A THESIS FOR FULLFILMENT OF A MASTER'S DEGREE IN

Industrial Design Engineering

CONVERSION OF A SIDECAR CONFIGURATION TO AN EV

A case study of the electrification of an IMZ-Ural sidecar motorcycle

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PROJECT
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PREFACE

This project is the culmination of 9 months of research and work. This report would not have been possible without the help and support of the team of Twentantis. In particular I would like to thank Filip Jonker for the unique design challenge and guidance throughout the process of the conversion of the IMZ-Ural. Without the location and resources provided by him, this project would not have been possible. I would also like to thank Yvonne Schmidt and Chris Weghorst. Their expertise has helped tremendously during the project.

I would also like to thank Dr. Ir. Roy G.J. Damgrave for guiding me and providing valuable insight. The feedback has been very helpful and provided the necessary handles to continue.

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2. ABSTRACT

This Master's thesis takes a deep dive into the conversion of a regular sidecar motorcycle into an EV. The introduction of EVs on the roads have led to various changes regarding the infrastructure. As a result, governments are striving to decrease exhaustion gasses. The governmental interest in combination with the strives in battery technology have peaked a great interest in EVs for consumers. However, the upfront costs of a brand new EV are higher than that of a traditional vehicle. The ability to convert a traditional vehicle into an EV is a suitable solution that allows for recycling of vehicles while actively lowering the exhaust pollution.

The report defines a roadmap that can be followed in order to successfully convert a vehicle with an internal combustion engine into an EV. The roadmap represents the conversion process based on the notion that the style of the original vehicle is not only adhered but actively extended throughout the conversion process. As a result, the deliverable of the project is an approach that allows the client to create a functional prototype of a converted EV that can not only be tested and validated but actively presented to a broader audience. The theory is substantiated and accompanied by a direct application with a case study.

The re-introduction of an old-school product of a by-gone era in a sustainable and futureproof fashion is rather unexplored. While there are examples of inspiration from older products, the active electrification of an older vehicle without losing authenticity has not been proven on a product scale. The sidecar motorcycle is selected as the most suitable option for conversion based on weight and space specifications. The IMZ-Ural cT is ultimately selected due to the simplistic and strong frame.

An indication of the factors that are necessary for the conversion based on battery modules, electric motor, electrical components and their respective location are elaborated upon. Research conducted indicates that the majority of the weight that is added during conversion should be located between the front wheel and the sidewheel. This ensures stability and drivability of the vehicle and improves it significantly. The style of the conversion is based on research with regards to design language, brand expression and potential stakeholders. A confident and traditional style in line with the original company is selected for the creation of two prototypes.

Based on the availability and application in the Jaguar I-PACE, the batteries used for the conversion are LG Chem JLR X590 modules. The dimensions of the battery allow for variety in orientation and location for the functional prototype. The Motenergy ME1616 allows for continuous power and is water-cooled, making it a good fit for the requirements regarding top speed and range. Before the creation of a functional prototype, a quick prototype is manufactured in order to determine the location of the components while simultaneously allowing public feedback from potential stakeholders. The quick prototype is demonstrated on The Dutch Innovation Days in Enschede.

The sequential step of the roadmap is the creation of a functional prototype. The functional prototype connects the components that are presented in concept method of an EV. The main construction of the functional prototype is based on the creation of the battery case and the motor mount. All components are added without altering the frame, opening the possibility to convert vehicles without destruction of the original vehicle. The functional prototype can be tested with regards to the specifications regarding range, top speed, electromagnetic compatibility and flaws regarding design language. The functional prototype is ready for RDW examination, the final step for an official launch of a converted sidecar motorcycle. In addition to the construction of the converted sidecar motorcycle, a market strategy is proposed that allows for nostalgia-driven marketing. The functional prototype is accompanied by a branding strategy consisting of a website, logo and social media.

The project provides proof-of-concept of the conversion of a traditional vehicle. Following the roadmap, a desired outcome is constructed that is able to be demonstrated at the Dutch Design Week 2022 in Eindhoven.

3. INTRODUCTION

3.1 GENERAL SCOPE

A shift in the word of Electric Vehicles (EV) is occurring. Over the course of the last 5 years, the amount of registered EVs in the Netherlands have increased significantly with over 215.887 Battery Electric Vehicles in the end of 2021[1]. The Dutch Government has set the goal in which 100% of all new passenger cars sold will be zero emission[2]. Since EV's have the introduction on the market have decreased in purchase cost and the popularity has increased. However, the introduction of electric motorcycles to the consumer market has not yet made a real difference. The electric models that are available are often expensive and have unique parts which are difficult to exchange when necessary. Additionally, various large cities throughout the Netherlands are prohibiting motorcycles from entering the city center due to noise pollution. As a result of the regulations imposed by the Dutch Government, it is no longer possible to ignore the technological advancements that are necessary in order to provide a more affordable market for electric motorcycles.

This Master's thesis takes a deep dive into what is necessary to convert a regular motorcycle into an electric motorcycle that can be legally driven on the roads. It is decided that the frame of the motorcycle cannot be altered significantly in order to allow for a quicker conversion. Additionally, the conversion of existing motorcycles allows for users to maintain a certain style without compromising the authenticity of the original motorcycle in comparison with a brand new motorcycle. The main focus will be on the design integration of the electric components with regards to the design and style. The change in form and appearance of an essential part of a motorcycle to a battery should not result in a loss of character and appearance. The conversion process is a guideline in the context of a company rather than an individual. As a result, the conversion process is meant as an advice of approach of converting sidecar motorcycles on a potential product scale instead of a one-off product. The research will go accompanied by a case study in which the theory will be directly applied to a specific model of a motorcycle, the IMZ-Ural cT. By accompanying the theory with a practical application, the feasibility of such a project can be determined and future recommendations can be identified.

[1] Netherlands Enterprise Agency (RVO.nl). (2021, oktober). Electric Vehicles Statistics in the Netherlands - data up to and including October 2021.
[2] Coalition Agreement 2017-2021, p. 43

3.2 COMPANY BACKGROUND

The Master's Thesis is commissioned by the company Twentlantis (referred to as 'the client'). The company is specialized in the start-up of smaller projects, often centered around the subject of water. The Electric Ural Project is the first project to actively start under the supervision of Filip Jonker, who specializes in the development of electric submersibles. The project encompasses the full electrification of an IMZ-Ural, with the introduction and launch of the product in 2023. The client is based at the Technology Base in Airport Twente. The team is supported by an electrical engineer, who is responsible for the applied electronic technology during the project.

3.3 IMZ-URAL BACKGROUND

IMZ-Ural is the leading company in heavy off-road sidecar motorcycles. After acquiring the design and production techniques for the BMW R71 during World War II, the former Russian-based company has been a developer of heavy duty motorcycles used at the Russian front. Initially, IMZ-Ural was built for military exclusively. The main goal of the sidecar motorcycles was to re-supply the front with equipment and partial mobilization of troop along the front lines. During the 1950's, the company decided to solely focus on the consumer market, breaking all ties with military production. The modern-day company has continued to build heavy off-road sidecar motorcycles that are suitable for rough terrain. The design and production techniques of the products have remain largely the same. Currently, the company is based in Redmond, Washington. As of 2022, all remaining production in Russia has moved to Kazakhstan as a result of the Russian invasion in Ukraine. While a prototype of an electric sidecar has been constructed in cooperation with Zero Motorcycles, the electric sidecar itself has not been finalized as a product.

3.4 REPORT SCOPE

As previously mentioned the client is interested in the launch of an electrified sidecar motorcycle as a finalized product. Since the project is currently in the early stage, a proof of concept has to be developed. This project encompasses the design process, manufacturing and testing of the functional prototype. The development of the final product will be touched upon in the final chapter of the report, however details of the final product fall outside of the scope of this project. The electronic connections and electricity flow is commissioned to an electrical engineer and are therefore not part of the report. The functional prototype will be shown on the Dutch Design Week (DDW) in Eindhoven in the end of October. The DDW will therefore act as the final deadline for the proof of concept.

3.5 APPROACH

This report can be divided into two different parts, a general part regarding the overall electrification of motorcycles and a case study that applies the theory in order to gauge the feasibility of such a project. The approach of this report is to construct a roadmap based on the general findings of the conversion of a traditional vehicle into an EV, with a sidecar motorcycle in mind. This roadmap, which will be reviewed at the end of the report, is validated through the use of the case study of the IMZ-Ural cT. Leading to eventual changes or feedback for similar projects in the future. The general information is presented in a black font that allows for readers interested in the general conversion process of a regular sidecar motorcycle. The case study is presented in a grey font that is directly explained when general information is presented.

4. RESEARCH

The conversion of a fuel-driven vehicle into an EV is a daunting task since the original vehicle is not originally intended for an electric driving experience. In order to get a better understanding and context of what is necessary in order to successfully introduce a converted EV to the market, research is conducted in order maximize the chances of success. This chapter of the report is dedicated to the theoretical approach of introducing converted EV's and sidecar configurations.

4.1 ELECTRIC VEHICLES

As previously mentioned in the introduction, the amount of EV's on the Dutch roads, as well as the European, have increased significantly. This can be explained by the mere fact that the total amount of vehicles on the road has continued to increase over the last decades. As a result, the means of transportation in the European infrastructure has led to a swift and relatively effective system. However, the increase of vehicles is directly connected to air pollution in urban environments. A report conducted by the European Union states that 28% of the total CO_2 (carbon dioxide) emissions can be accounted to the transport sector, in which 70% comes from road transport[3]. The zero-emission aspect of EV's has since been defined as the vocal benefit used to convince potential customers. For example CO_2, NO_x (nitrogen oxides) and SO_2 (sulfur dioxide) are present in exhaust pollution of regular vehicles, which are actively omitted with the use of an EV. However, there are several aspects that contribute to a surge in EV's with regards to competing with traditional vehicles. Another main benefit of EV's is the cost of electricity in comparison to fuel costs of regular combustion engines (Bláquez, Moreno, 2010), which is visualized in figure 1 below.

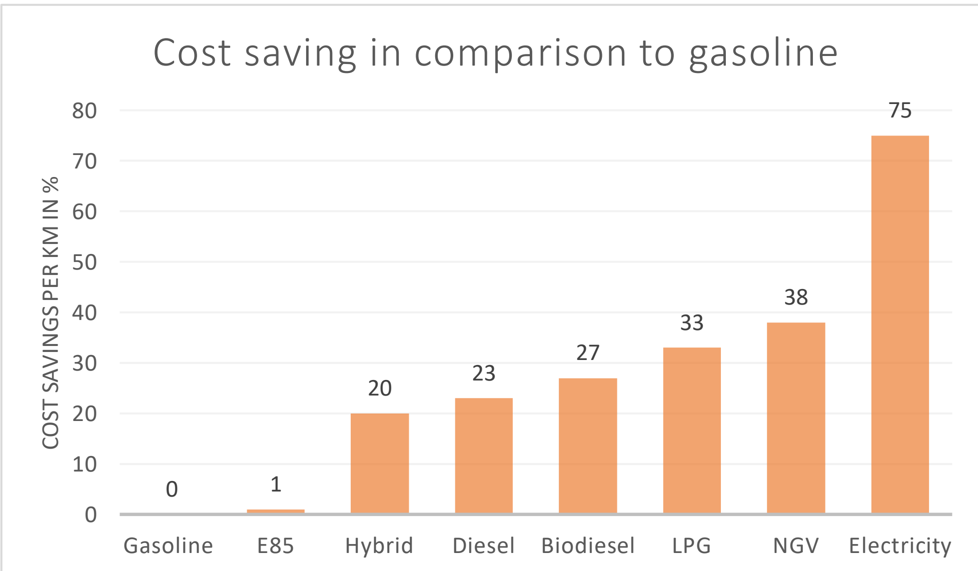

Figure 1: Comparison of cost savings per km with different propulsion systems

[3] European Commission. Transport in Figures'—Statistical Pocketbook. 2011.

While the aforementioned benefits are often the more vocal benefits of driving an EV. But there are some benefits from a more technical point of view as well. For example, the number of engine elements of a combustion engine dwarf the amount of electrical components . For this reason, having less and often more simple elements drastically increase the reliability of the vehicle. Ultimately, the amount of breakdowns or reparations necessary are actively reduced. The simplicity of the electric propulsion systems additionally provides a much cheaper maintenance picture. The more compact electric motor does not incorporate intricate systems such as gearshift or clutch, reducing the amount of vibration in the components themselves. Another technical benefit of current EV's is the efficiency. The efficiency of a traditional vehicle is much lower in comparison to an EV. For example the wheel-to-wheel efficiency of a vehicle driven by gasoline ranges from 11% to 31%, whereas EV's can provide an overall efficiency of up to 70%.

Even though the aforementioned benefits paint a clear and utopian picture of electric vehicles, it is relevant to inspect the challenges that EV technology currently faces. Since the beginning of the implementation of EV's in the current infrastructure, the main challenges can be identified as battery-related. For example, the driving range is dictated by the selected batteries. Since the available space in a vehicle is rather limited, the range of an EV is typically around 200 to 350 kilometers on a full charge. In comparison with 450 to 650 kilometers on a full tank in a regular passenger car, the range is considerably smaller in an EV. Additionally, large batteries are quite expensive when first purchased, increasing the upfront costs of EV's considerably. While the costs are levelled for the customer during its use-cycle due to the lower cost of energy, the higher upfront costs could lead to initial decrease of potential customers. Even though the price of electricity has increased over the past years, the price of fossil fuels has increased simultaneously and will continue to do so due to scarcity. In addition to the upfront expenses, the batteries are bulky and heavy, therefore providing a difference in the ratio between volume and capacity in comparison with a combustion engine. With batteries packs weighing up to 250 kg in an EV, the batteries need to be placed accordingly in order to prevent loss of driving stability due to weight distribution. The batteries therefore take up a sizeable portion of the available vehicle space. Lastly, the charging of batteries are a limiting factor for driving long range. Charging a battery pack to a full charge is estimated to take up 4 to 8 hours depending on the brand and type of battery/vehicle. However, most EVs are charged during parking instead. The process of top up charging is more common than charging the battery when it is completely depleted. Public charging points normally range from 7kW to 22kW, resulting in a range of 50 to 150 km per hour of charging time. The ability to charge an EV at home allows the user always leave home with a full charge, resulting in the need of charging at different locations. Since As of 2022, the amount of "fast charge" possibilities on the Dutch roads have increased significantly over the last few years. For example at the end of 2021 the amount of fast charge stations counted 607 stations with a total of 2500 chargers available (ANWB, 2022). This number has since increased ever since. These fast charges can charge the capacity of a battery pack for 80% in a timespan of around 30 minutes. While this is increasingly faster than charging at a regular station or at home, the waiting time is significantly longer than refueling.

Luckily, the battery-related challenges have proven to decrease overtime since the capacity and specifications of batteries are closely linked with the innovation that occurs in the field. The improved battery technology is relevant for the range, cost, weight and even charging time. As visible in figure 2, the trend of improvement of the battery capacity can be identified (Clean Technica, 2017). The continuous improvement has an almost exponential growth since 2016. This can be accounted to the exponential interest in EV and its infrastructure. As a result, more research and thus innovation has occurred, proving that the battery specifications will certainly increase in the coming decade. Ultimately, the downsides that are previously identified will become less significant, therefore increasing the probability of success and availability of EV's. However, the almost exponential improvement of battery capacity and its technology have a potential downside. Current technology and electric components are prone to be outdated in a short time.

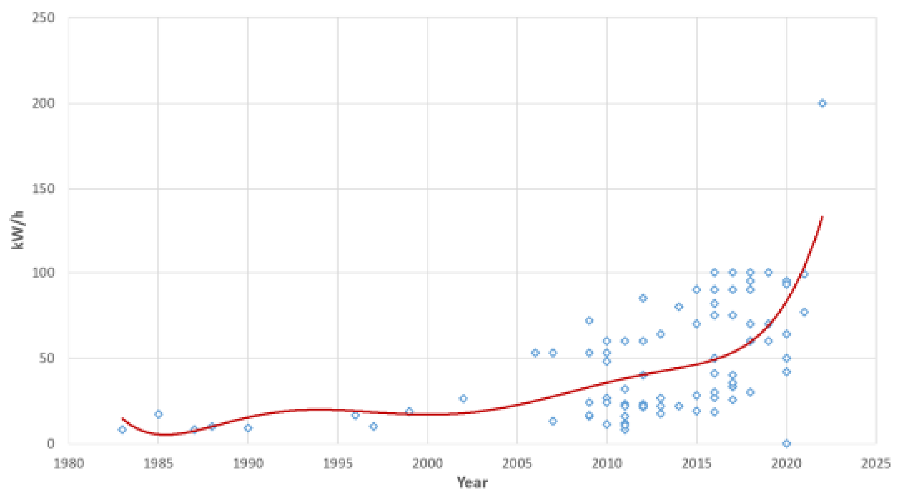

Figure 2: Evolution of battery capacity

Based on these parameters, it can be concluded that the future of EV's is closer than it appears. The benefits of EV's become more apparent to a large audience. The research efforts made in the last years, have made a serious competitor of the EV with regards to traditional vehicles. With governments striving for only EV's to be sold in the future, the trend of improvement is guaranteed. As a result, the improved batteries will lower the cost and increase the driving range, resulting in a vehicle that has no exhaustion gasses without compromising the current specification of a traditional vehicle.

4.2 CONCEPT METHOD

In order to successfully convert an EV, it is necessary to define which parts make up the electric propulsion system that is replacing the combustion engine. The electric propulsion system is made up of various components that each have their own influence on the system. While there are many little components that make up a more complex system, it is possible to reduce the technology to its core components. This chapter discusses the main components of the electric propulsion system necessary for an converted EV and the functions of the identified components.

Figure 3 shows a simplified diagram of the design of a traditional EV. Since most EVs that are driven on the roads are cars, the method of EVs are discussed based on the primary example of a car. The components that are necessary for an EV are the same when compared to a vehicle such as a (sidecar) motorcycle. The components that are identified are the minimum number of components that are necessary for the conversion of a traditional vehicle into an EV.

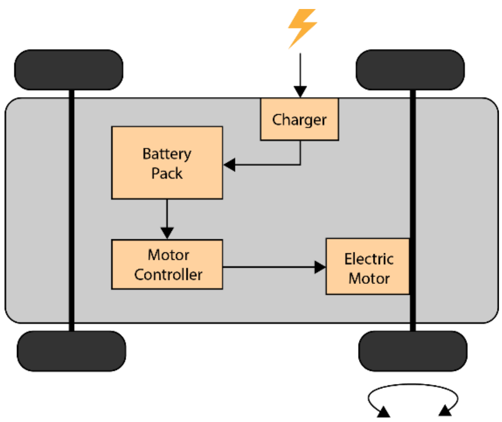

Figure 3: Simplified design of an EV

- Electric motor

The electric motor is the main driving force behind the propulsion system. The electric motor converts electrical energy into mechanical energy, which in its turn can be used to propel and power the vehicle. Every electric motor exists of a stator (stationary part) and a rotor (rotary part). Due to the simplicity of an electric motor, the reliability is one of the main contributors to its success. For example, an internal combustion engine (ICE) has over 2000 moving parts. As a result, the chances of failure within an combustion engine are significantly higher than its electrical successor. Electric motors are available in wide variety of sizes and outputs. For this reason, electric motors can be found in virtually every regular passenger in the form of electric chairs, heating systems, rolling windows, windshield wipers and many more. This multi-purpose applicability of the electric motors makes it an ideally component to convert a vehicle due to the variability of its technical requirements. The smaller electric motors are not significant in comparison to electric motors that are used for a propulsion system, it however, does show the functionality and application possibilities in regular vehicles. The difference and requirements of different electric motors are discussed in the component selection.

