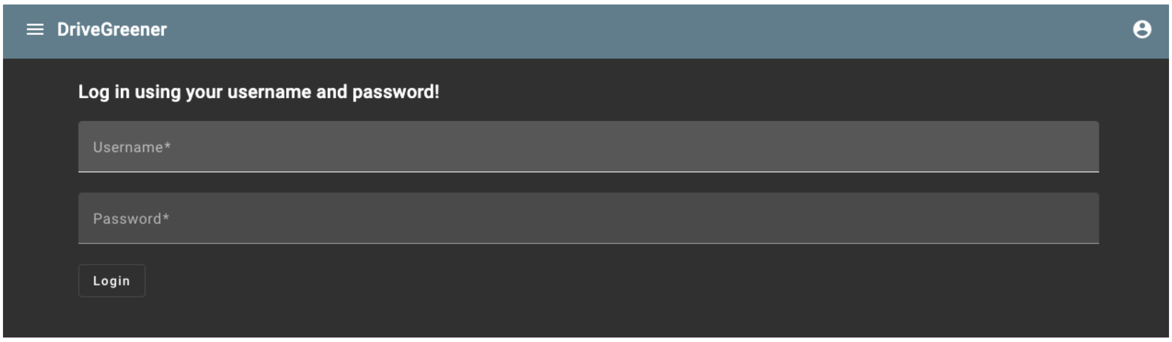

Figure 5 – Login page of DriveGreener.

However, to log in, the user needs an account. An email, username and a password are needed to create an account. This is shown in Figure 6. To keep the application small and for the scope of the thesis, this application does not have an e-mail service with the possibility to change username, password or email for now.

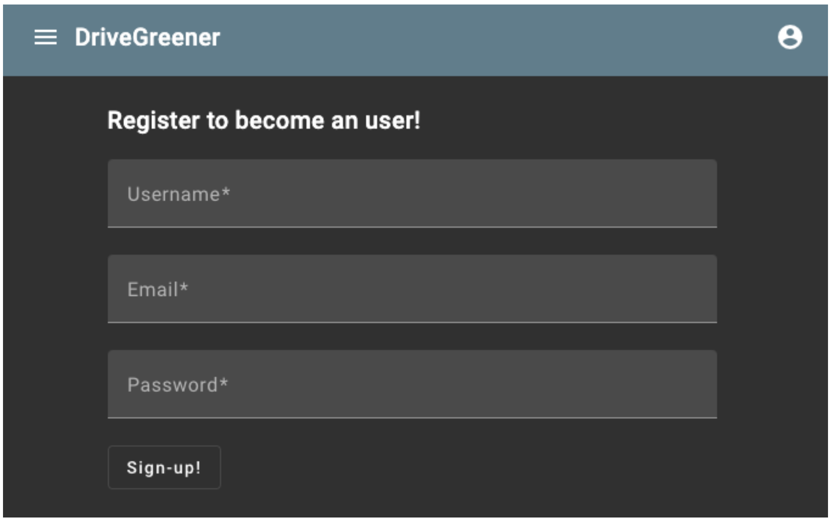

Figure 6 – Sign-up page of the DriveGreener application.

Home page

Figure 7 shows the home page that is displayed when the user is logged in. This page shows the user some basic data about their fleet: what vehicles the user has and the statistics for the entire fleet combined. The statistics displayed are the following: the sum of the distance that all of the vehicles have covered; the average price per 100km for the fleet combined, total CO_2 footprint, total cost, total fuel or energy consumed, and average fuel or energy consumption of the entire fleet.