- Motor controller

The motor controller functions as the “brain” of the motor. The motor controller determines the governs the output and performance of the electric motor. The motor controller is used to control and determine the speed, start and stop of the motor controller. Possible functions such as regulation/limitation of the torque and selection of the rotational speed and direction allow for effective output control of the motor. The right motor controller prevents overloading of the electric motor.

- Batteries

The power unit of an EV is the batteries. Batteries that are suitable for EV need to have a continuous power in order to allow for a constant performance. For this reason, a high energy capacity is necessary (Hannan, Lipu & Mohamed, 2017). Battery capacity encompasses the amount of energy that can be withdrawn from the battery at a certain time. Capacity is therefore measured in watt hour (Wh). The energy capacity of the batteries is directly tied to the top speed and the range of the EV. A secondary limiting factor of batteries is the energy density. A battery with a higher energy density is able to deliver a higher energy quantity with an equal size or weight. A higher energy density is therefore preferred for EV’s, actively reducing the needed space and weight of the vehicle. As previously mentioned, the batteries are the main challenge for wider EV implementation. Additionally, the rectangular shape of most battery modules, while stackable, will limit the possibilities regarding location placement significantly.

Since the battery pack is the most expensive factor in any EV (Green Car Reports, 2017), careful consideration is necessary when selecting the type of battery. In section 6.2, the difference in the batteries will be discussed in more detail.

- Charging system

Since the batteries are rechargeable, a charging system is required. For widespread implementation of EV’s in the current infrastructure, a fast and reliable way of charging is necessary. Since the current battery technology leads to a more limited range of an average EV, a newly adopted infrastructure for charging is deployed. As a consequence it is possible to charge at home, while simultaneously having the ability to charge at one of the electric charging stations that have been developed over the last decade. Different regions require different kinds of standards when it comes to charging. The standard that is adopted in the region of Europe is the IEC-62196 (International Electrotechnical Commisions, 2014). This international standard issued by the International Electrotechnical Commission establishes the specifications of the charging process, including the energy supply. This standard enables the user to charge the EV in four different modes. These modes are:

- Mode I (slow charge)

  This mode uses a regular power outlet. As a result, this charging mode is often used in a domestic environment. An intensity of 16A is the maximum.

- Mode II (semi-fast charge)

  This mode uses regular power outlets as well. The main difference is the maximum intensity of 32A. This mode is used in domestic environments or public areas.

- Mode III (fast charge)

  This mode requires the use of a specific power supply solely used for EV's. The intensity of a fast charging station ranges from 32 to 250A . This mode is often used at charging stations in public areas or along the highway.

- Mode IV (Ultra fast charge)

  This mode is relatively new. A direct connection of the vehicle to a DC supply network is necessary. As a result, the maximum intensity can be up to 400A. This charging mode can only be found a specific charging stations.

In conclusion, the main components that are presented here are the bare minimum that is necessary for the conversion of a traditional vehicle into an EV. It is recommended that these are the main focus for the client to focus on during the conversion process since the conversion encompasses a proof-of-concept. As soon as the concept is proven and the preliminary results meet the requirements, more complex tasks such as regenerative braking and other challenges can be added to the final product. The main challenge of the proof-of-concept comes from the selection of the right batteries. Batteries encompass the largest initial costs and limit the range, speed and reliability of the EV. However, a trend in improvement of technology regarding batteries capacity has been growing exponentially, allowing for cheaper and more reliable EV's. Since the original vehicle that will be selected for the conversion does not feature any of the components previously mentioned, it is essential that the right components are selected. These components have to be compatible with each other in order to create a functional converted EV. It should be noted that the aforementioned elements encompass the minimum components needed for the electric propulsion system to function. Other components such as the battery management system (BMS) and cooling system are discussed later in the report together with the selection of the components.

4.3 CONVERSION TO EVS

As described in the previous section, the effect of EV integration on the current transport sector is becoming more important in the infrastructure. As a result, it is important to look at further than simply purchasing a newly developed EV. Instead, achieving zero emission through electric motor propulsion systems can be achieved through various incentives as well. While the introduction of EV's is meant to contrast the large quantity of fossil fueled vehicles on the road, there is a difference in approach. An EV is mostly manufactured with the sole intention of being an EV. Newer technology indicates that a new possibility is rising in popularity; converting a fossil fueled vehicle into an electric version (Kaleg, Hapid & Kurnia, 2015). It is important to note that the conversion or electrification of fossil fueled vehicles is not yet widely adapted on a large scale. However, the deliberate choice for electric vehicle conversion is already applied by smaller communities and even government agencies. For example, the Indonesian Institute of Sciences (LIPI) has converted a vehicle into an EV as early as 2009 that is currently operable using the original electric motor propulsion system. Additionally, the Electric Vehicle of America (EVA) has compiled a list of various reasons to further implement electrification of existing vehicles. EV conversion advantages include:

- *Recycling of used vehicle*

  The most apparent and foremost reason to electrify existing vehicles is that no new frames or products need to be developed and manufactured. In contrary, the second-hand vehicle acts as a foundation in which new components are added. Additionally, a dysfunctional motor no longer means a total failure of the product. The wreckage, if suitable, can be used as a framework for new technology. Finally, an advantage in contrast with regular EV's, is that EV conversion actively reduces fossil-fueled vehicles on the road in a 1:1 ratio. A fossil-fueled car is replaced by an EV with limited waste.

- *Minimization of climate impact*

  As previously mentioned, environmental impact of internal combustion engines are a large contributor to climate change due to pollution. Internal combustion engines consume fossil fuel and emit several potentially harmful gases such carbon oxides, hydrocarbons and nitrogen oxides (Tie & Tan, 2013). The previously identified recycling of a used vehicle also impacts the minimization of climate impact significantly. Additionally to resource depletion, the manufacturing process is a large contributor to global warming. Emission is released in for example transport, chemical/thermal processes, demolition and waste processing. For example, steel that is manufactured

- *Elimination of lubricants and antifreeze*

  With the elimination of the engine itself, changing oil and lubricants are no longer necessary. Additionally, the usage of a water cooling system is no longer an obligation. This is dependent on the electronics that are selected during the conversion.

- *Allowing vehicle maintenance independently*

  This advantage is a little more ambiguous. However, it encompasses maintenance on broader scale. For example, exchanging a certain part of a combustion engine can be quite challenging to consumers without expertise due to the high amount of technical components. Exchange of for example batteries is a less complex task in comparison. Additionally, many consumers understand the basic mechanics of a battery (for example an empty battery needs to be recharged by loss of power) thus leading to a more plausible scenarios in which the consumer is enabled to perform vehicle maintenance. In addition to being able to perform less complex tasks as a consumer, the decrease in complex parts makes the vehicle more reliable as well. Less parts means less potential failure, therefore increasing the chances of a functioning vehicle.

Next to the identified factors listed, there is a complication that prevents conversion of vehicles on a larger scale. The converted vehicle needs to be reliant and safe in order to be approved by the RDW before it can drive on the road legally. As a result, there are regulations that the electrified vehicle needs to adhere to. The most important legal requirements are vehicle mass, electromagnetic compatibility, electric safety and protruding parts. Various regulations encompassing the previous requirements can lead to disapproval of the RDW. However, most of the regulations do not actively impact the freedom of design all that significantly. For example, the during conversion, the original internal combustion engine will be removed and replaced for batteries. It is expected, based on existing batteries currently on the market, that the weight will not increase significantly enough for disapproval. Additionally, the frame and bulk of the components of the original vehicle are still present in the final design, all of which have been pre-approved.

Looking at these various identified factors, it can be concluded that there certainly is merit in the electrification of combustion vehicles. As long as the conversion process is according to the regulations of the RDW, the introduction of EV's on the current market often cater towards a more sustainable future. A secondary reason for customers to purchase an EV as previously mentioned, is due to financial reasons. With this in mind, the identified factors such as recycling of current vehicles and minimization of climate impact are in line with the success factors of original EV's. Where traditional EV's are generally better for the environment in the eye of the consumer, converted EV's offer an even more sustainable solution with regards to manufacturing and ground materials. In addition to a familiar appearance for a wide selection of the population, converted EV's have a relatively high potential in the current market.

4.4 CONVERSION ROADMAP

With the selection of the proposed vehicle for conversion and the concept method for an EV in mind, a roadmap is constructed for the creation of 2 prototypes. The roadmap is visualized in figure 4. The stages of the roadmap are indicated in different colors in order to identify the workflow of the approach. The arrows indicate the influence each process and where feedback could lead to changes according to the prototypes.

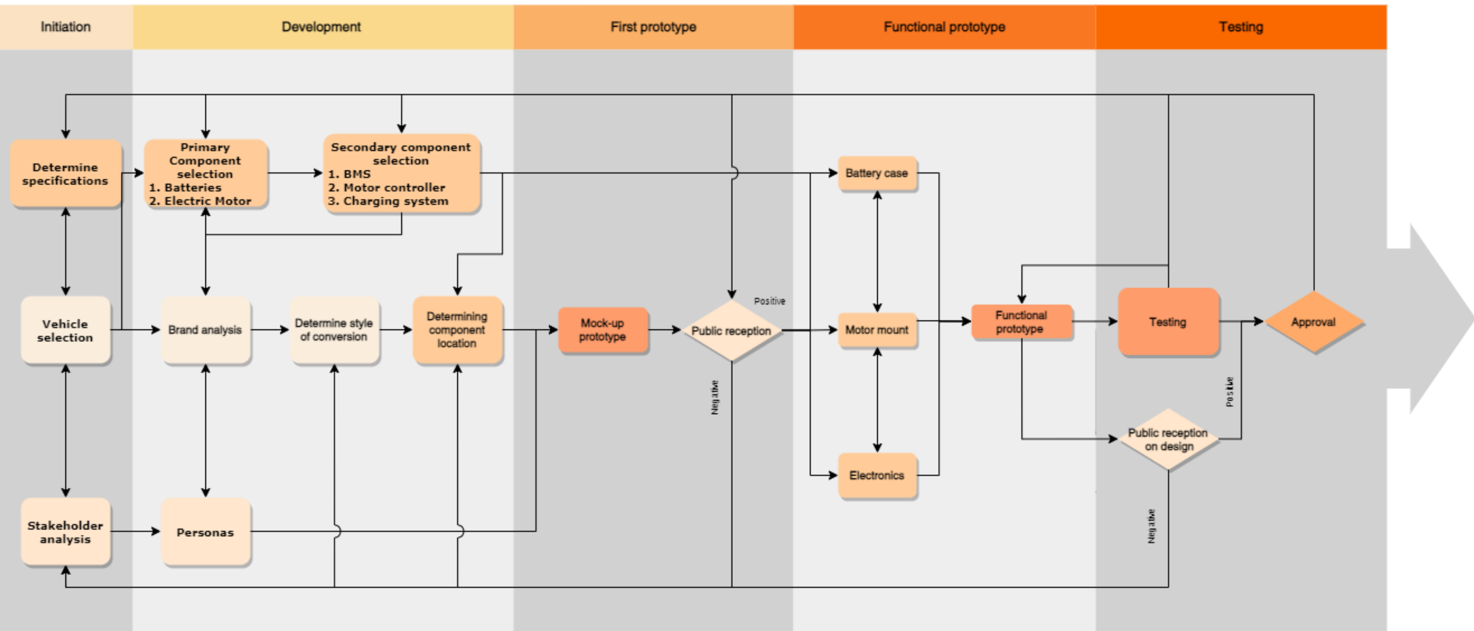

Figure 4: Roadmap design approach

The initiation phase of the roadmap counts as the starting point of the design approach. Each of the segments in this phase are dependent on another and will consequently influence the outcome of this phase. It is therefore recommended that the stakeholder analysis, determination of specifications and vehicle selection are done simultaneously in order to prevent changes later on in the conversion process. The development phase can be considered as the iteration phase of the approach. The segments in this phase are dependent on the outcome of the initiation phase and delve further into the specifics of how the prior phase can be achieved. The outcome of this phase is the foundation of a quick prototype that can be assessed during the third phase of the design approach. If the quick prototype is assessed as sufficient, the functional prototype needs to be developed. Design changes are made based on the feedback of the quick prototype. In this phase the identified technology is the key for conversion of the vehicle. This phase is the longest phase of the project since the technology needs to be connected, design challenges regarding connection points and new elements are created during this phase. It is expected that this phase will require some trial-and-error.

Finally, the functional prototype needs to be tested in order to provide the final proof-of-concept. Is it important that the functional prototype is both functional and stylistically in line with the foundation of the initiation phase of the project.

It should be noted that the proposed roadmap is suitable for a timespan of 9 months. As a result, some concession regarding time management have to be made. As a result, this roadmap focusses on the creation of a proof-of-concept rather than a final product. The reason for this is that the conversion of sidecar motorcycle into an EV has not yet been explored past a one-off project. At the end of the report, the design approach is re-evaluated. A larger version of the roadmap can be found in Appendix A.

In conclusion, the increased relevancy of EVs can be identified and is expected to increase. As a result, it is relevant to look at other adaptations of EV technology. By defining the concept method of an EV and the application of conversion, it can be concluded that there is merit in providing proof-of-concept of converted EVs. The five-staged approach defined in the proposed roadmap with regards of the creation of two prototypes, allows for a more structured design challenge.

5. INITIATION

Starting the project beyond research can be a daunting task. By following the first processes described in the roadmap for the design approach of converting to an EV, the foundation can be constructed. This section elaborates on the initiation phase of the conversion process. The findings are presented in a global way, followed by the application of the case study in grey.

5.1 VEHICLE SELECTION

Picking the right vehicle for the electrification is essential. Since the conversion is bound to be an expensive undertaking, selecting the right vehicle that supports and benefits from the conversion is of utmost importance for the feasibility of the project. Leitman and Brant (2009) argue that the selection of the right vehicle is mainly dependent on two factors; available space and weight. However, these two factors are often in contradiction with each other. A vehicle with more available space is often larger, thus weighing more than smaller vehicles. For this reason, a tradeoff is necessary with regards to vehicle selection. An example of this tradeoff is introduced by Leitman et al. (2009). The conversion of a vehicle would work best with a normal car, due to the reduced weight. However, the available space in a van allows for more batteries, thus increasing the range of the vehicle. In this particular case, the available space is linearly connected to the complexity of space management and time that needs to be invested in order for the conversion to be successful. More available space leads to an easier conversion due to absence of limitation with regards to component selection and location, hence making the process less complex. With a competitive range with regular combustion vehicles in mind, the vehicle needs to be a light as possible, while having as much available space as possible. As a result, a pick-up truck is the most ideal vehicle for the conversion in terms of four-wheeled vehicle. The spacious engine compartment in combination with the large trunk offer many options for conversion with regards to lay-out and configuration. Additionally, the trunk of a pick-up truck is designed to carry a load, therefore the additional weight of the batteries do not compromise the drivability of the vehicle.

The same principles apply for the selection of a motorcycle. In terms of available space, a regular two-wheeled motorcycle is not really suitable for conversion. The space that can be used for the placement of the batteries is mostly where the internal combustion engine used to be. While possible, the conversion for a regular motorcycle will be more complex due to the increase of restrictions with regards to available space. In contrary, the weight is heavily reduced in comparison to a four-wheeled vehicle. Consequently, less batteries are necessary for the same output in terms of range and top speed. An example of a motorcycle with more space is a trike. However, the more space is again a limiting factor due to the weight of the vehicle. For a comparison, the average Harley Davidson trike weighs around 550 kg while a two-wheeled motorcycle averages at 320 kg. A more suitable option for the conversion is therefore a motorcycle that meets the previously introduced tradeoff. A suitable option for electrification is therefore a motorcycle with sidecar configuration. The additional sidecar offers for more available space without compromising the weight too much. Additionally, the sidecar is manufactured in a way that it can bear a significant load, without altering the drivability significantly. A trade-off graph is created that shows the consideration between available motorcycle variants with regards to weight and complexity as visible in figure 5.

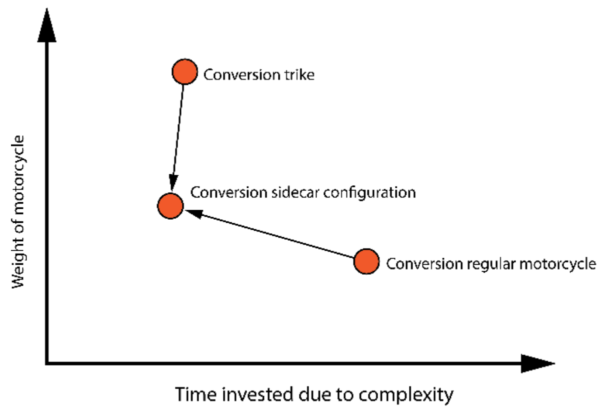

Figure 5: schematic overview of weight distribution and time investment

In addition to weight and available space, it is essential that the frame is suitable for conversion. After selecting a sidecar motorcycle, it is important to fixate on the simplicity and strength of the frame. Having a reliable foundation to base the conversion on is a defining factor for the final product. The quality of the final product is dependent on the foundation of the conversion process. The strength of the frame is not determined by the conversion but rather by the original product. By selecting a reliable product to base the conversion on, the chances of a successful product line beyond a one-off product increase significantly. The reliability allows for a quicker manufacturing process since the client is no longer tasked with the strength issues of the materials beyond the added components. Consequently making the conversion process smoother.

The selected motorcycle with sidecar is the IMZ-Ural cT (depicted in figure 6). An additional reason for this model to be selected is due to the simplicity of the frame. Simplicity in this particular case encompasses the production methods used during manufacturing. Consequently, simpler processes allow for easier alterations during conversion into an EV, since possible reconstruction does not require complex production processes. The most common methods used during the construction of the IMZ-Ural cT are mainly welding, casting and folding. These methods are a remnant of the production processes that were used during WWII. As a result, the models of Ural have not been altered drastically throughout the years. Consequently, the simplicity of this particular model is the lack of complex systems and additional functions. After the elimination of the combustion engine, a solid foundation is left to work with.

Figure 6: IMZ-Ural cT

5.2 DETERMINATION OF SPECIFICATIONS

Before the selection of the components that are used for conversion are determined, it is necessary that the specifications of the converted vehicle are indicated properly. The desired specifications ultimately dictate what components are necessary for a successful conversion. The list of requirements allow for quick validation and alteration during before finalizing the concept. Due to the importance of the requirements it is essential that the requirements are checked after the completion of the functional prototype. This ensures the quality of the requirements and can be altered based on new findings. The list of specifications is therefore more a list of wishes that allow for the converted vehicle to be competitive. The composed list of specifications can be divided into two categories, functional requirements and user requirements. The functional requirements dictate the technical expectations of the final concept, making it safe to use for the consumer. The user requirements are focused on the requirements that have to be performed by the consumer during usage of the product, in order to make the concept comfortable to use. It is important to note that the specifications are classified as wishes or intentions for the converted vehicle. As a result, not meeting the specifications does not directly mean that the converted vehicle has failed to meet the requirements, but rather means that concessions have to be made regarding performance. It is important to strive for an ideal set of specifications when it comes to conversing a vehicle. If the converted vehicle is significantly worse than the original vehicle, the conversion process has little to add to the product.

The desired specifications are mostly based on the clients wishes. The specifications are made during sessions with various specialists in their own field of expertise, all weighing in on the achievability of the specifications. With regards to user requirements it is necessary to take into account that, due to the fact that the project encompasses a conversion, most of the specifications are based on competitiveness with traditional vehicles. One of the main wishes of the client is to make sure that the electrified sidecar is on par with the regular model. Defining certain specifications as a comparison is therefore quite useful in the case of the IMZ-Ural cT.

User specifications

- The user is able to drive the vehicle with a regular license (A1 or A2).
- The available cargo space is competitive (the cargo space is not decreased in comparison to the original vehicle)
- The user is able to see the amount of charge left in the battery before recharge
- The user is protected from electric shocks or malfunctions (safety regulations)

Technical specifications

- The sidecar configuration has a competitive top speed (~90 km/h)
- The sidecar configuration has a competitive range (200+ km on a full charge)
- The sidecar configuration is able to reverse
- The components allow for recharge
- The battery system is inaccessible without the use of tools
- The sidecar configuration is directionally stable
- The sidecar configuration has rollover stability
- The magnetic field does not influence other mechanical components (according to EMC pre-compliance testing)
- No protruding parts of sharp edges are present due to the conversion

These specifications are not necessarily a list of requirements. It is a list of desired specifications that the client wants to achieve by converting the IMZ-Ural cT. The components that will be selected need to strive for the desired specifications.

5.3 STAKEHOLDER ANALYSIS

Prior to determining the selection of components for the conversion of the motorcycle, a clear imagine of the stakeholders involved has to be determined. The inclusion of a secondary company that is responsible for the conversion based on a product that is designed by another company could result in a scattered field of stakeholders. For this reason, research has to be conducted in order to fully integrate a new segment of potential end-users without rejecting the established target group of the original company. It is recommended that the client organizes the stakeholders accordingly, this way the conversion company is able to determine when interaction with stakeholders is necessary. The information that is gathered during the analysis can be used to develop and assess the feasibility of projects, specific decisions and even objectives (Varvasovszky & Brugha, 2000). As a result, strategies can be developed in order to manage important stakeholders and therefore add to the strategies that are previously established by the original manufacturer. The main strategy of a converted product is to create a source that is able to provide products to convert with an alternative source that provide conversion components. It is important that these stakeholders are scalable in order to ensure that the final product is not an one-off. Lastly, the end-user should be identified and a way needs to be determined to approach the end-users in order to widen the target group beyond that of the original company.

The stakeholders of a converted IMZ-Ural are categorized in 4 different segments; each segment represents the interest in the product and plots it against the influence that the stakeholder has on the product. The segment that the stakeholder is plotted is linked to an action for the conversion company. The stakeholder mapping is visualized in figure 7. By creating a visual overview that is coupled with an action, the client is able to determine what action is necessary with regards to the stakeholders of a converted product such as the IMZ-Ural cT. The company IMZ-Ural is responsible for the manufacturing and transportation of the original product. As previously mentioned, original parts can be ordered directly from the company. However, since the company is only responsible for the manufacturing of the original product, the only benefit of the converted product is that the sales increase. However, if the company decides to halt the production of the sidecar motorcycle, the conversion of the model is impossible in the future. Consequently, the influence of the stakeholder on the project is high. As a result, the possible benefit for IMZ-Ural lays within the satisfying the company with additional sales. A stakeholder that needs to be managed more closely is the official retailer/importer. The official retailers/importers act as middle man, making it possible to purchase official components directly in stock without the need of transportation from the factories. By managing the importer accordingly, it is possible to order a brand new frame from IMZ-Ural without an internal combustion engine. The main reason for this is to make sure that the frame is not compromised through extensive usage over the years. This frame is produced and shipped directly from the main factory in Kazakhstan and imported by the official importer of IMZ-Ural in the Netherlands. This would have been impossible for the client without the cooperation of an importer.

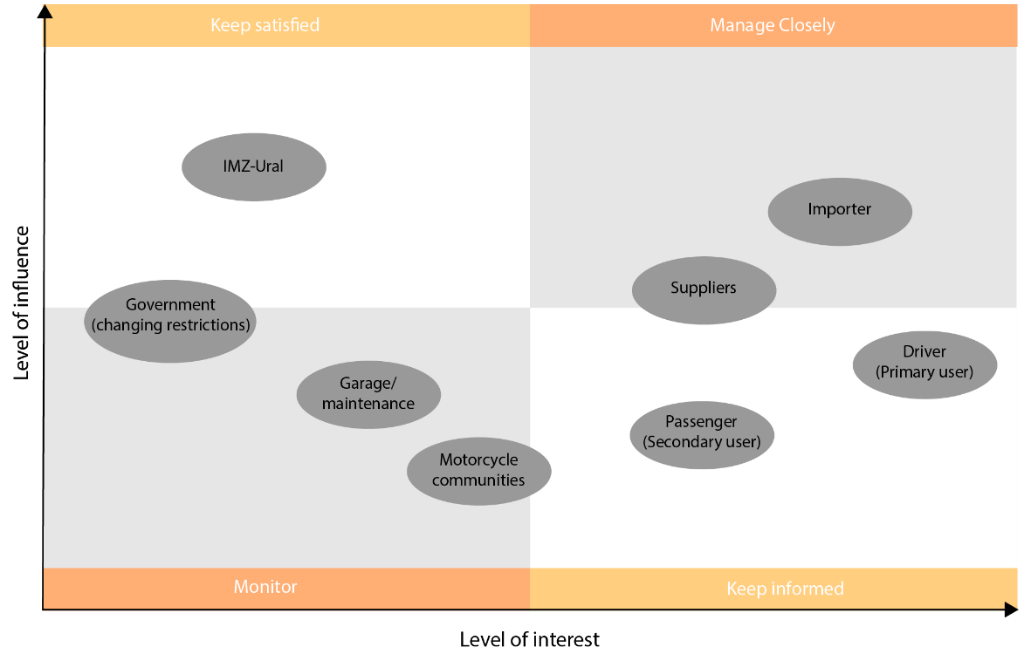

Figure 7: Stakeholder map

The end-user is the stakeholder with the most interest in the converted sidecar motorcycle. Since the user-experience dictates the satisfaction of the consumer, the relation between the stakeholder and the product requires focus. It is important that the end-users are informed of the value of the product and the converted product is able to reach the end-users. Consequently, the user group can be divided into a primary and a secondary user. The primary user is the driver of the vehicle. The responsibility and control of the vehicle is in the hands of the primary user. As a result, the changes that are made with regards to the design and functionality of the motorcycle directly impact the primary user. The secondary user can be identified as the passenger of the vehicle. The passenger is a passive user of the product. While it is important to accommodate the secondary user, the interaction between the secondary user and the product is limited to comfort. The focus on end-users in the project of a converted vehicle is relevant since the product needs to be attractive for both users of regular

5.3.1 Personas

As briefly mentioned in the previous paragraph, the stakeholder with the most interest in the converted product is the end-user. In order to get a complete picture, personas can be created in order to get a better understanding of the end-users of the final product as intended. Valuable information such as motivations and social interactions are identified. Personas are imaginary persons that represent actual user segments (An, 2018). These personas can be identified using two contrasting methods, qualitative and quantitative persona creation. Quantitative Persona Creation is a method in which algorithms are used in order to create representative and up-to-date personas from numerical and textual data (Salminen et al., 2020). This data is often a representation and/or collection of information gathered from actual social media accounts. As a result, the created personas are often quite representative for larger target audiences. Qualitative Persona Creation is an approach in which research is conducted prior to the creation of the personas. The most common research methods for Qualitative Persona Creation are interviews, field studies and usability tests. Since this approach requires more manual labor, it is not as scalable to larger audiences as Quantitative Persona Creation is.

However, since the user segment for the conversion of motorcycles is quite narrow, the need for scaling to large data-sets is redundant. Since the segment of converted motorcycles is rather unexplored, using data gathered from social media is superfluous and will not lead to significant benefit. As a result, Qualitative Persona Creation is recommended as a research method for the creation of personas regarding the conversion of a sidecar motorcycle.

Since the product encompasses a sidecar motorcycle, it can be wrongly assumed that this is the only target group for the electrified sidecar. While the market for a motorcycle with sidecar is rather niche, the electrified sidecar offers a more modern appeal. Therefore opening the possibility to a wider target group, without alienating the original target group of the initial company. As a result, the personas that are created are divided into two extremes. One persona fitting the target group envisioned by IMZ-Ural, while the other persona is proposed as a modern and new target group for the converted motorcycle. This is done on purpose in order to widen the scale of the potential target audience. As a consequence, the scope of the target group is not limited from the start, but rather expanded upon. This could significantly increase the market potential of the converted motorcycle. The personas are depicted in figures 8 and 9. By defining two extremities, similar customers with similar lifestyles that lay within this interval can be considered as a potential customer.

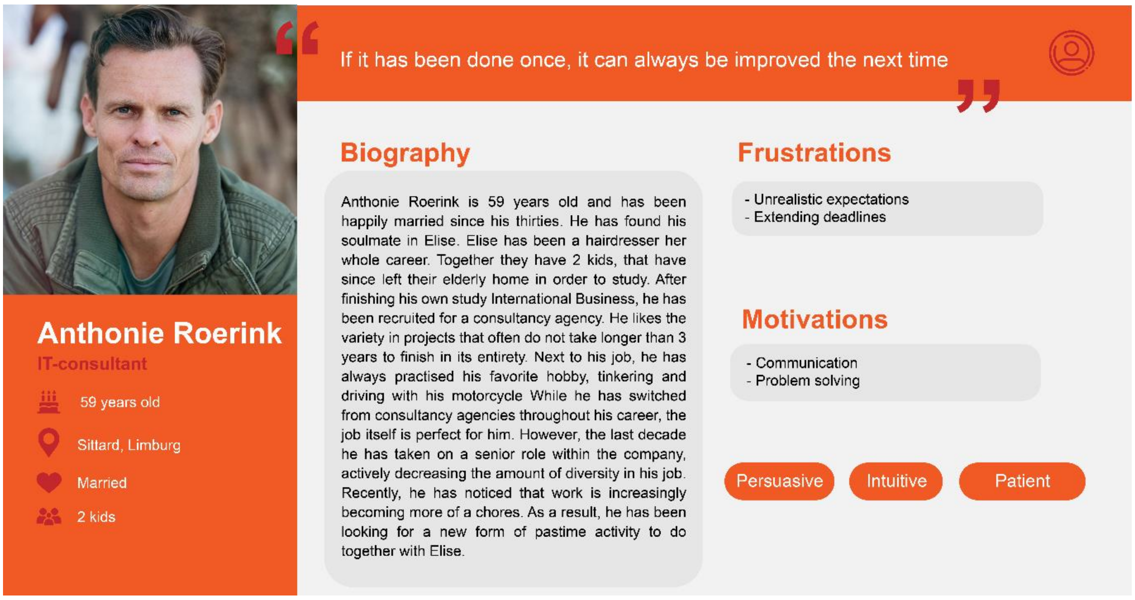

Figure 8: Created persona Anthonie

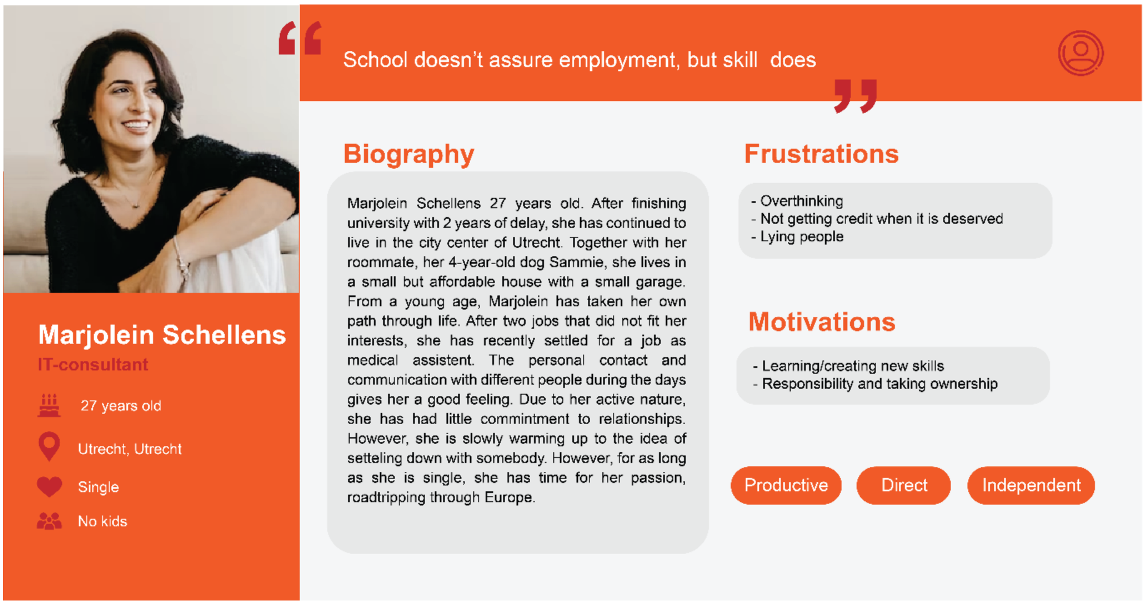

Figure 9: Created persona Marjolein

The most visible contrasts between the encompass age and relationships. Anthonie is has been in relationships his entire life and is currently married. While this is an external circumstance, it can influence behavior and interaction. For example, expenses have to be discussed and purchase will have an influence on the family and their available space, which could ultimately dictate customer behavior. This is an important factor in the market placement of the product. However, the fact that the product is meant to accommodate a passenger, the converted sidecar allows for joint activities such as longer trips or driving to a restaurant. Since Anthonie lives just outside of a larger city, the distances covered are longer. The larger range of the sidecar offers several advantages. In contrary, Marjolein is in the situation in which he is mostly responsible for her own expenses. Additionally, Marjolein is a lot younger, taking away the potential nostalgia to the product of a sidecar. However, the trend of retro products gaining a new audience in the modern era has never been more relevant. A deeper dive into nostalgia driven marketing will be given in section 8.2.2. For a persona such as Marjolein, the electrified sidecar motorcycle offers a different kind experience. Due to the smaller house with garage in the middle of a city center, the sidecar motorcycle offers a quick and new way of transportation. The ability to take a passenger or use the sidecar as baggage space through the city allows for a silent and smaller alternative for a car, while offering a possibility for road tripping during the holidays.

It is also important to note that there are several similarities between the personas. Both personas are looking for something that helps them as a form of transport. The electrified motorcycle offers a silent solution to driving a motorcycle. While the motivation for both personas might be different, the need for both personas is the same. Anthonie benefits from a silent sidecar motorcycle in order to take his wife on the road, allowing for communication during travel, actively improving the joint activity. Marjolein benefits from a silent sidecar motorcycle because the city center does not allow loud vehicles. Additionally, both personas like to be in charge of their own choices, be it in their personal or professional life. A silent sidecar motorcycle that allows for transportation over various terrains therefore accommodates both personas accordingly.

In conclusion, the seemingly contrasting personas are valuable for validation of the potential target group. Conclusions such as the need for a converted sidecar motorcycle can be identified. By accommodating to both these extremes, the functional prototype can be valuable for the interval of the target group that falls in between. The personas are used to further validate the market possibility through the use of a quick prototype.

6. DEVELOPMENT PHASE

The organization of stakeholders and persona creation have identified various motivations for the need of a converted vehicle. The selection of components determines the feasibility of the specifications. For this reason, the key components for a functional prototype are selected and criteria are given that help to determine a suitable selection. Additionally, research regarding stability due to weight distribution is elaborated upon. Since the conversion can be perceived as the upgrade of an older model, the developed approach of conversion is dependent on the initial brand. This chapter focuses on a guideline in which a style that is complementary to the original design can be selected. It should be noted that while this section of the report is written linearly, the mentioned process happen simultaneously. The findings are directly applied to the case study of the IMZ-Ural cT.

6.1 BATTERY SELECTION

As mentioned in the concept method, most of the challenges presented in EV technology arise in the form of battery challenges. For this reason, the selection of the right battery is one of the most important factors for the success of a converted EV. The battery determines most of the weight and use of available space of all the components that are necessary for the conversion. In the current state of EV's, various different batteries are used and there is a lack of standardization when it comes to battery selection. For this reason, there are many different kinds of batteries available on the current market, however not all batteries are suitable for EV's. Currently, the most applied types of batteries are lithium-ion batteries, nickel-metal hydride batteries and lead-acid batteries (Nykvist,& Nilsson, 2015). The batteries are compared with regards to energy density, costs and efficiency in mind. Other characteristics such as cycle time and specific power might attribute to a specific choice but are not considered to influence of choice in a significant way.

Lead-acid batteries

Lead-acid batteries were the first form of rechargeable batteries, first designed in 1860. Energy is stored in the batteries as chemical energy, which can be turned into electrical energy following chemical reactions in the lead plates. Ever since the invention of the lead-acid batteries, it is still the most commonly used type of battery with rechargeable properties. Lead-acid batteries are widely applied in traditional vehicles, but can also be found in various EV's such as the Toyota RAV4 EV. These batteries are commonly known for their high reliability and low cost. The specific power (the power output divided by its mass) is relatively high for lead-acid batteries. However, lead-acid batteries have a low energy density, consequently a large mass and volume of lead-acid batteries is necessary for sufficient energy. As a result, EV's that are equipped with this type of battery regularly have a smaller range on a full charge.

Nickel-metal Hydride batteries

Nickel-metal hydride batteries are a battery stemming from the 90's. Different kinds of metal can be used as negative electrode such as iron, cadmium or zinc. These batteries have a higher energy density, than lead-acid batteries, actively improving the range and space efficiency (Haschaka & Schlieck, 1986). Additionally, due to an doubled specific energy the choice for batteries in EV's since the 90's has been nickel-metal hydride over lead-acid batteries. Heavy machinery is often still driven by electric energy powered by nickel-metal hydride batteries. An example of EV's that use nickel-metal hydride batteries is the Toyota Prius. Nickel-metal hydride batteries require quite a high working temperature.

Lithium-ion batteries

Lithium-ion batteries are the most commercialized type of battery currently used in the automotive industry. Due to high energy density, long life cycle and high efficiency, the lithium-ion battery is widely adopted as a preferable choice when it comes to EV's. The batteries use lithium ions that move through an electrolyte from the negative electrode to the positive electrode. Due to the fact that this is a reversible reaction, the batteries can be easily recharged. Due to the high stability in both the thermal and chemical process, the lithium-ion batteries are very reliable for a longer period of time, thus expanding the lifecycle of the battery. For this reason, the batteries can be found in many current EV's such as the Tesla models, BMW i4 and the Nisan Leaf. An additional benefit is the low cost due to the high availability.

When it comes to selecting the right battery type fit for conversion of a traditional vehicle, there are multiple characteristics that can be of importance. For example, characteristics such as energy density, power output, life expectancy, working temperature and cost need to be considered during the selection stage of the conversion (Affanni et al., 2005). In order to get a more definitive overview over the different characteristics that can influence the battery choice for the conversion, the characteristics are provided in figure X. It should be noted that this information is from 2019 and further development regarding capacity and cost have been done, significantly decreasing the prices for effective batteries. In terms of compatibility with EV technology, the lead-acid battery is the least fitting solution. Since the technology has been around for a long time, it is a matured technology. As a result, the reliability is quite high. However, in comparison with nickel-metal hydride batteries, lead-acid batteries have around half the specific energy output and a far smaller energy density. As a result, lead-acid batteries can be perceived as too bulky while simultaneously having less specific energy. For conversion without frame alteration this is a large disadvantage, since the space is dictated by the selected design.