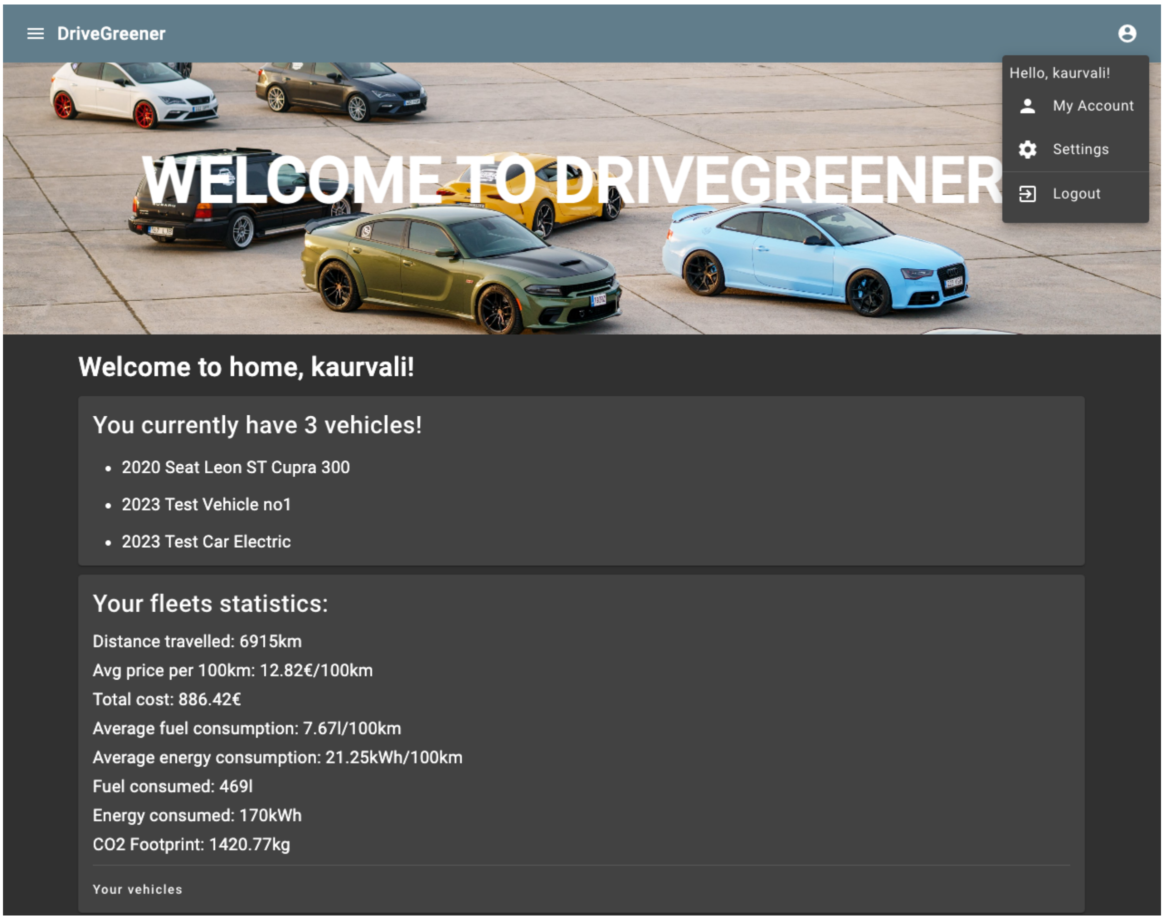

Figure 7 – Home page when the user is logged in DriveGreener.

Vehicle page

One of the most essential pages of the application – the vehicles. This page is shown in Figure 8. This page lists the vehicles that the user has with detailed specs and some calculated values for each vehicle. The parameters are the average fuel consumption, distance travelled, CO_2 produced, total cost and total fuel used. These are calculated via the fill-ups page, which opens up when clicking on a vehicle. If a vehicle is new and has less than two fill-ups, which is the minimum to calculate these parameters, then “No Fill-ups yet” is displayed to the user.