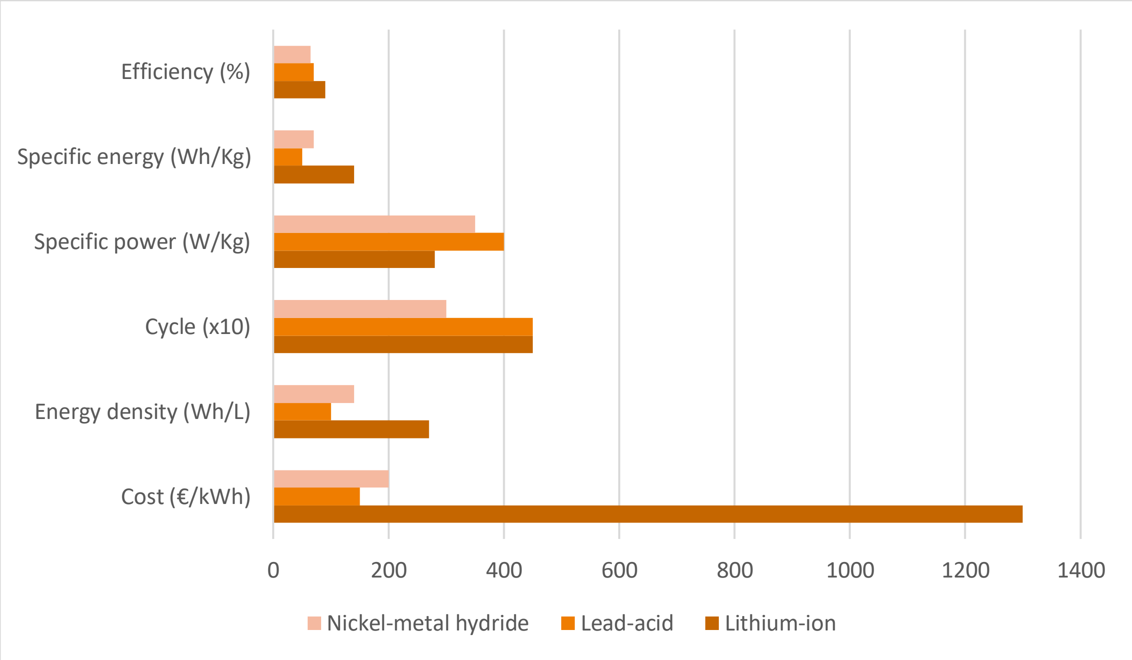

Figure 10: Schematic overview of different battery types

In order to make the most suitable decision regarding the type of battery, it is essential to determine which characteristics are the most important for the conversion itself. As previously discussed, one of the most important characteristics is the energy density. The energy density determines the size of the battery for the largest portion. Since the conversion is of a traditional vehicle, the available space has not been determined with batteries in mind, but rather with a combustion engine. As a result, the available space is not optimized for EV technology. A denser and smaller battery type is therefore of utmost importance, since the limited available space will determine the output, such as speed and range, of the converted vehicle. As visible in figure 10, the energy density is by far the highest in lithium-ion batteries. Additionally, the lithium-ion batteries are the most efficient when compared to the other batteries. The biggest downside is the price, which is much higher than the other types of batteries. However, as previously explained, due to an increase in research and interest in EV technology, the price of lithium-ion batteries has decreased significantly over the past years and is expected to decrease even more in the near future.

It can be concluded, based on these characteristics, that the lithium-ion batteries are the most suitable for the conversion of a traditional vehicle such as a motorcycle with sidecar configuration. It is therefore recommended that this battery type is selected.

In the case of the conversion of the IMZ-Ural cT, the recommendation of the usage of lithium-ion batteries is therefore taken into account. For the conversion itself there are two possibilities that are considered. The first possibility is making a battery module from scratch using cells. The main advantage of developing a new battery module is that there is more flexibility in space management. Since the cells itself are smaller, it is possible to make battery modules in a shape that fits perfectly with the original frame. As a result, it is possible to have more energy output packed in a smaller space. Additionally, it is no longer necessary to stack the cells in a rectangular shape, as is done in most regular battery modules. A large disadvantage of this process is that the newly developed battery module needs thorough testing in order to be legally driven on the road. Additionally, it is more expensive due to the time and effort needed to optimally develop a new battery module.

The second possibility is using an existing battery module that is used in other vehicles. A large advantage is that these battery modules are already road legal. Since the battery modules can be found in vehicles that are present in the current infrastructure, it can be assumed that they have been approved by the RDW. These modules are optimized and have withstood the testing that is done by the government. The disadvantage of existing battery modules is that the shape of these modules are predetermined based on the form that is necessary for the original intended usage. However, most of the module shapes that can be purchased are quite compact and have an rectangular shape that is stackable.

There are two different batteries that fall within the specifications that are desired by the client. The battery modules are lithium-ion and reliable enough to meet the technical specifications such as the top speed and range. The most suitable modules are the EVE LF280K module and the LG Chem JLR X590. Both battery modules are widely applied in the field of electric technology. The EVE LF280K modules are smaller but therefore more modules are necessary for a larger capacity than the LG Chem JLR X590. The capacity of the EVE LF280K is 0.9 kWh compared to the 2.6 kWh of the LG Chem JLR X590. As a result, for every LG Chem module, around 3 EVE modules are necessary for the same output. However, the smaller modules allow for more configurations with regards to placement. While this is an initial benefit, it means that more connections between the modules are necessary, actively complicating the electrical system.

Based on these specifications, the LG chem JLR X590 module (figure 11) is selected by the client. This module is currently used as a battery pack for the Jaguar I-pace. The LG chem is a lithium-ion battery, with a total of 12 cells within the module. The battery is selected based on the previously described features of shape, weight and wide availability.

Figure 11: LG Chem JLR X590

Capacity:	2.6kWh
Voltage:	11V
Length:	357mm
Width:	151mm
Height:	110mm
Mass:	12kg

The LG Chem modules are widely available and have been tested thoroughly since the modules can be found in cars that are currently sold and driven all over the world. The battery is quite compact and is easily connected to multiple modules. Since a single battery will not nearly have enough capacity to successfully power the IMZ-Ural cT. The traditional IMZ-Ural cT has an estimated top speed of 120 km/h, it is therefore necessary that the newly converted vehicle will have a similar top speed in order to be competitive with the traditional vehicle. A larger number of modules results in a higher top speed. However, the weight of the battery pack will increase with 12 kg with each added battery. Consequently, more space needs to be available to house the batteries. Therefore it is essential that the lowest amount of batteries necessary to satisfy a competitive top speed is preferred.

number of batteries	Vmin	Vnor	Vmax
1	8,4	10,8	12,6
2	16,8	21,6	25,2
3	25,2	32,4	37,8
4	33,6	43,2	50,4
5	42,0	54,0	63,0
6	50,4	64,8	75,6
7	58,8	75,6	88,2
8	67,2	86,4	100,8
9	75,6	97,2	113,4
10	84,0	108,0	126,0

Figure 12: Influence of number of batteries on the top speed

As visible in figure 12, a total of 10 battery modules result in an optimum speed of 108 km/h. The maximum speed is estimated to be around 108 km/h based on the power of the battery in comparison to weight. 10 battery modules is therefore the first possible amount of battery modules needed for a competitive top speed. It is determined that 10 battery modules is the necessary amount for a successful conversion using the LG Chem modules. By increasing the amount of the battery modules even further the increase in top speed is no longer relevant, the increased speed would be arbitrary since sidecar motorcycles at higher speeds are becoming increasingly more undrivable. The total capacity of the 10 LG Chem modules is 25 kW with a total weight of roughly 120 kg.

In the future, when the proof of concept is developed, it can be valuable to take a closer look at creating new modules. This way, the specifications of the converted vehicle can be even more optimized and a more refined shape can be achieved in the near future. However, for a proof-of-concept these battery modules offer adequate specifications.

6.2 COMPONENT SELECTION

With the right batteries selected, most of the available space and weight has been determined. It is now of utmost importance to select the remaining components that are compatible with the batteries. These components together partially determine the success of the converted vehicle. However, there is a partial correspondence between the battery and the other components. These factors influence each other and are dependent. It is recommended that the component selection and battery selection are done during the same time interval. However, the batteries are the main challenge during the conversion process due to the weight distribution and the large volume. As a result, the component selection is largely dictated by the batteries and influence of the component selection is limited on the selection of the batteries. It should be noted that for the conversion of the IMZ-Ural cT, the definitive choice of the components are made by the client. This sections functions as a guideline of what components are selected by the client.

6.2.1 Electric motor

The electric motor itself, is the center of the propulsion system. The mechanical energy that is generated is needed to power the converted EV. The selection of the type of electric motor therefore needs careful consideration. The most important requirements for selecting a motor encompass torque, high power output, ease of control and efficiency (Lee & Nam, 2016). There is a large variety of electric motors on the market and not all meet the aforementioned requirements. The three most considered types of electric motors for EV technology are: induction motors (IM), permanent magnet motors (PM) and switched reluctance motors (SRM).

The selected motor for the IMZ-Ural cT conversion is the Motenergy ME1616 (figure 13) permanent magnet synchronous motor (PMSM). The ME1616 is water-cooled, providing a higher output power than other motors without cooling. The ME1616 is selected based on the requirements. The high rotor speed allows for a high top speed of the vehicle. Because the driving axis is reversible, a direct connection with the cardan shaft results in the ability to reverse. Additionally, the ME1616 widely used for heavy duty application due to the protective outer shell and continuous current.

Power:	20 kW Continuous, 55 kW Peak
Max. rotor speed:	6000 RPM
Voltage:	24-96 VDC
Current:	250 Amps AC continuous
Peak current:	550 Amps
Weight:	24.3 kg
Cooling:	Water-cooled

Figure 13: ME1616 PMSM brushless motor

The motor is encapsulated in a IP67 case that can be mounted via the four attachment points that are located near the driveshaft. The easy attachment method in combination with the high efficiency of 92%, make it a suitable option for the conversion of the IMZ-Ural cT. Additionally, the position of the driving shaft of the ME1616 eliminates the need of raising the motor within the frame. The only alteration that needs to be done with regards to positioning is a slight tilt in order to connect to the drive shaft of the IMZ-Ural cT.

6.2.2 Motor controller

As previously described, the motor controller functions as the brain of the electric motor. The selection of the motor controller can only be done after the selection of the electric motor. In order to select the right motor controller, the first consideration is to take into account the nominal voltage of the electric motor. The range of voltage needs to be in line with the nominal voltage of the electric motor. Additional factors that need to be taken into account for selecting a motor controller are the continuous current that the controller needs to supply and the control method.

The motor controller selected for the conversion of the IMZ-Ural cT is the DMC SuperSigma 2 PMS 92T2 (figure 14). The SuperSigma 2 is developed specially to control PMSM and IPM motors. The nominal voltage ranges from 24V up to 120V. This makes the SuperSigma 2 an ideal motor controller for the ME1616 since they are compatible. The choice of the motor controller is made because of the improved ability to tune the motor controller with the electric motor. Even when the motor is already installed, the controller allows for tuning.

Nominal voltage:	24V – 120V
Nominal power:	up to 30kW
Peak power:	60kW
Dimensions:	200x200x72mm

Figure 14: DMC SuperSigma 2

6.2.3 Battery Management System

An often overlooked component that is necessary for the conversion of a vehicle is the Battery Management System (BMS). A BMS is the controller that autonomously executes the functions regarding battery management in a rechargeable battery. The BMS monitors the battery and provides protection from operating outside of the safe operating area. By monitoring the rechargeable battery closely, the performance is continually optimized and balanced. Additionally, the battery's operational state is constantly estimated and the data can be externally communicated to other devices.

The selected BMS fort he conversion of the IMZ-Ural cT is the Emus CU021C (figure 15). The Emus CU021C is specifically intended to be used with lithium-based battery cells such as Li-ion, LiPO or LiFePO4 batteries. Due to the selected Li-ion LG Chem modules, the Emus BMS is a good fit fort he conversion. An important reason why the Emus CU021C is selected is that an USB data interface makes it possible to connect to an host device for example for configuration or maintenance is required. The advantage of the easy connectivity with an host device that the BMS can be tweaked accordingly, resulting in more control over the selected batteries.

Storage temp.:	-40°C to +95°C
Operating temp.:	–40°C to +80°C
Supply Voltage:	9V – 32V
Dimensions:	97.4x30x54.5 mm

Figure 15: Emus CU021C

It should be noted that the selection of components is done by the client. Some of the components were considered based on intuition and experience with certain components. Due to the strict timespan given for the creation of the functional prototype (9 months), it is relevant to consider the familiarity of components as well. All the components are readily available and have been applied across various industrial fields. By selecting a component that does not require new intelligence for the application, time can be saved. It is recommended that for similar projects regarding conversion of traditional vehicles, the selection of components is delved into deeper with regards of the effect on lifecycle and how these components influence each other. For the functional prototype however, these components are selected based on compatibility and availability and suffice the specifications that have been set.

6.3 STABILITY & WEIGHT DISTRIBUTION OF A SIDECAR CONFIGURATION

Due to the lack of symmetry in the configuration of a motorcycle with sidecar, the directional and lateral stability is affected heavily. The weight distribution of the components is therefore a large contributor to the overall stability of the final motorcycle. Since the components will most likely be situated on a different location than previously, battery configurations require more space, it is necessary to determine the impact of weight distribution on the stability. Directional stability is stability of a moving body or vehicle about an axis which is perpendicular to its direction of motion. Vehicles that are directionally stable have the tendency to return to the original orientation even when an opposite, rotational disturbance occurs. While driving, this is translates as a “push” to its original direction, thus resulting in the tendency to keep the vehicle oriented in the original direction. A thorough analysis of directional stability of a sidecar outfit negotiating a turn has been conducted by Dimitri Lurie.

In the particular case of a sidecar motorcycle configuration, the weight is applied to three different locations rather than two. The wheels are the only point of contact with the road. As a result, for the motorcycle with sidecar the weight is distributed as followed:

$$W = W_{front} + W_{back} + W_{side}$$

Since the coordinates of the wheels are in a fixed position, the center of gravity is dependent on the distribution of the total weight in relation to the wheels with two independent parameters. The lateral forces as depicted in figure 16, are linked with the slip angles and the stiffness as followed:

$$F_{fy} = C_f \alpha_f, \quad F_{ry} = C_r \alpha_r, \quad F_{sy} = C_s \alpha_s,$$

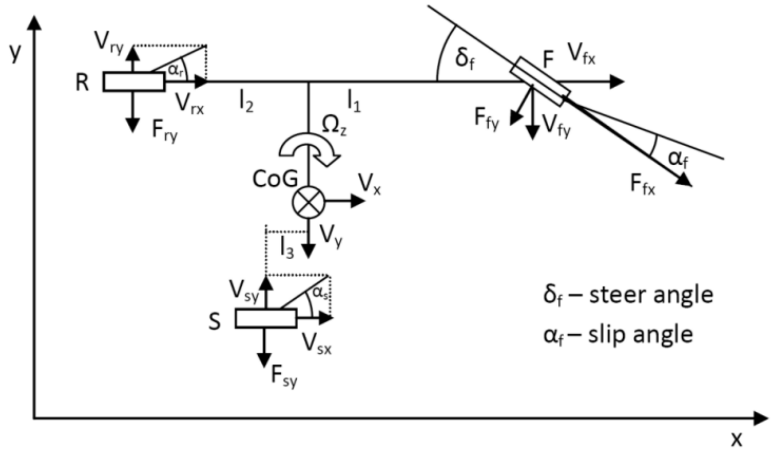

Figure 16: Schematic representation of the sidecar configuration

According to the analysis conducted by Dimitri Lurie (2012), the mass distribution does not significantly alter the overall directional stability in a significant manner. As a result, the sidecar configuration while negotiating a turn is directionally stable as long as the opposite disturbance is not too radical and/or uncontrolled. In order to show the weight distribution more clearly, a second graphical representation is introduced. In figure 17, the total triangle of the wheel location (123), is divided into three separate triangles (102, 203, 103) using the center of gravity (O). It can be assumed that each of the newly divided triangles is proportional to the weights W_{front}, W_{back} *and* W_{side}.

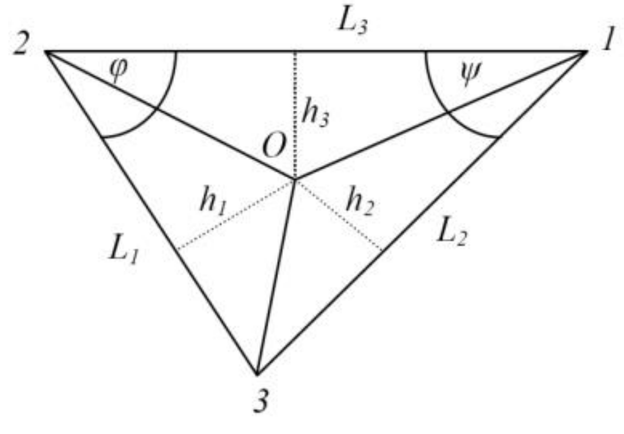

Figure 17: Schematic representation of the center of gravity of the sidecar configuration

As a result, it can be derived that directional stability occurs if the following formula is satisfied.

$$W_{front}L_3 + W_{side}L_1 \cos\varphi\,(C_f + C_r + C_s) \geq W(C_f L_3 + C_s L_1 \cos\varphi$$

From this formula, it can be concluded that a sufficient load on the front and side wheels are necessary in order to guarantee directional stability while driving at any velocity. Additional load on the back wheel does not significantly alter the directional stability of the sidecar configuration. It can be concluded that a sidecar motorcycle with more weight placed between the front and sidewheel has a better directional stability and therefore is easier to drive in straight lines.

Another prominent reason for weight distribution is rollover instability. Rollover instability is a result of a sharp lateral acceleration causing the vehicle to roll over its center of gravity (Li & Bei, 2019). This acceleration is often caused by environmental factors such as wind or terrain. In the case of a sidecar configuration, accelerating or breaking during negotiation of a turn can cause rollover instability. Looking at figure 20, most rollover accidents happen on the 1-2 or the 1-3 axis.

For a functional converted sidecar configuration it is of utmost importance that the rollover instability is minimized in order to increase the safety of the vehicle. Therefore, it is essential to look at the possible factors that could lead to rollover instability. When a force or acceleration (a) is applied perpendicularly to the 1-2 axis, rollover is impossible if:

$$a \leq \frac{g}{H} min\left(\frac{h_1}{\cos \varphi}, \frac{h_2}{\cos \psi}\right)$$

A large contributor to a potential rollover to occur is the height of the center of gravity (H). The effect of H on the formula implies that lowering the center of gravity results in more stability.

The results that are presented regarding the stability determine a clear recommendation for the location of the battery case within the conversion of the IMZ-Ural cT. As previously mentioned, the amount of necessary LG Chem battery modules is estimated at ten modules. The resulting weight that needs to be added to the sidecar motorcycle is estimated around 120 kg. Adding 120 kg to a location on the sidecar motorcycle will have a direct influence on the stability and drivability of the vehicle. It is proven that the directional stability is directly linked to the weight that is located between the front wheel and the side wheel. In combination with the increase of rollover stability by lowering the center of gravity, the perfect location for the majority of the weight is directly below the sidecar. It is decided that the location of the largest contributor to the weight (in this case the battery modules) will be located directly below the sidecar. The orientation of the battery modules is determined during the construction of the quick prototype.

6.4 BRAND STRATEGY OF THE ORIGINAL MOTORCYCLE

The conversion of a specific motorcycle offers some specific challenges that need to be addressed. Since a regular motorcycle is originally designed with a combustion engine as the main functional component, the exterior is adapted to this shape. Additionally, the design language of the specific brand is one of the main reasons for consumers to buy a certain brand (Blijlevens, Creusen & Schoormans, 2009). Consequently, the challenge that arises from a graphic design point-of-view is that the electrical components that are selected, are not manufactured with the intent of the specific brand of motorcycle. As a result, the brand equity of the brand itself can decrease based on the mismatch of the integration of newer technology that is not in line with the expectations of the company. Brand equity is defined as a set of assets such as name awareness, loyal customers, perceived quality, and associations that are linked to the brand (Aaker, 1991). These assets increase the value of the products. Therefore, the implementation of the new technology, in line with the values of the brand, is an important factor in the feasibility of a converted motorcycle. In order to increase the feasibility of the conversion, it is recommended to analyze the brand before selecting the technical components.