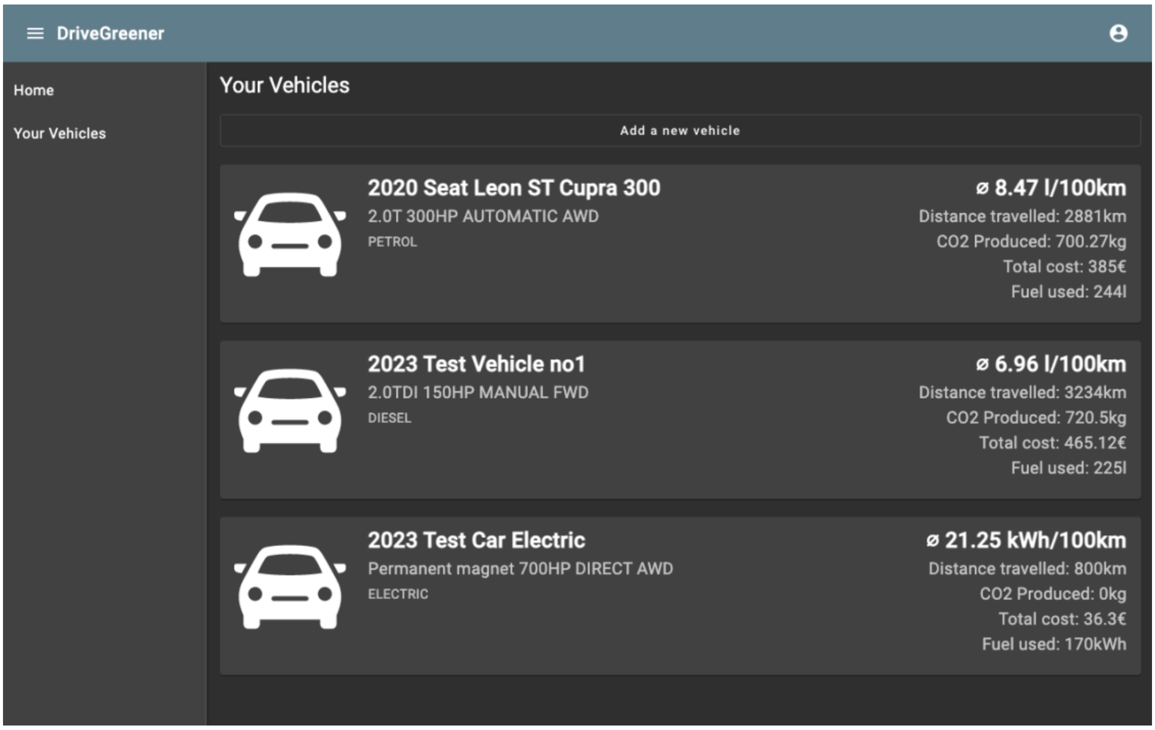

Figure 8 – User’s vehicles page in DriveGreener.

When the user first creates a new account, there are no vehicles associated with the account, and the vehicle view is empty. To add a vehicle, users must use the add a new vehicle form via the button on the vehicles page. The form itself is visualised in Figure 9. The add a vehicle form has many fields which the user has to fill, these fields are: Fuel Type, vehicle year, make, model trim, engine, power, transmission and drivetrain. These fields are necessary for it to be possible to differentiate between different vehicles.

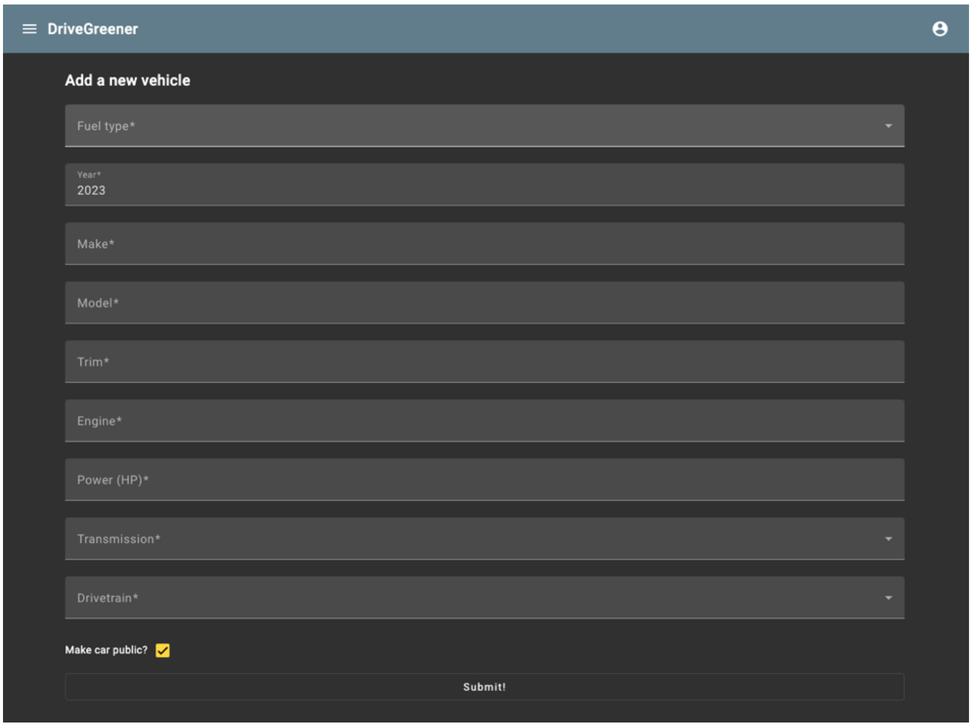

Figure 9 – Add a vehicle form in DriveGreener.