6.4.1 Archetypes

The first step is to determine what a company stands for. In 1954, Jung argued that humans use symbolism in a way to simplify and understand complex concepts. This symbolism stems from a universal view on character traits that are recognizable and interpretable more easily. In the particular case of brands, these character traits are projected on the consumer audience in order to identify potential customers. Jung identified these traits as archetypes. Since archetypes allow for a company to align their customer base with their portfolio, it is essential that the company is aware of the archetype. In the particular case of a secondary company that is responsible for the conversion, a deeper understanding of the motorcycle that is converted is required. As a result, the identity, and therefore archetype, of the conversion company is secondary to the design choices but highly influences the outcome of the project. Since conversion can alter the overall feel of the motorcycle, it is relevant to determine what expression is desired with the final product. It is recommended that the approach of finding the archetype of the original company is a first step in the overall design of the conversed product in order to maintain the spirit of the converted vehicle. A difference in archetype can lead to a different directions with regards to design intent. For example an archetype such as *Artist* has a different intent behind its design than an *Outlaw* since the latter is more concerned about leaving an impression rather than the innovative nature of an *Artist*. A more applied example can be given by looking at brands such as Yamaha and Harley Davidson. While both brands produce motorcycles, there is a clear difference in the way that the companies present themselves to the customers. Having a defined direction for the design language is therefore essential as a standardized foundation for the conversion of different brands of motorcycles.

Figure 18: Overview of Jung's archetypes

In the case of IMZ-Ural, the archetype of the initial company is quite well-defined; *The Explorer*. The personality traits revolving around the explorer are perceived as adventurous, unique and though (Bechter, Farinelli, Daniel & Frey 2016). As a result, this translates to a rugged brand personality. The explorer archetype finds inspiration in risk, travel and new experiences. As previously mentioned, this archetype aligns with the potential customer base. As visible in figure 18, the Explorer archetypes is encompassed by the quadrant Espiritual Journey. In essence, this means that the explorer archetype focusses more on experience rather than appearance. The acquisition of an Ural Motorcycle will result in the ability to explore the world around the consumer. The product, the motorcycle with sidecar, acts as a tool for the consumer to feel freedom on their own terms. This is an important aspect that may not be lost during the conversion of the motorcycle.

Quick and accurate examination of the archetype can be determined by looking at the website of the company and how it positions itself on social media. Bechter et al. argue that the personality traits of the archetype can be found in the customer base, consequently the marketing is almost always catered in a similar fashion in order to attract new consumers with similar interests.

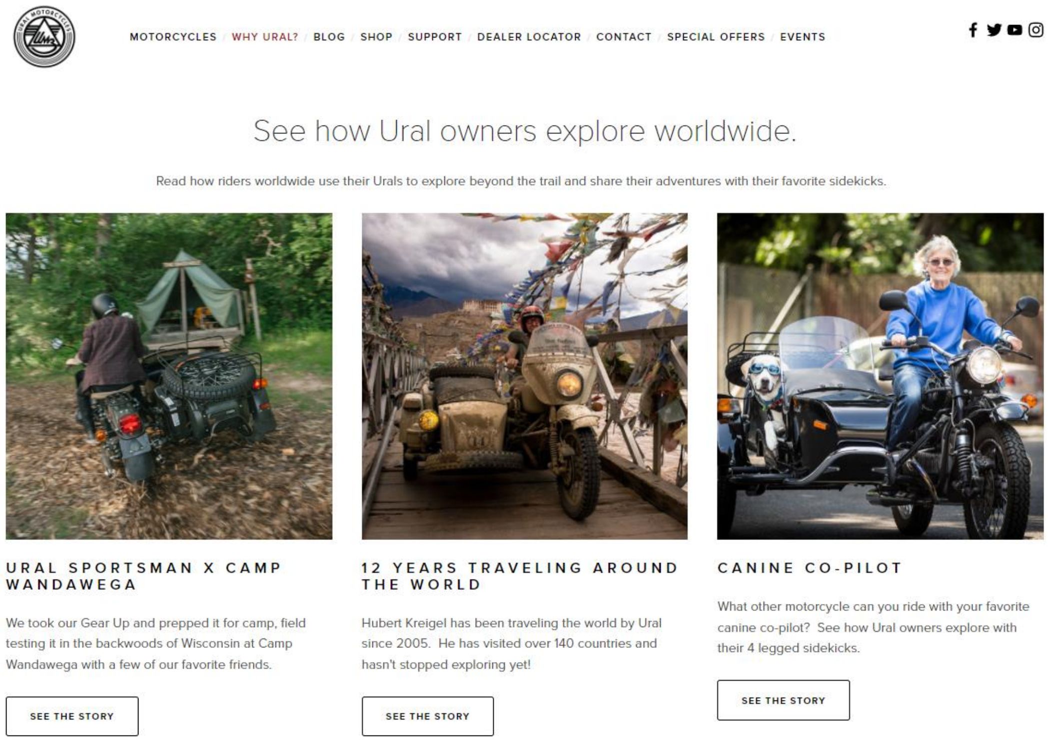

Figure 19: Snapshot of the website of IMZ-Ural

A quick glance at the website of IMZ-Ural confirms the archetype of the company instantly. The website offers various stories from customers that are often related to the exploration of the rugged terrains and foreign countries. In figure 19, the company intentionally uses the word "explore" in the first sentence of the website. It can therefore be concluded that the company has a strong relation between the archetype of IMZ-Ural and the personality traits of its customer base.

However, the introduction of a conversion company makes the case more complex. Since the electrical components that are necessary for the conversion are not manufactured nor designed by IMZ-Ural itself, it is possible that some of the initial intentions are lost in translation. On the contrary, this is also where possibilities arise.

6.4.2 Vision

The vision is the core ideology of a company. The core purpose of the company remains fixed while the business strategies and practices adapt to the evolving world in order to stay relevant (Collins & Porras, 1996). The core ideology encompasses the enduring character of a company. This ideology consists of an identity that transcends the lifetime of the products and even technological advancements throughout the years. For this reason, the definition is of utmost importance even prior to the designing stages of production. As a secondary company responsible for the conversion, it is important to adhere to the original vision to a certain extent. Straying away from the core ideology of the original company could lead to exclusion of the potential target group. On the contrary, it allows for a possibility to add or even amplify the core ideology in a new and refreshing manner.

IMZ-Ural strives to create a sense of ruggedness that allows for exploration beyond boundaries. This ruggedness makes up for a significant portion of their image. As a result, the portfolio exists solely of motorcycles with sidecar that are equipped for rough terrain. The previous model resemble the current products with minimal changes to the exterior. This indicates that the company wants to focus on the exploration of the world in the near future and will not change the portfolio in a drastic manner. The slogan, "Where will you explore?", enforces the portfolio and the direction that they are headed.

The vision of IMZ-Ural can be described as:

"To push the boundaries of exploration with robust products that can empower the user to go further where other motorcycles stop."

6.4.3 Brand Expression

The way that a company expresses its message and even products is a large portion of how the customer interacts with a product and views the product as valuable. Brand perceived value is the result of a cycle including consumption and purchase experiences (Cronin, Brady & Hult, 2000). Therefore, the way that the products can be purchased plays a significant role in the experience for the consumer. Additionally, the aftercare and service are a large portion of user satisfaction, therefore increasing the value of the brand significantly as well.

The brand expression of IMZ-Ural, while seemingly straightforward, is rather effective. The brand aims at targeting an audience that is affectionate for travel and exploration. This is mostly translated in the aftercare and service of IMZ-Ural. During travel, equipment is bound to malfunction in the long run. The website offers various parts that can be purchased directly from the factory. By providing users with the replacement service, users are able to singlehandedly exchange parts. Consequently, the essence of exploration is boosted by allowing the user to explore the various components and even replace them if desired. In terms of purchase experience, the strategy is rather simplistic. The potential customer is directed towards various dealers that provide a test drive. This simplistic approach is a common practice in the field of vehicle purchases, not straying from this approach is therefore not a negative.

As of February 24th, an ongoing war has commenced due to the Russian invasion in Ukraine. Since the company IMZ-Ural originated in Russia, the war has negatively impacted Russian companies, both financially and public image. Since the start of the war, IMZ-Ural has actively condoned the war and has posted messages on its outlets with the request to put a halt to the invasion on Ukrainian soil. It is important to mention that the company is currently USA-owned and used to only outsource the production of components to Russian factories. Therefore it is too early to tell what the impact is on the public image of the company and its products. Currently, all production has moved to Petropavlovsk in Kazakhstan, effectively cutting ties with its Russian roots.

6.4.4 Brand Translation Prism

Since the conversion of a sidecar configuration comes with more challenges than just the design elements of the original company, it is essential to have a clear and finalized picture of what the secondary company has to incorporate on a surface level. A brand translation prism based on the previously identified brand identity prism can help to give an overview of the details regarding the brand portfolio. These details range from the two-dimensional plane to the macro scale of the product in its intended environment. An overall collage containing the implicit and explicit design characters allow for the conversion to more abstract associations with the brand. First order associations are assigned to the images through conducted research and a short survey, consequently defining the core of the brand through the second order associations.

As previously mentioned, the design of the products within the IMZ-Ural portfolio strike a close resemblance throughout the years. The limitation of manufacturing processes at hands have resulted in a style that is often a callback to older times. In addition to the fact that the products do not rely on modern technology in order to function. The color palette is often a statement on its own. While the technical components itself are often a muted color, the chrome details and colorful body are striking and effective. The design language relies on curved surface combined with contrasting horizontal lines. A large and significant detail in its appearance is the block engine that is present in all current products. The second order associations that best describe IMZ-Ural are adventurous, confident and old-school. The full brand translation prism of IMZ-Ural is depicted in figure 20.

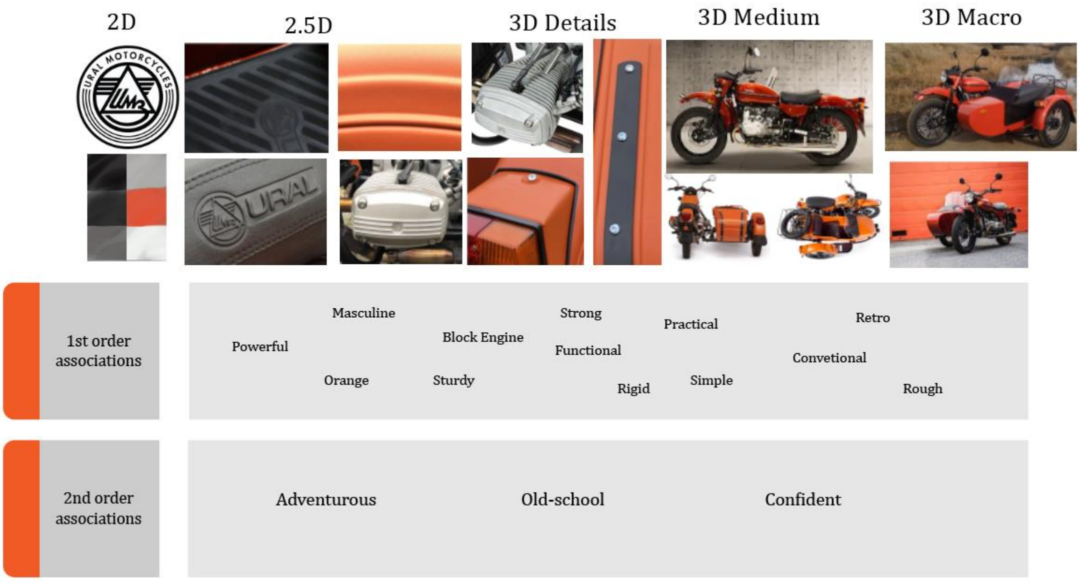

Figure 20: Brand translation prism of the brand IMZ-Ural

Adventurous, ready to take on the environment yet to be explored with a motorcycle. As previously mentioned, the archetype that the IMZ-Ural strives for is the Explorer. Realized by a sturdy, rigid look, the IMZ-Ural cT reinforces the adventurous and explorative nature of the brand. Additionally, the product offers a variety of additional equipment, allowing for customization based on the requirements set by the user. As a result, customers are able to personalize the sidecar configuration that suits the way they choose to explore the world

Confident, as in not reliant on over-the-top and profuse ideas in order to function. The base model IMZ-Ural cT has exactly what is necessary to function in a way that is familiar to expectations. The sidecar configuration is often painted in a bold color that is not afraid to stand out and attract attention.

Old-school, the minimal design changes throughout the years is a testimonial to the retro-style of the product. The sidecar configuration itself is an old-fashioned concept on its own. The reliance on the old-school look has amassed a loyal fanbase. Additionally, the sidecar configuration does not rely on heavy usage of modern techniques but rather return to the roots of the company.

With the components selected and the style of the initial company identified, it is time to combine the processes into a quick prototype. This prototype is then validated with various stakeholders that have been previously defined in a public appearance. The quick prototype therefore combines the development phase in a tangible product set-up.

7. PROTOTYPE DEVELOPMENT

The development phase that encompasses the component selection and the brand analysis are the foundation of a clear concept. While these processes influence one another during the development phase, it is important that the processes are combined in a clear vision of the converted vehicle. By providing prototypes, the converted vehicles can be assessed and tested to continually improve the product. This chapter focuses on the theory of developing prototypes of converted EVs, followed by the direct application within the IMZ-Ural cT case.

7.1 PROTOTYPING APPROACH

The creation of a functional prototype is a process that often involves trial-and-error and several iterations. Since the proof of concept is often more complicated than the theory implies, it is almost a certainty that alterations are necessary during the design process. As a result, functional prototypes are often not the finalized product but a reflection of the proposed design that is ready for testing. Because the design of the functional prototype can be perceived as quite unstructured, it is relevant to propose an approach that can be used during the manufacturing of the functional prototype. The proposed approach can be applied for the conversion of other EVs. It should be noted that this approach is mainly focused on the design of the housing/placement of selected components rather than the electric components and the connections. This portion of the conversion was tasked to an electrical engineer and are therefore described briefly in the previous chapter. It is assumed from this point that the selected components are used for the prototype. However, feedback or conclusions from the constructed prototype lead to reconsideration of the component selection.

1. Determine location of the components

The stability and drivability of a motorcycle is dependent on the weight distribution of the vehicle. Determining the right location is therefore a significant contributor to the success of the creation of a functional prototype. It is recommended that this step is followed sequentially after the determination of the electrical components for the electric propulsion system.

2. Quick prototype

The connections between the components and the frame are a significant part of the conversion process of the traditional vehicle. As previously mentioned, the main design challenge of the conversion of EVs is the limitation on the alteration of the frame. The frame cannot be compromised in any way, resulting in the need for custom-made connections between the components and the frame. A quick prototype is enough to validate the placement possibilities and allows for quick feedback on the design style for the conversion.

3. Functional prototype

After validation of the quick prototype, the manufacturing of the functional prototype can be started. However, the creation of the functional prototype is divided into three different sections that occur simultaneously and influence one another. The battery case that houses the battery modules is designed with regards to optimal space usage and orientation for the connectors. As a result, the orientation of the modules is determined during the first step of the design process. The second section that is designed is the finalization of the motor connection to the frame based on the findings of the quick prototype. The battery modules are connected to the motor through the BMS and connected to the motor controller. The functional prototype is again tested on public reception. However, the functional prototype allows for the validation of the requirements that have been constructed.

The design process is part of the proposed roadmap introduced in section 4.5. This diagram shows which steps influence other steps and where final decisions have to be made before continuing to the next step. Additionally, the diagram shows which steps are taken simultaneously, allowing for a smoother process.

7.2 QUICK PROTOTYPE DEVELOPMENT

The next step in the proposed roadmap is the use of quick prototyping. The geometry of a vehicle with an internal combustion engine is not designed for the electrical components that have been selected. As a result, certain elements require custom-made connection in order to prevent the frame for alterations. Consequently, rapid prototyping can be used during the prototyping stage of the conversion process. Rapid prototyping is the term for creating components without the need for traditional tooling and manufacturing processes (Upcraft & Fletcher, 2003). Rapid prototyping decreases the dependency on highly-skilled modelmakers or manufacturers. The main form of rapid prototyping is often layer-based, additive manufacturing processes. The starting point for a rapid prototype is a 3D CAD model, that is converted to a .STL file. This file is then used for the layered construction of the component. Rapid prototyping makes it possible to create complex components in a short amount of time with limited resources, allowing for quick feedback regarding product placement or functions. This makes the process of rapid prototyping suitable for this stage of the project.

Additionally, other forms of quick prototyping can be beneficial during this stage of the conversion. For example, the final position and orientation of the batteries needs to be determined at this stage of the process. While it has been established that adding the majority of the weight directly below the sidecar improves the drivability significantly, there is still some flexibility in the determination of the location. By making quick mock-ups, various variations can be considered within a small time interval. Lastly, by providing an indication of the final product, the vehicle can be judged with regards to appearance. This is valuable information with regards of the appearance of the vehicle. If it turns out that the early prototype strays to much from the design intent of the original company, concession need to take place. With series-based manufacturing of a final product, it is more beneficial to have a standardized manufacturing process. Additionally, the 3D-printed parts, while allowing for more complexity and reduced production time, are often les reliable in terms of strength and fatigue (Rouf et al., 2022). Therefore, it is recommended that the use of rapid prototype is reduced to the prototyping stage exclusively.

Since the stakeholders and component selection are quite dependent on each other, a rapid prototype can be used to determine a trade-off between the two. The most important goal of the quick prototyping in the case of the IMZ-Ural cT is not necessarily to test the functionality of the final product. The first necessary component that is manufactured using rapid prototyping, is a stand in which the ME1616 electric motor is placed. One of the main benefit of the IMZ-Ural cT model for the conversion is the cardan shaft instead of a chain. As a result, the electric motor can be directly attached to the shaft, resulting in a direct transfer of the power. However, the cardan shaft is angled in comparison to the frame of the sidecar motorcycle. Therefore, the preliminary design of the motor mount serves two purposes; the positioning of the ME1616 electric motor at an angle and the attachment to the frame. Since the shape of the motor is difficult to approximate in a component made with traditional tools, rapid prototyping offers a quick solution. The rapid prototype that is developed using 3D printing therefore exists for determining the position of the motor in the functional prototype that needs to be developed in later stages of the conversion. The motor mount designed for additive manufacturing is depicted in figure 21.

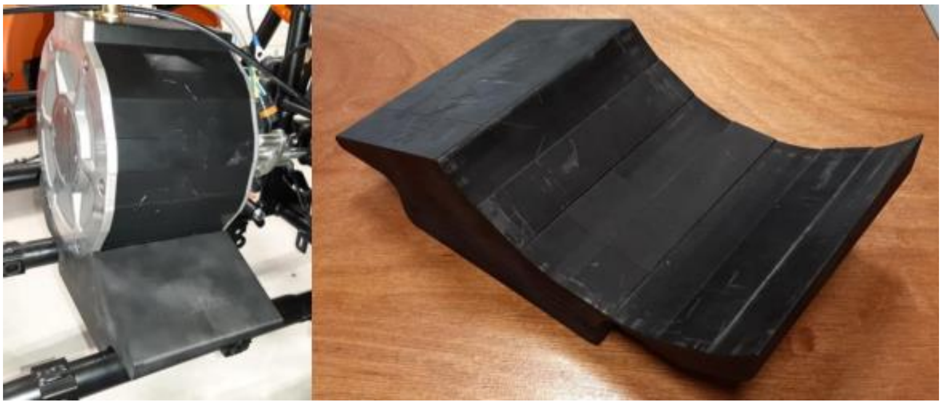

Figure 21: Motor mount created with rapid prototyping

Additionally, the position of the batteries needs to be finalized at this stage of the process. The previously determined LG chem JLR X590 modules have a rather simple form and therefore do not require rapid prototyping. As a solution, the module dimensions are measured and translated into foam duplicates (figure 22). The foam duplicates have several benefits at this stage of the project. The lightweight duplicates offer more flexibility with trying out several configurations. Additionally, the bulky and heavy modules easily damage the vehicle when not handled with care.