Fillups page

The most crucial application page is the fill-ups page, which is unique and connected to each vehicle. Using this, the user can keep track of each fill-up and get the statistics they need to make better decisions.

The first thing to do is to add a fill-up, which is displayed in Figure 10. There are many data collected for many reasons. The most important part is the vehicle odometer, fuel amount, and price. It is crucial to mark what type of fill-up it was: a full fill-up, partial fill-up and a first fill-up, the last of which is used to mark the initial odometer of the vehicle. That is the essential data, which is used to calculate the fuel consumption and fill-up price.

Other mandatory parameters include tires, driving style, amount of luggage, and city driving percentage. All of these parameters affect the vehicle's fuel consumption. They show the user how fuel consumption changes when using a vehicle in different ways and situations.

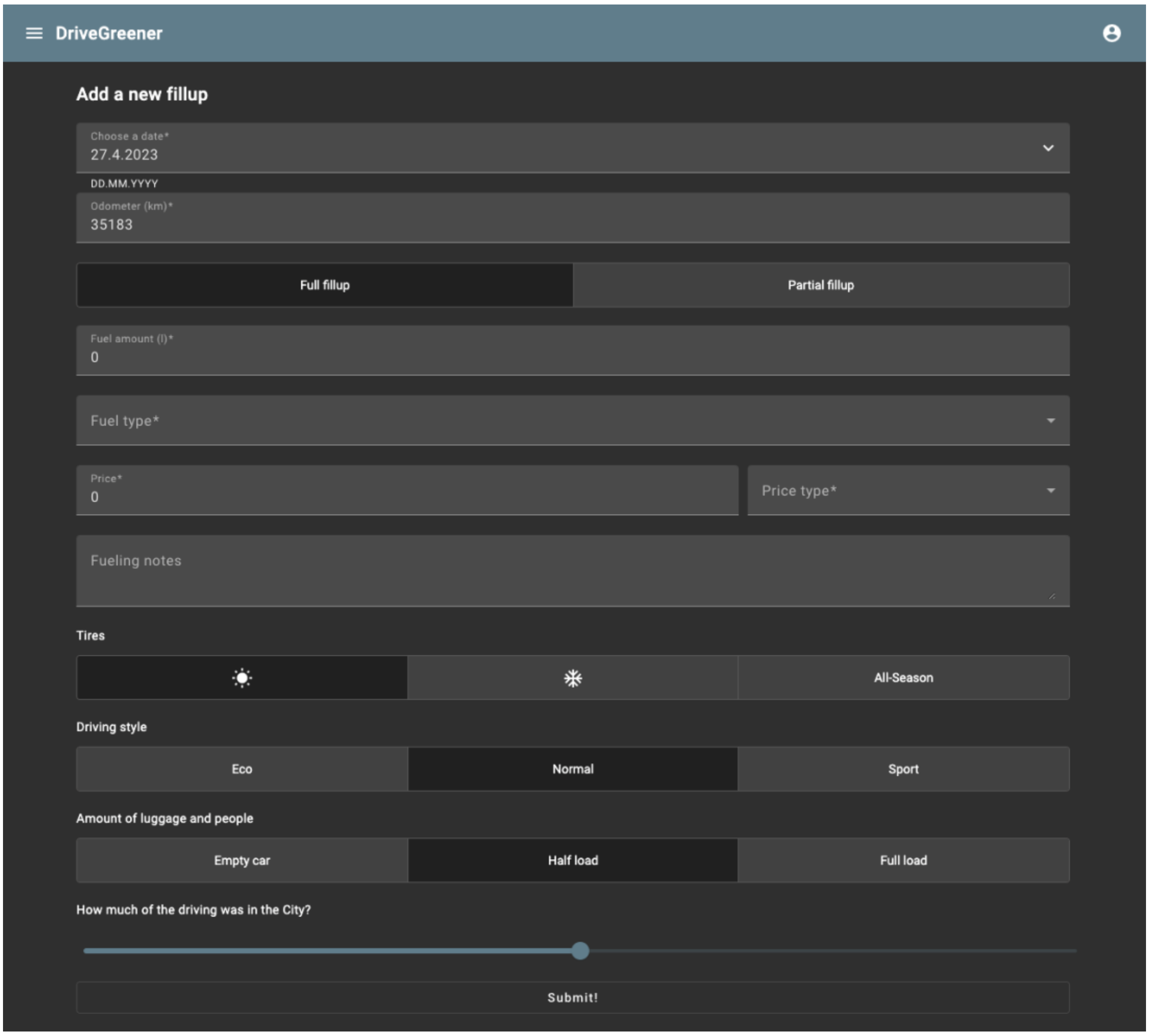

Figure 10: Screenshot of a page to add a fill-up in DriveGreener.