The foam duplicates are so lightweight that there is no possible chance at denting or scratching the vehicle. During the research phase of the project it was determined that the stability of the sidecar is significantly proportional to the weight distribution. Placement of the battery modules can therefore be allocated to the space under the sidecar, actively lowering the center of gravity. Configurations are therefore limited and only several configurations are possible. The configurations are mainly based on orientation of the battery modules. The orientation was ultimately decided upon based four different configurations. The configurations are further elaborated on in the report of another student. While all configurations are dependent on placing battery modules below the sidecar, the other configurations placed a smaller portion of the modules in different locations such as a the space of the original combustion engine or a jerrycan at the side.

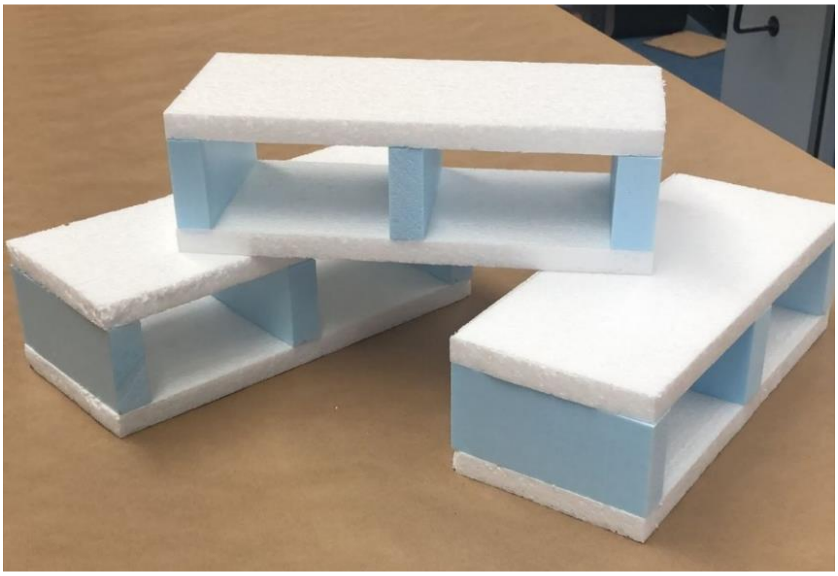

Figure 22: Foam duplicates of the battery modules

However, the benefits of the improvement of the directional stability as described in section 7.2, significantly prioritize locating the majority of the load between the front wheel and the sidewheel

Aside from the added benefits of additional stability, either rollover and directional, the most available and unused space is directly below the sidecar. Additionally, the connections between the battery modules line-up when the short ends of the modules are oriented in the same direction. Placing batteries in different locations along the motorcycle largely increases the complexity of the electronics and therefore increase the possibility of failure. Extra wiring is associated with a higher degree of electromagnetic interference and could lead to additional challenges of passing the RDW requirements of electric safety. As a result, these two factors both contribute to a clear a definitive configuration that is not only beneficial for the conversion, but also to the overall experience of driving a sidecar.

After determining the most optimal location with the use of foam duplicates of the battery modules, a mock-up of a potential case that houses the battery modules is created. The main purpose of this mock-up is to evaluate the overall appearance of the addition of a large component directly below the sidecar. The dimensions of the battery case approximate a possible finalized design. This way, various measurements that are necessary for further development can be conducted. An example of an important measurement is the distance from the bottom of the mock-up to the ground, this measurement dictates whether the design is feasible for the road structures in Europe. Additionally, the mock-up will be used to gather feedback in the form of public reception. Eventually, the shape can be altered based on the feedback from potential customers. It is at this stage that a concept drawing is constructed in which the brand analysis is used as inspiration.

Figure 23: Concept drawing of the quick prototype

The concept drawing (figure 23) is mainly focused on the battery case and the impact it has on the appearance of the sidecar motorcycle. Since the inclusion of the ten battery modules will impact the appearance of the motorcycle the most, the color black is selected for the battery case. By using the color that largely present in the frame and construction-based components of the IMZ-Ural cT, the battery case is not as obtrusive. The orange color is still the eyecatcher of the vehicle, while the black color fades into the background.

The wooden mock-up that is constructed based on the concept drawing, is able to house all ten LG Chem battery modules. The top of the case is covered by a rubber mat, a detail that is present in the original model. As a result, the top view of the sidecar motorcycle is not compromised significantly. The wooden mock-up is directly attached to the frame with tie-rips. The full wooden mock-up can be seen in figure 24.

Figure 24: Wooden mock-up of the battery case

The prototyping in this stage of the conversion has been critical for the placement and evaluation of the battery modules. Components such as the electric motor and battery modules have been given a location on the traditional vehicle. Consequently, the vehicle can now be shown to the public for peer feedback, since the appearance now resembles a clear example of a potential solution for the electrification.

7.3 PUBLIC RECEPTION OF SIDECAR CONFIGURATIONS

The adaption of converted EV's into the modern-day infrastructure is a challenge in itself due to regulations. However, the motorcycle segment provides an additional challenge in the form of public reception. It is recommended that a deeper dive into the public reception of the initial vehicle is conducted. If there are strengths of the original vehicle, either functional or aesthetically, it can be beneficial for the public image of the converted vehicle. This starts with the public reception of sidecar motorcycles itself. Research (Gardner & Abraham, 2007) has highlighted several categories of car driving motivations such as journey time concerns, effort minimization, personal space concerns, and monetary costs. Since most consumers use vehicles as a means of transportation, these categories are common factors for consumers to consider when purchasing a vehicle with the intent of driving. Driving a motorcycle however, is often perceived as a hobby or passion due to the requirement of an additional, necessary license. In short, the usage of a motorcycle is no longer just transportation, but additional skills are required without a direct benefit in terms of transportation. This is reflected in the amount of registered motorcycles in the Netherlands. At the beginning of 2022, the Netherlands counted approximately 718.000 registered motorcycles (CBS, 2022), in comparison with approximate 8.9 million passenger cars. Consequently, the perception of motorcycles is different than regular vehicles such as passenger cars. It can be concluded that this has ultimately resulted in a decline in current sidecar configurations. Historically, motorcycles used to be a cheap alternative to a car. The ability to transport more passengers/cargo on a cheaper motorcycle resulted in popularity of the sidecar configuration. The light taxation of vehicles with less than four wheels in combination with the unavailability of passenger cars has increased the amount of sidecar configurations accordingly. After 1950, the production of smaller and cheaper passenger cars has limited the practical purpose of sidecar configurations significantly. This trend has been continued in the new century. The practical purpose and need of a sidecar configuration has become obsolete due to the availability of other, often more practical, alternatives.

However, due to the public view on motorcycles in the form of a passion or hobby, an upwards trend can be identified. When universally-loved products become obsolete due to technical advancements and are replaced by newer products with similar functionalities, the products can become niche commodities. This phenomenon can be recognized in other products that have reached the status of niche commodities such as vinyl or even cassettes. Even though there no longer is a utilitarian purpose for the vehicle, a community of enthusiasts can keep the product relevant. While a niche market can look like a downside for the product cycle, it offers some advantages. Due to the intensification of competition in the market, a splintering of successful brands can occur (Dalgic & Leeuw, 1994). As a result, larger companies stay more relevant over time, while others, often smaller businesses, become less relevant. Niche marketing allows for positioning in a market that is no longer relevant or is even ignored by current, sizeable companies. Consequently, a smaller but vivid community is able to sustain a niche company, while additionally allowing for potential growth in the future if the trend is able to reconnect with a larger audience in another manner.

As mentioned in the previous paragraph, the IMZ-Ural cT itself, before configuration, is a niche commodity. After validation with the official importer of Ural within the Netherlands (Richard Busweiler), it can be concluded that the minor, but vivid community of sidecar enthusiasts is enough to sustain the product on a smaller scale. The biggest challenge for the Ural is to reconnect with a larger audience, outside of the niche community. The electrification leads to a potential new group of customers. In order to get a better understanding of the view outside the community of sidecar enthusiasts, it is decided to use the mock-up prototype that has been developed as a way to gauge public interest in the converted vehicle. It is decided to present the mock-up and the ideology of electrification at an exhibition. Exhibitions allow for verbal feedback and make it possible to answer questions regarding the product individually and in more detail. The Dutch Innovation Days (DID) is an annual exhibition in Enschede where new ideas are presented to the public. Since the idea of electrification of vehicles is rather unexplored, an exhibition that encompasses innovation and new ideas is beneficial. The main target group of the DID is more focused on the exploration of ideas and new technology. For this reason the visitors are less biased towards the use of a sidecar configuration, resulting in feedback that is based on the first impressions of being exposed to the product. Additionally, a small questionnaire is constructed in which the more interested visitors could take part, allowing for a bit more insight for the latter stages of the project. The full questionnaire can be found in appendix B.

The first impressions of the vehicle were abundantly positive. The orange sidecar configuration gathered a lot of attention amongst the modern, clean products that were presented. In most cases, visitors were initially interested at the reason why such an old vehicle is being exhibited at the DID. It can be concluded that the sidecar itself attracts interest on its own. The additional electrical components mostly gathered questions regarding the output of the finalized product in terms of range, speed limit and drivability. The questionnaire was entirely optional. This is done in order to attract the target group that is actively interested in the electrification of the vehicle. The total number of respondents was 13, while this may seem low, the overall feedback is in line with the visitors that walked by quicker after a small interview. The main goal of the questionnaire was to determine whether the style of the conversion that was selected would click with the target group that is identified during the early stages of the project. For this reason the smaller amount of responses allowed for genuinely interested respondents to give a more informed opinion. However the smaller amount of respondents ensures that only preliminary conclusions can be drawn that will be used during the development of the functional prototype.

The first section of the questionnaire existed of general questions about the respondent and EVs. One of the first questions was regarding the driving habits of the respondent. The respondent was asked whether they are currently driving in an EV. As visible in figure 25, the majority of the respondents currently drive an EV. It is important to mention that these numbers resemble the visitors that actively took their time to fill in the questionnaire, which shows light bias towards affinity with the subject of EVs.

For this reason, a secondary question for the respondents that do not drive an EV is constructed. This question asked whether the respondent would consider ever purchasing an EV. Surprisingly, the vast majority would be open to driving an EV as visualized in figure 26. The biggest obstacle for purchasing an EV in the first place in almost all cases, is the large upfront costs when purchasing a vehicle. Additionally, the secondary market of EVs is still relatively minor, making it inconvenient for most respondents to buy an EV.

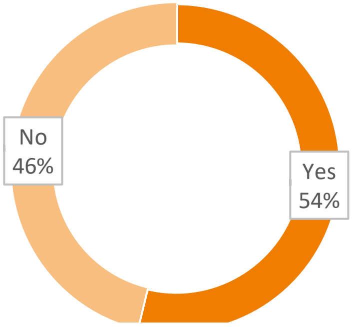

Figure 26: Overview of respondents that drive an EV

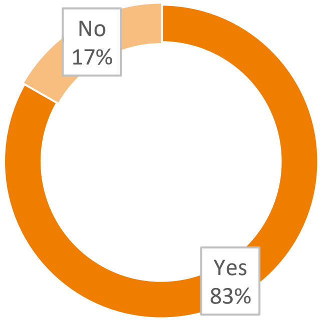

Figure 25: Overview of respondents that consider driving an EV

Lastly, the final questions were catered to the conversion of traditional vehicles in the context of sidecar configurations. The most important finding of this portion of the questionnaire was the consideration between a regular or an electric variant of the same model if given the choice. A vast majority of 93% of the visitors would consider an electric variant if it meant that the original style of the vehicle is preserved. This bodes well for the concept of electrification, since this is solely based on the mock-up prototype and thus based on the appearance.

Based on the initial public reception of the sidecar configurations in its entirety as well as the concept of electrification of the IMZ-Ural cT at the DID, it can be concluded that there is a growing interest in electrified vehicles. The strength of the concept, according to respondents, lies within the preservation of the original design. Even without the validation of a functional prototype, a convincing majority would actively consider picking an electrical variant of the same model if presented with the choice when purchasing a vehicle.

7.4 FUNCTIONAL PROTOTYPE

After validation of the early prototype, the next sequential step is to either create a functional prototype, or reconsider changing the design. The design changes at this stage are based on two factors; the evaluation of the design choices by the team and the gathered public feedback. If the choice is made to move forward with the conversion project, the manufacturing of a functional prototype is the largest contributor to the success of a final product. In this stage, the proof of concept is ultimately presented.

7.4.1 Battery case

As previously mentioned, the most weight is distributed with the location of the batteries. Through research regarding stability and overall appearance, it can be concluded that the most ideal location for the battery case in a sidecar configuration is directly below the sidecar itself. The functional prototype will therefore use the available space below the sidecar. In addition to the batteries, other components need to be situated in the battery case as well. Most importantly, the batteries need to be connected and a contactor needs to be included. As a result, the battery case needs to be designed in such a way that the electronics are accessible for maintenance and finalizing the electronics. The total amount of time that is allocated to the manufacturing of the prototype is around 4 months. For the development of a functional battery compartment it is essential to cover the following basics:

- Available space for battery modules
- A skid plate to protect the battery modules from below
- A fitting top plate to cover the electronics
- Available space for the BMS and wiring/cables
- An attachment method (no welding or altering the frame is allowed)

The basics described above attribute to a functional battery compartment that is necessary for a functional prototype of a converted sidecar motorcycle. During this stage of the project, it is essential that different team members are assigned to specific tasks in order to create the most optimal prototype.

The design process is divided into various stages. The first step is the dimensions based on the battery modules with respect to the dimensions of the frame of the sidecar.

For the construction of the converted IMZ-Ural cT, three engineers in total were responsible for the creation of the battery case. The preliminary design of the battery case is created by another student. An electrical engineer is responsible for the connections and adjustments of the technical components.

Ultimately the first iteration of the battery case is constructed and tested. The case is made out of one sheet of 1 mm stainless steel. The sheet is folded by an external company. The advantage of the single-component battery case, is the increased strength. The folded corners provide a stronger frame. In order to avoid deformation, additional stainless steel beams are placed between the battery modules. These beams add more strength to the compartment and keep the battery modules in the right place. The additional beams are welded to the case in order to ensure maximum strength. The preliminary framework of the first iteration of the battery compartment is shown in figure 27.

In order to provide space for the BMS and cables, a metal skid plate was designed that ultimately wraps around the bottom of the compartment with a slanted front. Additionally, the preferred attachment method of the client revolved around the idea of pipe clamps. It should be noted that the initial design was created by a secondary student solely focusing on the manufacturing of the first battery compartment. This report dives deeper in the strength distribution and legal implications of a self made battery compartment.

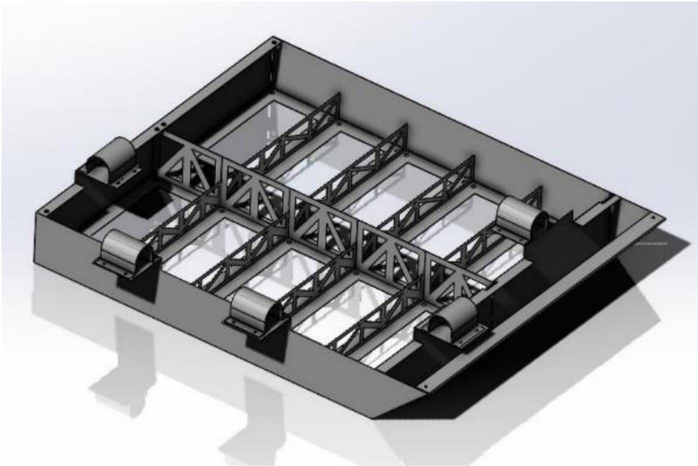

Figure 27: Preliminary framework of the battery case

Ultimately, the design provided insufficient support for the battery modules. The main problem that arose during the manufacturing of the preliminary battery case, was that the material was deemed to thin for welding. As a result, the additional beams could not be welded to the frame of the compartment, resulting in a lack of internal structure. No additional testing had to be conducted due to the visual confirmation of severe deformation in the battery compartment. Unfortunately, the aforementioned student responsible for the preliminary design could not finish a revision of the functional prototype due to time constraints. However, an ideal starting point for a second iteration of the battery compartment was defined. As a result, it can be concluded for the general information of the electrification that more attention needs to be paid to either the material choice or the connection between the beams and the frame.

However, since the weight of the 10 LG Chem JLR X590 modules is a total of 120 kg, a thicker stainless steel plate would increase the weight significantly. The battery compartment as a whole could not weigh more than 10 kg. Secondly, the selection of a different, stronger, material would increase the cost greatly. As a result, it is decided that a new design is necessary in which further welding is omitted.

The new design exists of 4 different brackets. These brackets form the outer shell of the case. The brackets are spaced with the use of aluminum T-profiles. The T-profile adds additional strength that was not present in the first iteration of the battery case. While the inclusion of T-profiles in the original design were a possibility, it would result in a battery case located closer to the ground, actively lowering the vehicle as a whole. Instead, the new design allows for the removal of material at the bottom of the battery case, decreasing the total weight. Figure 28 shows the preliminary design of the second iteration of the battery case.

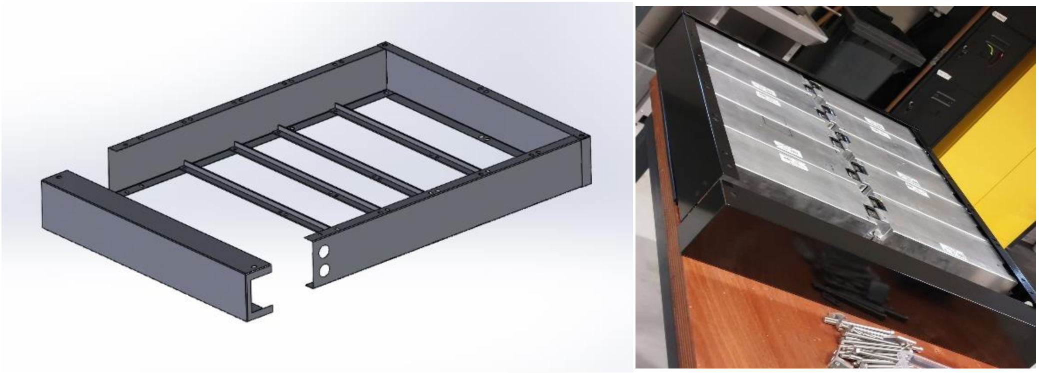

Figure 28: Final iteration of the battery case

The four brackets allow for better access during the stage in which the batteries are connected. For example, the front bracket can be attached as the last piece of the battery compartment, allowing for final connection of the BMS and contactor. Additional space is factored into the front bracket. Consequently, the contactor and BMS can be placed in the space in front of the battery modules. The wires that connect to the electric motor are accessed through holes in the side of the front bracket, resulting in a single access point for all electricity.