The way the page of fill-ups looks is shown in Figure 11. This page contains graphs and information about each fill-up. For each fill-up, trip, fuel consumption and price per 100km are calculated. The basic information: date, odometer, fuel type, driving style, price and fuel amount is shown. The fuel consumption is not calculated in the case of a partial or a first fill-up.

The fill-up data calculation logic is straightforward, after each fill-up, the distance between the current and previous fill-up is calculated using the odometer data. Then using that distance and fuel filled, the fuel consumption is calculated per 100km. For internal combustion vehicles, the fuel unit is a liter, for electric vehicles, kWh or kilowatt-hours is used.

The partial fill-up is also one of the most essential and complex features to implement in the application. The partial fill-up is the situation when the user fills up a tank but not entirely, for example, adds 10 liters to a tank. Because of that, it is impossible to calculate the fuel consumption accurately. When the user has used up 90% of the tank and travelled 450km but only adds 10 liters of fuel to the tank, the calculated fuel consumption is 2.22l/100km, which is inaccurate. The fuel consumption is only calculated when the user has had a full fill-up so that it is known that the fuel tank is completely filled. Otherwise, the data shown would be inaccurate and useless to the user.

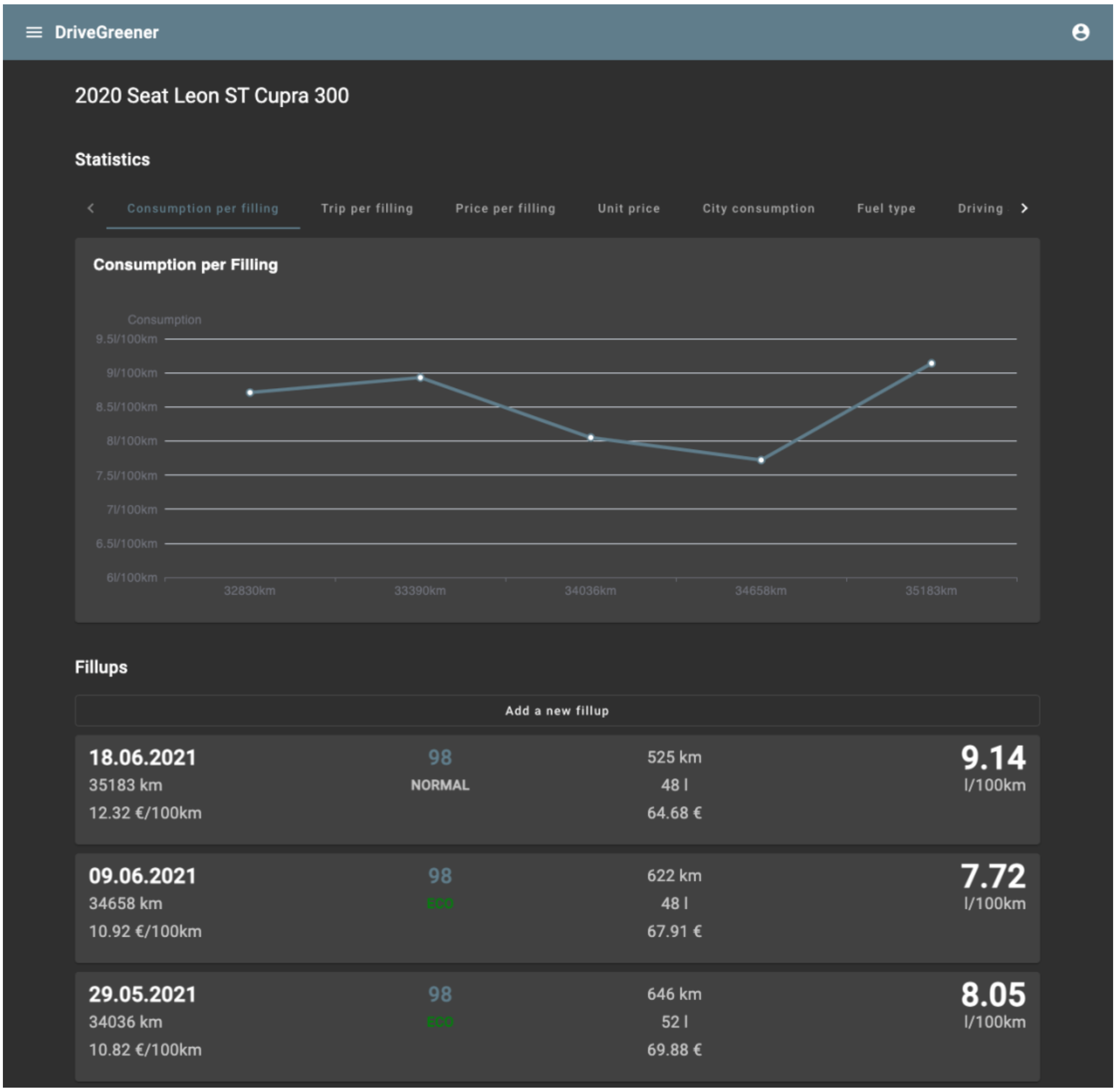

Figure 11: Screenshot of fill-ups page for a vehicle in DriveGreener.

Figure 11 also contains, on top of the page, the graphs for the fill-ups for each vehicle when there are more than two fill-ups. The reason for needing more than two fill-ups is that without it would be impossible to calculate fuel or energy consumption. The graphs contain valuable data for the user, which help the user make better decisions. These graphs are created from the data collected from the fill-ups and use extra parameters like driving style, city percentage, fuel type, and load type for more accurate information.

The most basic graphs are line graphs with the data about each fuelling – consumption per filling, trip per filling, price per filling, and unit price per filling. One of the most important charts is city driving percentage fuel consumption - on the x-axis is the percentage driven in the city, and on the y-axis is the fuel consumption. That graph shows the user how good their vehicle is on fuel when they drive more in the city and more on the highway.

The other graphs are bar charts, which display fuel consumption with parameters like fuel type, driving style, and vehicle load. The last chart is an overview of the average fuel consumption over different months of the year.

5.3 Validation