With regards to the increased internal structure necessary for a successful design, a revision of the battery connection is done. Instead of increasing the thickness of the material, small metal plates (from now on referred to as "cookies") were created that joined the battery modules together, limiting the ability of the material to flex (figure 29). The cookies exist of a 3mm thick layer of sheet metal with holes suitable for a connection directly through the battery module. As a result, the 10 LG Chem JLR X590 modules are connected, with the use of the same screw, to the cookies and the aluminum T-profiles. This actively negates all possibility for the battery modules to flex, creating an internal structure that is based on the strength of the battery modules itself. As a result, the battery compartment exists of a solid compartment that is unable to deflect due to the weight of the batteries.

Figure 29: Cookies used to reduce the flexibility

7.4.2 Motor mount

Another important component that needs to be manufactured for a functional prototype of a converted vehicle is the motor mount. The electric motor needs to be attached to the driveshaft of the vehicle. For the development of a functional electric motor mount it is essential that the following basics are covered:

- The electric motor is supported
- The electric motor is placed directly onto the driveshaft
- The electric motor is fixed in one place
- Deformation due to external forces are withstood
- The electric motor can be attached and detached without alterations to the frame.

If the following requirements are met with the design of the motor mount, the electric motor can be placed accordingly for the functional prototype. The design of the motor mount is modeled after the alignment of the quick prototype.

The starting point of the functional motor mount is modeled after the quick prototype that is created with additive manufacturing. The main conclusion that is drawn from the quick prototype is that the material polypropylene (PP) is sufficiently strong and holds the ME1616 electric motor in position in comparison to the cardan shaft. However, the material is not made for extended usage in the automotive industry for loadbearing components. The extended usage is likely to cause stress and vibrations on the motor mount, resulting in failure of the part. Additionally, the usage of additive manufacturing for serial production is not recommended if the part is able to be manufactured with more traditional production techniques. As a result, mainly the dimensions and angular orientation of the quick prototype are recommended for the functional prototype as these have proven to be sufficient. The main conclusion is that a different material and production technique is selected for the functional motor mount.

The designed motor mount is constructed of 6mm thick stainless steel. As a result, the weight of the ME1616 is supported with ease. The thickness of the part is determined by the welding production technique that is applied. The thicker material allows for a strong weld that ensures that the motor mount can withstand extended stress and vibrations. The production technique of welding is used all over the original IMZ-Ural cT, resulting in a coherent and distinct style. The consequence of the new material and shape is that another attachment method is necessary.

The motor mount is attachable to the frame through the holes that are present in the frame of the IMZ-Ural cT for the footrests. As a result the motor mount is detachable from the frame directly without alteration. The final motor mount is shown in figure 30.

Figure 30: Manufactured motor mount with established connection points

7.4.3 Assembled functional prototype

The functional prototype requires that all the parts are connected and in place in order to test and validate the performance of the converted EV. The connections between the electric components are commissioned by the client to an electric engineer. However, the placement of the remaining electrical components such as the motor controller, cooling system and the charging system is still relevant for the performance of the functional prototype. As previously described, the goal of the functional prototype is to validate the proof-of-concept of a converted sidecar motorcycle. For this reason, priority is given to the functionality and placement is therefore flexible after the functional prototype is constructed.

The approach that is recommended for the placement of the final electrical components is to determine the connections with the established locations of the battery case and the motor mount. For example, the motor controller is linked to the electric motor. As a result, it is more sensical to place the motor controller close to the electric motor. Additionally, this approach decreases the complexity of the electronic circuit. By lowering the amount of wiring necessary for full functionality, the EV is less likely to have electromagnetic interference. This design approach is applicable to all remaining components for the functional prototype.

The consequence of the proposed approach of placing the components close to the connection points, is that it is not always the most suitable place with regards to style and space. However, by keeping these restrictions in mind, it is possible to find the most optimal space while decreasing the amount of wiring necessary. The SuperSigma 2 motor controller is connected adjacent to the ME1616 electric motor, leading to a direct connection. Additional to the proximity approach of location determination, a closer look at the perceived affordance of the components that have been replaced during the conversion process. For a user it is clear if the perceived affordance and actual affordance of a component are aligned. For example, it is clear that a jerrycan affords the refueling of the vehicle in the traditional sense of the vehicle. The design choice is made that the charging system is located in a jerrycan between the motorcycle and the sidecar in the place of the original exhaust.

By combining these approaches the cooling system, including an electric pump and radiator, is placed accordingly. The affordance of the tank is to contain a liquid. However, the conversion eliminated the necessity of the tank completely. The tank heavily influences the side profile and style of the vehicle and therefore cannot be removed without compromising on the traditional style. It is decided that the radiator is placed close to the electric motor and pumps the liquid through the tank through the original openings.

The battery case is attached to the frame of the sidecar through the use of brackets made from 6 mm stainless steel. The brackets fold around the outer shell of the battery case and use the same connection points of the batteries. As a result, the brackets are connected at different corners of the battery case, giving it enough strength to fully support the battery case. Additionally, a connection between the battery case and the frame of the motorcycle itself is constructed. This distributes the weight evenly among the entire vehicle The connection of the battery case and the frame are shown in figure 31.

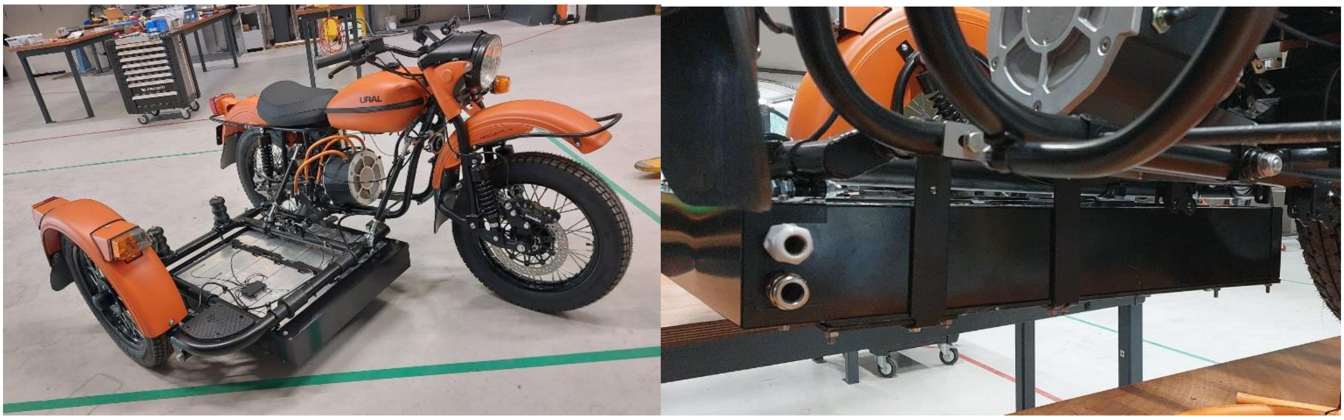

Figure 31: Attachment of the battery case to the vehicle

The fully assembled functional prototype is shown in figures 32 to 34.

Figure 32: Side view functional prototype

Figure 33: Front view functional prototype

Figure 34: Back view functional prototype

8. MARKETING AND BRANDING OF THE POTENTIAL PRODUCT

With the creation of a functional prototype that can be used for testing and validation, it is important to take a closer look at the potential placement of a finalized product that is developed before launch. Since the deadline of the project is the public presentation at the Dutch Design Week 2022, this chapter takes a closer look at the importance of marketing and branding for the launch of converted sidecar motorcycles. Since the product can be both perceived as a new product as well as an upgrade of a regular vehicle, it is essential to determine how the product is presented before the actual launch of a final product.

8.1 VALUE PROPOSITION

The functional prototype is extremely important for providing the value proposition of the final product. If the company is not able to demonstrate the claims that are made regarding a product, the customer is most likely to dismiss the features as a market strategy (Anderson, Narus & Van Rossum, 2006). For this reason, especially in the case of more expensive and often high-end products, it is essential that the market claims are backed by actual and measurable evidence. A functional prototype allows for evaluation of the proof of concept. While electric motorcycles have been present in the Dutch road infrastructure, chances are significant that a regular inhabitant of the Netherlands has not yet been exposed to driving an electric motorcycle. As of the 31st of October 2022, 1.349 electric motorcycles have been sold in the Netherlands[4]. It is therefore probable that the average customer needs convincing of the concept of driving an electric motorcycle. For potential customers, a proof of concept is therefore most likely the first interaction of driving an electric motorcycle. The value proposition is consequently linked with the functional prototype.

Creating value for the consumer is quite a broad task. Therefore it is recommended for a company to pick one specific strategy in order to avoid a confusing value proposition. Since the product encompasses a conversion process, the value proposition is quite clear. The value is created by favorable points of difference with the original product or possible alternatives. The functional prototype should proof that the product is an upgrade of the original product and offers advantages that the original does not. By actively highlighting the points of difference through marketing and the functional prototype, the product has a clear functionality. Consequently, the customer is directly able to see the benefits of the converted product.

The approach of creating value through points of difference can be applied to the converted IMZ-Ural cT directly. As previously mentioned, the most important factor is that the electrified vehicle, at minimum, should be competitive with regards to performance. For example, the range and top speed need to be comparable. As a result, the choice between a traditional IMZ-Ural cT and the electrified version, is ultimately not a serious downgrade with regards to performance. With a

[4] https://nederlandelektrisch.nl/actueel/verkoopcijfers

comparable and competitive converted vehicle as a baseline, it is important to highlight the aspects in which the converted Ural is different. The main, and most marketable, difference of the converted sidecar motorcycle is the absence of noise. A sidecar enables the driver to take another passenger along for the ride. Under normal circumstances, the passenger is situated next to the internal combustion engine, with the consequence of having to endure an abundance of noise. The silent electric motor allows for a more comfortable ride for the passenger. The silent motor even allows for communication between the driver and the passenger while driving. By improving the experience for the secondary user, the sidecar motorcycle is given a new life in which both stakeholders are given a way to bond during usage.

The absence of sound is not only beneficiary for the passenger. As mentioned in the introduction, many municipalities in the Netherlands are considering to ban loud vehicles from the city centers. As a result, many vintage vehicles such as old-timers and retro motorcycles are no longer allowed to enter the city. Without sound pollution, the converted IMZ-Ural cT is a perfect vehicle to drive in the city. The direct attachment of the electric motor to the drive shaft allows the converted sidecar motorcycle to drive in reverse.

Meanwhile, the positioning of the battery case underneath the sidecar results in sizeable storage space. Additionally, the electric components are much smaller in comparison to the internal combustion engine of the traditional vehicle, giving even more storage space as a result. As described in section 7.2, the placement of the weight improve the drivability of the sidecar motorcycle significantly. As a result, the primary stakeholder, the driver, is no longer constantly being occupied with the task of actively steering in order to drive straight ahead. Additionally, the steering of the sidecar motorcycle has improved significantly as well due to the lower center of gravity. With these factors, it can be determined that the user experience has improved for both the driver and the passenger.

Lastly, the converted IMZ-Ural allows the user to drive an EV without having to compromise on the old-school and confident appearance. The electrical components such as the batteries and the electric motor ensure that the vehicle is 100% electric. Consequently, it eliminates exhaust pollution in its entirety. Another core benefit of the conversion process is the active prevention of a vehicle with an internal combustion engine from entering the road. As a result, the conversion process reintroduces a traditional vehicle as an electric vehicle.

In conclusion, the main points of difference such as absence of noise, elimination of exhaust pollution and a better driving experience contribute to the added value of the converted IMZ-Ural cT. The conversion process reinvents the usage of the sidecar motorcycle and provides a more future-proof solution to sidecar motorcycles as a whole.

8.2 BUSINESS AND MARKETING OPPORTUNITIES

8.2.1 Business opportunities

The Ural Electric Project encompasses the manufacturing of a functional prototype. However, the prototype is a starting point for the sale of actual consumer products. Therefore it is important to determine the scope in which the company can approach the sale of end products. As previously mentioned, the market of motorcycles with sidecar configurations can be defined as a niche commodity. The market of electric motorcycles with sidecar configurations adds another component to the product. This allows for a new opportunity. As explained in the prior research, the field of EV's is growing exponentially. By adding a newer technology that is currently regarded as a potential solution for sustainability, the hype created by EV implementation allows for a more refreshing and modern take on a niche product. Additionally, the trend of electrification of regular vehicles is in the early stages of its hype cycle (figure 35) (Dedehayir & Steinert, 2016). While there are some early adopters, there is no real activity beyond early adopters. For the original sidecar motorcycle, the hype cycle is no longer applicable. Mainly because the rise of the product has already been established in the past and the overall function of the product has been caught up by newer, more functional products. It is therefore quite essential that the product, while maintaining the spirit of the original, rebrands the product accordingly in order to avoid catering to the same market group. Since there are no known specific companies that allow for electrification of established second-hand vehicles, it can be determined that the conversion of a motorcycle with sidecar configurations would fit in the category of early adopters in terms of electrification of regular vehicles. It should be noted that EV technology itself is in the maturing state of the development process. As a result, the potential customer market has already been established. The introduction of a converted vehicle is therefore a similarly enough product that it will not alienate the established customer market of original EVs.

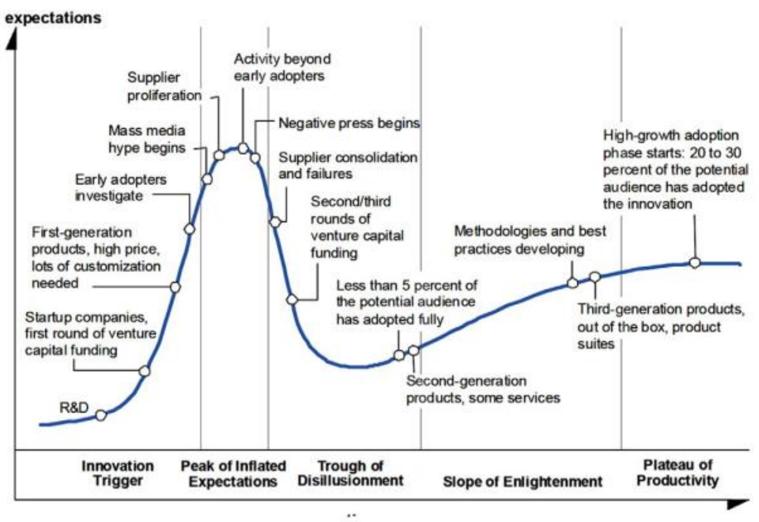

Figure 35: Representation of the hype cycle

The argument that the converted vehicle needs to retain the spirit of the original product is more significant when it comes to the application of the business opportunity of the IMZ-Ural cT. The strength that lies within the simplistic and nostalgic design of the sidecar motorcycle is a large contributor to the fact that the motorcycle is still being manufactured to this day. However, simply contributing to the same imagery and target group will not benefit the new product in terms of marketability. As a result, rebranding of the product is necessary in order to increase the potential target group. The electric Ural CT should cater to early adopters of the conversion process target group and the established market of EV technology. In order to make the product more desirable, a closer look into the possible branding needs to be

8.2.2 Marketing opportunities

In essence, all marketing and branding is concerned with enchantment and connection to a product, which can be defined as rendering something ordinary into something exciting, magical and emotionally-charged (Hartmann & Brunk, 2019). A way in which this attraction can be amplified is by using nostalgia. In terms of marketing, the product is best described as a classic that is updated for a sustainable future. As a result, the product strongly resembles a link to past-themed market resources. According to B. Hartmann & K. Brunk, enchantment for products can be achieved through 3 different routes driven by nostalgia.

Re-instantiation

The first way to persuade consumers through nostalgia is the most obvious solution, re-instantiation. This regressive point of view on nostalgia is paired with the sense that past constructs were superior by symbolically traveling back to something better/happier that is now lost. Re-instantiation can therefore be seen as romanticization of past-themed resources.

Re-enactment

A more progressive sense of nostalgia can be achieved through re-enactment. Re-enactment is the symbolic return of past-themed resources or ideals of the past. These remnants from the past can now be used to shape a better future. In comparison to re-instantiation, here the experience of belonging is created by drawing parallels between the past and present. Re-enactment therefore can be seen as a vision of a more advanced and better society than the present through nostalgia.

Re-appropriation

Lastly, a more playful approach to nostalgia-driven enchantment is re-appropriation. Playful nostalgia is, in comparison to the other approaches, strictly rendered in the present. Re-appropriation is focused on standing out creatively through playful remnants of the past, often deeming the present as too boring. Here, past-themed remnants are seen as playful, ludic and often ironic past condition that enlivens in the present.

In order to provide a clear vision to the potential customer, it is important to take a clear approach in the image that the converted vehicle is trying to convey. By sticking to one or two of the nostalgia-driven approaches presented, the image of the converted vehicle can be understood immediately and provide a strong message during the launch of the final product.

For the case of the IMZ-Ural cT, the clear line between the three various nostalgia-driven routes is not as easily identified. There is a combination of two opposing factors, namely a traditional vehicle and battery technology. Since battery technology is a new technology that is still developing and evolving, there is no nostalgia that can be identified. The Ural sidecar however, is a remnant of the past that no longer has a clear function outside of the niche market. The nostalgia is therefore the main drive for customers to purchase a sidecar in the current market. As a result, sidecars such as the IMZ-Ural are an example of re-instantiated products. The IMZ-Ural cT looks and feels like an object that is lifted from the past. As previously mentioned, the design has not changed significantly throughout its history and even the newest models clearly resemble the first designs.

However, the stark contrast between the original product and the new battery technology opens the door for a more interesting approach to nostalgia driven routes. The incorporation of EV technology in a traditional motorcycle is more of an example of re-enactment. The EV industry largely focuses on sustainability and preserving the planet for future generations. For this reason, the converted product enchants the consumer through progressive nostalgia. The electric IMZ-Ural cT can be seen a combination of a vehicle that has not been altered to look futuristic, but has the specifications of an EV. The combination of re-instantiation and re-enactment provide a new and rather unexplored opportunity for market positioning, ultimately leading to a higher chance of success.

8.3 BRANDING FOR THE PROTOTYPE

Branding of a product is a large contributor to the success of a product. Branding can increase the perceived value of a product significantly in the eye of a customer (Airey, 2009). As a result, the brand identity is a factor that needs to be incorporated in the final product. For a conversed product, establishing a coherent brand identity can be rather difficult due to the introduction of a conversion company as discussed in section 5.1. With a developed functional prototype, a plan regarding the branding and identity before the launch of a final product is essential.

8.3.1 Logo

While the design of a logo seems out of the scope of the conversion process, a well-designed logo acts as a visual element that associates the product with the brand (Kaur & Kaur, 2019). Since the vehicle is converted and turned into a new version of the traditional product, it is recommended to rebrand the product accordingly. The electrification is provided by the conversion company rather than the original company. Rebranding the converted vehicle slightly, while recognizing the original company, allows the customer to distinguish the new vehicle beyond functionality. A logo, while subtle, is a great visual que that provides the customer with the knowledge of a clear distinction from the original product. It is recommended that the conversion company outsources the design of the logo to an external marketing company.

For the sake of the client, the logo design is done as a part of the case study. The logo is based on two main design principles: simplicity and relevancy. Kaur & Kaur (2019) argue that simplicity allows for more recognizability and versatility of the logo. For example, a simple logo enables multi-purpose usage over a variety of different media, including websites, business cards and even merchandise. Additionally, simple designs increase the chance of creating a more timeless design. In the case of an electrified IMZ-Ural cT, a more timeless design is of great importance. The style of IMZ-Ural is more retro and nostalgia driven. Consequently, a rebranded logo for the client that is still timeless but updated for the current market, is an sensible opportunity from a marketing perspective. This way the logo reflects that the electric IMZ-Ural cT is an futureproof product.