This section discuss the validation and testing of the application. Testing and validation are necessary to determine whether the application satisfies its corresponding functional and non-functional requirements, is comparable to the competing applications, and meets its potential user expectations, and hopefully, helps them to make better decisions.

Methodology of testing

The validation of the application is conducted by user experience interviews, where a user has to complete several tasks in the application and, after that, answer some questions. The tasks describe real-world tasks that could happen when using the application. The investigator monitors the tasks without any intervention and asks questions later. Testing helps to figure out any possible issues in the application and helps to compare the experience in different applications. In the testing, participants were chosen from the potential target audience of the actual users of the application. Each participant used all of the features of the applications in a random order and completed the same tasks in all three application (e.g., DriveGreener, Fuelly and Spritmonitor).

The participants in the testing were people aged 18 to 60 that have personal vehicles. This group of people was chosen because they are most likely to use the application. Because the participants own a personal vehicle, they need to fill it up and want to track the expenses related to the vehicle. Without a personal vehicle, a user would not need to use the application.

The exact testing sheet with questions and answers is in Appendix 1. Each interviewee also had to agree to the terms of testing and sign a consent form added in Appendix 2.

Results from interviews

During the interviews, three people tested all three applications – DriveGreener and the competition, Fuelly and Spritmonitor. Participants were tasked to complete tasks and were questioned about their experience. The sheet with tasks and questions is in Appendix 1.

From the interviews, it turns out that the most difficult to use is Spritmonitor. All of the participants struggled with finding the page where to add a fuel-up to a vehicle. Participants said that Spritmonitor looks outdated and is confusing to use. The confusion comes from the lack of clearly labelled buttons and that many buttons are links in the text. Participants said that the design of the application is cluttered with text. None of the participants could find the view where you can see more specific fuel consumption statistics like consumption per driving style.

Spritmonitor has no functionality issues once the participants found the correct place to do the tasks. However, participants commented that the fields in adding fuel consumption form are relatively small and, in some places, difficult to understand. Participants found that one of the strong points of Spiritmonitor is the amount of different data displayed. However, users were unsure whether that data was correct.

Fuelly had a better user experience than Spritmonitor. Participants could find the vehicle and the place to add fuelling more quickly. Even though the vehicle was found more quickly, the participants commented that the button to add fill-up is too small and difficult to find. Overall, Fuelly looked better than Spritmonitor but still felt outdated to the participants.

One of the most significant points of confusion for the interview participants in Fuelly is the amount of distance driven in the city. Users expected the distance driven in the city to be used somehow to display fuel consumption in the city, because it was collected in fuel-ups, but it is nowhere to be found. Because driving style and city consumption parameters are not in Fuelly, users felt some valuable data was missing from the fuellings.

Participants were able to do the tasks very quickly and did not have any major issues with DriveGreener. They commented that the application looks visually very good, modern and simple to use. However, one participant commented that the buttons are difficult to spot initially because the colour is similar to the background. Participants praised the graphs and data presentation of DriveGreener. They found it very clear, understandable and liked the amount and visualisation of the data.

All participants of the interviews said that the usability of the DriveGreener application is the best out of all three applications tested. The application is modern, has the best graphs and data visualisation, with the most data available according to the interviews. Users also found the sporty driving style and fuel consumption in the city useful for saving money, especially how the city consumption was displayed.

5.4 Possible further developments and ideas

Because of the time and size limitations of the thesis, many features were not implemented because it would have been too big of a project. For example, expense tracking is one of the significant features that was left out. The expense tracking would give the user a better view of how much they spend on servicing and other vehicle-related expenses like tax.

One other feature which was left out because of the development size and complexity is the possible tracking of other cars which were set to be public and accessible to other users. This would create a big database of vehicles, which contains real fuel consumption for vehicles with good statistics. This would be a big help to potential car buyers.

There are multiple ways to take this application further. One of these possibilities is automating the fill-up service, for example, collecting using the OBD-II port, which exists on most modern cars. Using the diagnostics port, it is possible to access all of the vehicle's computers to read many types of data, including speed, fuel or energy consumption, fuel tank level etc.

Combining OBD-II vehicle data with GPS data - speed, elevation, and direction would mean very accurate graphs and information that show precisely what to do to save fuel while using a vehicle. In essence, this would mean a device, which is plugged into a vehicle’s computers, has a GPS and is connected to the internet. This device then sends data to a server to do the necessary calculations and display it to the user using the front-end application.

One of the other ideas is to automate the price and filling amount collection method. Currently, the user has to take out their device and insert the data by hand, which takes time and is annoying. There are many ways of doing it; one could be for the service station to forward that data via an API to the DriveGreener application. Another could be by getting it from bank statements and forwarding it to the application. This would make the usage of the application much more straightforward, and combining it with the diagnostic device would make the application completely autonomous without any need for the user to insert data.

6 Conclusions

Because of the rising prices and crisis of living costs, this bachelor's thesis aimed to find a solution to that by informing the user about the costs of their vehicle. The solution was developing a new application, called DriveGreener, which is used to track the fuel consumption of vehicles, analyse and display that data to help the user make more informed decisions about their vehicle and driving.

Before the development of the application, some research was done into vehicle fuel consumption factors. The research showed multiple factors of fuel consumption that can be affected by the driver. The developed DriveGreener application collects data from the user on each fuel-up using a simple form. The form contains parameters like odometer, fuel amount, and price, also parameters found in the research - distance travelled in the city and vehicle weight. The collected data is analysed, and statistics are calculated. The statistics are displayed cleanly and simply for the user to make better-informed decisions.

There are two main competitors to DriveGreener – Spritmonitor and Fuelly. Both of these applications have the main aim of tracking fuel consumption. However, all of them are different in looks and functionality. The developed solution was successful and did well when comparing it to the competition. In testing, the participants chose DriveGreener as the best application out of the competition with the best user experience. Users also noted that the developed solution had the most useful and informative graphs, and the application looked modern.

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Appendix 1: Application testing sheet

Setting Description: Testing occurs in a quiet working space in a separate room. The participants use a provided laptop with the application loaded and logged in.

Introduction: The DriveGreener project aims to create a new fuel consumption tracking application with new, never-seen-before features that are much better to use than the competition. This test aims to see how comparable the created application is to the other solutions available on the market. We will ask you to perform a few tasks on DriveGreener and competitor applications and answer some questions about your experience in using the applications.

Complete the task list in all applications in the following order – DriveGreener, Fuelly and Spritmonitor.

Task list

The account has been logged in previously by the investigator, which has some prefilled data collected previously. User starts on the home screen.

Task 1: Add a new filling to the vehicle named „Skoda Superb Sportline" with the parameters, which were provided separately by the investigator. After the task, answer the following questions.

- How would you rate the rate the experience on a scale from 1 to 10?
- How difficult or easy was it to complete the task?
- Do you feel anything was missing or confusing?

Task 2: While browsing the application, find out, what is the fuel consumption when driving the vehicle in a sporty manner? If not possible, let the investigator know, as all applications might not have that feature.

- Was the data displayed in a useful manner?
- How difficult or easy was it to complete the task?
- Is this data useful to you, if you would try to save money on vehicle expenses?

Task 3: While browsing the application, find out, what is the fuel consumption when driving the vehicle in a city for certain amount. If not possible, let the investigator know, as all applications might not have that feature.

- Was the data displayed in a useful manner?
- How difficult or easy was it to complete the task?
- Is this data useful to you, if you would try to save money on vehicle expenses?
- Do you think this data is accurate? Why?

Finishing questions for each application

- How would you say the application looked like in your opinion? Are there any issues? Explain.
- How was it to use the application? Explain.
- What did you like in the experience? What didn't you like?
- How would you rate the application on scale from 1 to 10?

Interview end questions:

- Which of the tested applications had the most useful graphs and data?
- Which of the tested applications had the best user experience according to you?

Appendix 2: Consent Form

Consent to Act as a Participant in a Research Study

(the consent form is the same for all participants)

Study title: DriveGreener – fuel consumption tracking application.

Principal Investigator: Kaur Vali

Introduction: As a potential user of the DriveGreener application, you are invited to complete validation and testing of the application. The purpose is to compare the application to the market and identify potential improvements for the application.

Content of the study: This study is conducted by a Kaur Vali, bachelor's student from the University of Tartu (Estonia) as part of his Bachelor's Thesis work. The aim of this study is to test the DriveGreener applications usability against competition.

Participation requirements: Person aged 18-60, who is an English speaker and owns a personal vehicle.

The expected duration of the study: The testing will take about 30 minutes of your time.

Risks and Benefits: The risks that are associated with this research are no greater than those ordinarily encountered in daily life. There are no direct benefits to participants but the researchers anticipate potential societal benefits being derived from their research.

Privacy and Confidentiality: The researchers will follow the following procedure to protect participants' identities during this study: The original audio files will remain on the original recording device which is only accessible to the Principal Investigator. The audio files will be transcribed, potential identifiers will be removed or aggregated.

Your data and consent form will be kept separate. Your consent form will be stored securely and will not be disclosed to third parties.

By participating, you understand and agree that the data and information gathered during this study may be used by the University of Tartu for publication purposes. However, any identifiable information will not be mentioned in any such publication or dissemination of the research data and/or results. The University of Tartu requires all research records to be maintained for at least 5 years following the final reporting or publication of a project. Aggregated data will thus be archived by the Principal Investigator for that timespan.

Questions about the Study: If you have any questions, comments, or concerns about the study either before, during, or after participation, please contact Kaur Vali (kaurvali1@gmail.com).

Voluntary Participation: Your participation in this research is voluntary. You may discontinue participation at any time during the research activity. Your decision regarding whether to participate in this study will not result in any loss of benefits to which you are otherwise entitled.

I am age 18 or older. I have read and understand the information above. I want to participate in this research and continue with enrolment in the study ☐ Yes ☐ No

Participant: The above information has been explained to me and all of my current questions have been answered. I understand that I am encouraged to ask questions, voice concerns or complaints about any aspect of this research study during the course of this study, and that such future questions, concerns or complaints will be answered by a qualified individual or by the investigator(s) listed on the first page of this consent document.

Investigator: I certify that I have explained the nature and purpose of this research study to the above-named individual(s), and I have discussed the potential benefits and possible risks of study participation. Any questions the individual(s) have about this study have been answered, and we will always be available to address future questions, concerns or complaints as they arise. I further certify that no research component of this protocol was begun until after this consent form was signed.

Date and place: May 2023, Tartu

Participant___________________________________

Investigator__________________________________

Appendix 3: Licence

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1. grant the University of Tartu a free permit (non-exclusive licence) to reproduce, for the purpose of preservation, including for adding to the DSpace digital archives until the expiry of the term of copyright, my thesis Web application to track fuel usage of cars: DriveGreener, supervised by Mohamad Gharib.

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Kaur Vali
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