The most important change to the sidecar motorcycle is ultimately the fact the vehicle is powered by electricity. This is where the principle of relevancy is most important. To show the customer that a clear distinction is made through the electrification, it is essential that this is somehow reflected in the logo. A lightning bolt is often associated with electrical power. Therefore, it is the perfect symbol to be reflected in the logo. By associating the logo to the electrified vehicle, the connection of an electric propulsion system is immediately assumed.

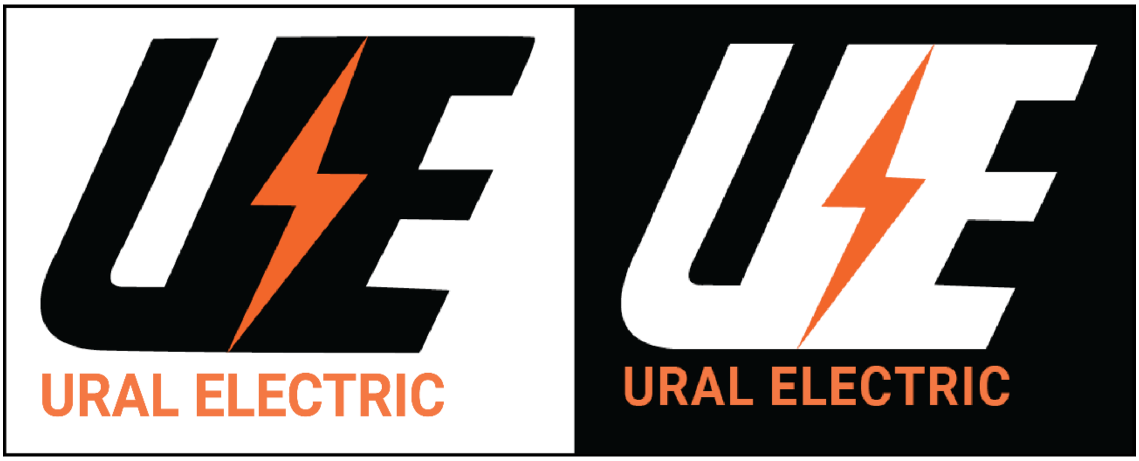

Figure 36: The logo of Ural Electric

The logo that is designed for the Ural Electric is a simplistic design that uses the three main colors that are presented in the brand translation prism. As a result, the logo is an addition to the brand style that is created by IMZ-Ural. The logo is shown in figure 36. While the logo of the original company will not be removed from the vehicle, the Ural Electric logo will act as a addition to the vehicle in order to distinguish the version. An example of this strategy can be found in the automotive industry by the company Volvo. In 2009, a partnership between Volvo and Polestar (under the brand name Polestar Performance) was started in which models like the Volvo S40, S60, C30 and the V60 are tuned with the focus on performance. Volvo models that are "Polestar Engineered" carry a small plaque with the Polestar logo on the front grill, actively showing the distinction between the regular vehicle and the tuned vehicle[5] (figure 37).

Figure 37: Polestar Engineered plaque on a Volvo model

In conclusion, the simple and relevant logo that is designed allows for clear distinction between the traditional vehicle and the electrified vehicle. The logo ensures a brand identity that is in line with IMZ-Ural while updating the style for the new version that is to be introduced on the market. The logo design is both suitable in light and dark mode, while using the orange accent color in the form of a lightning bolt, strengthening the association with electric power. This logo will be used in the marketing of the final product as well.

8.3.2 Website

Internet is the main source of information that helps users to navigate the current interconnected world. With the launch of a new product, whether it is converted or entirely new, the potential consumer needs to be aware of the product information. Constructing a website that boosts sales and inform the customer is therefore a necessity. Abrahamsson & Lundgren (2004) argue that simply being on the internet is enough to enhance sales and marketing efforts. Unfortunately, the internet has widely grown the past decade, burdening the company with a need to grab the attention of the customer in an abundance of information. Therefore it is important to consider the main objects that a functional e-commerce website needs to strive for in order to be competitive (Cormier, 1999).

[5] Home. (n.d.-a). Polestar Engineered. Retrieved October 24, 2022, from https://engineered.polestar.com

- *Establish a brand identity and image*

  It can be argued that the website is the actual representation of the product and the company. As a result, it is important that the website successfully reflects the brand identity and public image it wants to achieve. The website is a tool to attract potential customers, but also has the possibility to discourage customer. Careful consideration is therefore necessary.

- *Establish connection between user and company*

  As mentioned, the website provides the potential customer with the right information. The internet provides a company with the ability to highlight information in the form of product specifications, newsletters, contact information or even comments.

- *Establish an advertising medium*

  The website also acts as a means to call the viewer into action. By providing a form of an interactive brochure on the website, the potential customer is tempted into buying into an idea or product. The website can provide updates on products or even introduce new products.

- *Establish a customer service tool*

  In order to accommodate potential customers, a customer service tool that allows for a way to help or answer questions if necessary. Being able to provide communication between the user and the company allows for clearing up confusion.

While marketing and website design itself is a complex and different task on its own, it is essential for a conversion company to take the time and resources in order to create a website that functions as an extension of the product. It is recommended that the site is outsourced to a professional company that specializes in online marketing.

In line with the design of the logo, the process of website creation is taken into the scope on a basic level. For the sake of the client, the framework of a functional website is constructed as a part of the conversion project. During the research regarding IMZ-Ural and its brand expression, the core vision of the brand is given. In order to not alienate the target group of the original company, it is decided to use this vision for the new product, but update and add to it. As a result, the product is perceived as a next step in the existing market, while simultaneously targeting to a new target group. The adventurous, old-school and confident appearance (as described in section 5.1.4) of the vehicle is still present after conversion and should therefore be incorporated in the design language on the website. Furthermore, the website is mostly focused on the product and its advantages that arise from the electrical components that are added during the conversion process.

The front page shows the functional prototype in action. This is meant to show the proof of concept to the customer. Even though the product is not yet finalized, it is essential to show the potential customer what the final product will be capable of. It is at this stage of the project that it is decided that the website will include the functionality of pre-ordering the product for its intended launch in the final quarter of 2023. The main benefit of including a pre-ordering system is that the client acquires insight in the amount of products that will have to be manufactured in the coming year. This allows the client to construct a more accurate understanding of the amount of resources that are necessary. Additionally, the money that is invested by the pre-ordering can be used for the preparation of the conversions, actively softening the initial invest of the client. A benefit of the pre-ordering system for the customer is that the customer is ensured to receive the product as early as possible. The added anticipation of receiving one of the limited converted vehicle is appealing as well.

The full design of the website can be found in appendix C. Parts to highlight about the website besides the pre-ordering system are a product page that encompasses the electrical components and other specifications of the electrified vehicle. The fact that the purpose of the converted vehicle is still to be able to drive on different terrains is present on the home screen alongside a performance indication. This triggers the customer to click on the link that redirects to the product page. A pop-up with announcements on the top of the screen enables a direct connection between the client and the customer. Additionally, a contact form, including al contact information, is provided that functions as a customer service tool.

The style throughout the website is based on the design language that is established on the basis of the prior research in combination with the designed logo. The framework that is created during the process is the foundation of the final website. Since October, a new employee of the client has taken over the media management side of the project. The website is still mostly unaltered with slight tweaking in positioning of text and design elements. In conclusion, the website that is developed for the client as a part of the conversion process functions as an online brochure that allows customers to find information on the product. Additionally, the customer is able to pre-order the converted IMZ-Ural cT before its launch in 2023.

8.3.3 Social media and publicity

Social technologies connect people on a larger scale than ever before. Social media has become a means of sharing information with one another (Evans, Bratton & McKee, 2021). Consequently, it allows for companies to target their potential customer more directly and providing information in a direct approach. The main purpose of social media, from a business perspective, is to increase awareness surrounding a product or service. This form of social publicity can increase the interest in certain products significantly. In the case of converted vehicles such as sidecar motorcycles, it is relevant to determine what role social media can play in the marketing of converted EVs.

The converted vehicle is mainly focused on the improvement of the driver experience. Aspects such as being able to communicate while driving is a large benefit of the electrified vehicle As a result, it is wise to allow for a platform in which users can share their experience with the new vehicle. An Instagram account that allows users are asked to share their favorite tour or vacation is therefore a suitable option. Additionally, a dedicated page for updates regarding models or public events is a necessity. It is recommended that the conversion company outsources this to a marketing agency that is responsible for the campaigns.

In the case of the electrified IMZ-Ural cT, the media management is outsourced to a new employee. As a result, the social media campaign of the client is taken care of. Currently, campaign exists of a Facebook account and an Instagram account that are being managed.

For the electrified IMZ-Ural cT, it is determined that the initial publicity for the final product will be gathered by presenting the functional prototype in public. The functional prototype will be presented for the first time at the Dutch Design Week 2022 (DDW22) in Eindhoven. Conventions such as the DDW22 offers a possibility to stand out in comparison to the modernistic and futuristic approach that is often prevalent on design conventions. The bright orange sidecar motorcycle is meant to subvert what is expected for a future-focused convention. Ultimately, the functional prototype is meant to create attention for the finalized product. As a result, it is decided that test driving will be started in the beginning of 2023. Other conventions such as the EV Experience in Zandvoort or more international conventions need to be considered when the converted product is finalized.

9. RECOMMENDATIONS FOR FUTURE DEVELOPMENT

This chapter takes a deeper dive in the possibilities that extent beyond the creation of a proof-of-concept. While this is outside of the scope of the functional prototype, it is the defining factor for a successful introduction of converted EVs such as With a functional prototype ready, it is important to take a closer look at how a converted motorcycle can be positioned in such a way that it is a feasible product on the current market.

9.1 MARKET VARIANTS

As previously mentioned, the conversion of traditional vehicles into EVs is mostly done by small groups with the intent of creating a converted vehicle for private use or as a hobby project. The market of conversion company has not yet been widely explored. As a result, an important choice needs to be considered in the way that the converted sidecar motorcycle is offered to the client. There are two possibilities of providing the product to the customer.

1. Conversion kit

   The first possibility is the sale of the components in the form of a conversion kit. This allows the customer to convert their own second-hand sidecar motorcycle on their own. Providing the customer with more of an experience at the hands of an instruction manual provided with the electrical components. The conversion kit caters towards the customer segment of the more hands-on motorcycle enthusiasts. Since driving a motorcycle is often perceived as a "lifestyle", the fact that the motorcycle needs maintenance and can be upgraded is a rather significant portion of the acquisition of a motorcycle. The electric components require little maintenance once installed, but the installation itself needs to be conducted after acquisition. This way of offering the conversion kit to the customer changes the way the product is perceived. As a result, the purchase of a conversion kit offers the customer with more of an experience rather than just a product. It empowers the customer in transforming their own vehicle with sentimental value into a futureproof vehicle. A major downside to this approach is the fact that the installation process requires working with high voltage and can therefore be deemed as unsafe without proper instructions.

2. Conversion company

   The second possibility is to have a secondary company (in the case the client) act as an intermediary. The conversion company is responsible for the full electrification of the vehicle. There are two possibilities for the client when it comes to the purchase of a converted vehicle. The first option is for the conversion company to let the customer bring a privately-owned sidecar motorcycle. Similarly to the conversion kit, this allows the customer to bring in their own vehicle with sentimental values, actively creating a futureproof vehicle based on something they are already fond of. The conversion company has to conduct a standardized examination of the vehicle in order to determine whether the vehicle is suitable for electrification. The second option is for the conversion company to import a new frame of the sidecar motorcycle without internal combustion engine. Consequently, the frame is thoroughly tested and production ready without compromised damage from usage of the product. The conversion company can therefore start the conversion immediately and provide a sidecar motorcycle that is virtually brand new.

During launch of the converted vehicle, it would be possible to use both approaches. However, it is essential that a clear direction is selected rather than a scattered approach.

The benefits of the conversion kit are quite apparent. As previously explained, the expected target group for a converted vehicle will encompass a group users that are well versed in the maintenance and technical components of motorcycles. Using the sentiment of their hobby or nostalgia from tinkering with motorcycle components in the marketing can provide a feeling of similarity. Consequently, the conversion kit can be seen as a form of extension for motorcycles. As a result, the conversion kit is more likely to be perceived as an upgrade rather than a new product. Additionally, the scalability of the conversion kits is much broader. The kits can be applied to other versions of the same company or even extended to other motorcycle companies. The main complication in the development of conversion kits is the reliability on the customer. For example, before actual conversion can start, the motorcycle with an internal combustion engine needs to be partially disassembled. The removal of engine with boxer cylinders and the clutch is challenging due to the shape and weight of the components. Additionally, without the right tools, the vehicle is easily damaged in the process. Damage to the frame can compromise the stability of the frame that is used during the conversion process. For customers with sufficient knowledge of motorcycles, the disassembly process can be familiar. On the contrary, for customers without extensive knowledge of disassembly of motorcycles, this process would need to be explained thoroughly through the use of an instruction manual. However, even for the more seasoned motorcycle-owners, the conversion with electric components will be mostly new territory. The instruction manual needs to be foolproof since the components such as the battery cases are dangerous if not handled with care. A final benefit for the customer would be the affordability of the conversion kit. Providing the components without the need for personnel during the conversion process will lower the costs significantly. The user is responsible for the tools and time invested in the conversion process.

A conversion company will eliminate the reliability on the customer entirely. The conversion company is able to streamline the conversion process internally. As a result, the customer can either provide their own sidecar motorcycle. With the conversion kits, the user is responsible for examining the vehicle, possibly resulting in liability issues. In the case of the conversion company, a standardized inspection needs to be constructed. Important factors of the inspection need to be:

- Authenticity

  Since it encompasses the electrification of a second-hand vehicle, it is likely that some of the original components have been replaced during the use cycle. Low-quality components of different brands could compromise the internal structure of the vehicle and therefore should be checked accordingly.

- Damage

  Extensive use of the vehicle can lead to tear or material fatigue. Since the internal structure of the vehicle needs to be intact in order for components to be attached to the frame, damage could result in potential harm of the customer.

- Weld seams

  A majority of the connections of the frame itself are welded. Extensive vibrations that occur during use of the sidecar motorcycle can ultimately lead to compromised weld seams (Wang et al., 2020).

- Tightening of bolts and screws

  Similar reasoning to the weld seams can be applied to the connection based on bots and screws. Vibrations over a longer period of time could influence the tightness of connections.

- Electric components

  While the electrification process adds various electric components, a sidecar motorcycle already has some established electronic parts such as the headlights, alternator and the sparkplugs. These components need to be inspected carefully, since most of the electric parts are integrated in the conversion process.

While the proposed inspection might be elaborated upon, the mentioned factors are the core of the inspection. These factor determine whether the vehicle is suitable for electrification. Further benefits for picking the role of a conversion company include the assurance for the customer that the product is functioning as intended. The certainty of knowing the conversion is done to perfection can be comforting to a customer, especially if the conversion is costly. Additionally, the conversion company can act as an intermediary whenever a component need replacement as well as act as a garage for repairs. This benefits both the customer and the conversion company, since the customer has an allocated place to contact in order to fix complications while simultaneously providing the company with a potential second stream of income. A limiting factor of the introduction of a conversion company, is that the company requires more personnel that is responsible for streamlining the conversion process. Consequently, the scalability to other models or even brands is more difficult to achieve, since it requires more time to develop and streamline. However, the scalability in regards with conversion of the same model is larger. Since the conversion process is streamlined with regards to tools and knowledge, scaling the conversion process to more products at the same time is more achievable.

Since there is merit to both approaches, the choice between market variants is recommended to be based on the ultimate goal of the conversed product. If the conversion process is meant to accomplish a large wave of change throughout the transportation infrastructure, the wide availability of different brands and materials is preferable. However, since the conversion process is not yet widely applied, a more well-rounded approach of providing a user with a converted vehicle can be preferable in order to show the concept in its full potential. A combination of both approaches could be an opportunity in the long run. For a starting company, keeping the conversion process in-house is the most secure way of providing the converted product.

This choice is also established in the case of the conversion of the IMZ-Ural cT. As mentioned, for a starting company such as the client, the most secure way of providing the electric Ural is to keep the conversion process within the company. The first and foremost reason is that the product is not yet ready for final production. The functional prototype has proved that the conversion is possible and feasible in the near future. However, before introducing the motorcycle as a final product, there are still some complications that need to be figured out before production. In order to minimize the external factors that could influence the product (such as damage in the frame or replacement parts due to extensive use) it is decide early on in the process that the first batch of final products will exist of brand new frames directly delivered from the IMZ-Ural factory in Kazakhstan. Automatically, the decision for the client to act as a conversion company is made during the start-up of the company. While it can be argued that selecting brand new IMZ-Ural cT frames is an expensive first step, it ensures that the sidecar motorcycle is brand new, even after conversion. Additionally, the client has a close collaboration with the official importer of IMZ-Ural in the Netherlands. As a result, it is possible to import a brand new IMZ-Ural cT without an combustion engine, against a slight reduced price. This has been done for the creation of the functional prototype and is recommended for at least the first batches of the final product.

Another reason to decide on the role of conversion company rather than conversion kits, is the legal side that was briefly mentioned. In order for any new vehicle to drive on the road legally, it needs to be evaluated and approved by the RDW. With the imported vehicle, it is approved as an L4e classification by the RDW. However, when conversed, requirements such as electromagnetic compatibility and electric safety need to be re-evaluated. The evaluation of the RDW based on a newly imported vehicle is more likely to be approved than the conversion of a much older variant. For the first batches it is therefore essential that a standardized version based on the new frame is approved.

9.2 RECOMMENDATIONS FUTURE DEVELOPMENTS

The functional prototype that is recommended in the approach of the launch of converted vehicles allows for determining the factors that require alteration or attention. For this reason, it is important that the functional prototype is tested thoroughly, both on a technical and a design level. Based on these results, recommendations for the manufacturing of the first products can be done.

The first recommendation for optimization for the final product is based on the technical specifications that have been established before the actualization of the functional prototype. If the output of the functional prototype does not align with the specified wishes, this is the final chance to change the product significantly. The most important factors that could instigate technical changes to the concept are;

- Range

  In order for the conversed sidecar motorcycle to be competitive with either the original product or competitors, the range is one of the most important limitations. If the range during extensive testing is less than desired during the design stages of the process, concessions have to be made.

  Possible recommendations:

  Reconsider the amount of batteries.

  Decrease the total weight.

  Additional cooling.

- Top speed

  While the top speed of a converted sidecar motorcycle is not the most important factor in the conversion process, it is important that the top speed is at least in the approximation of the original vehicle.

  Possible recommendations:

  Reselecting the electric motor.

  Select lightweight replacement parts.

- Electromagnetic compatibility

  If it turns out that the functional prototype exceeds the limits of CISPR-12/CISPR-25 and CISPR-16 (RDW, 2021), the vehicle cannot pass the final inspection of the RDW. This means that the electrical noise of the functional prototype could result in disturbance/interference for other vehicles on the road.

  Possible recommendations

  Shielding for cables and wires

  Redesigning circuits

  Reselecting electrical components

The technical requirements of the prototype are the most easily defined by the functional prototype. However, it is important that the functional prototype can be analyzed with regards to design changes. Design features that are selected during the early prototyping stage are mostly based on design choices rather than technical requirements. As a result, it is possible that the functional prototype uncovers certain problems with regards to the design elements. With a better understanding of the functionality of the prototype, and therefore the desired output for a final product, new design changes can be considered or alterations can be made accordingly.

- Contrast in design language

  The design language that is determined during the earlier stages of the project can be altered due to last-minute changes in the functional prototype. As a result, the converted vehicle does not look cohesive.

  Possible recommendations

  Redesign of the exterior of the battery pack

  Redesign of design elements

  Recoloring of parts

- Dimension issues

  During construction it is possible that dimensions of the functional prototype do not align with the initial expectation set during the design phase of the product. As a result, the proportions of the sidecar motorcycle need reconsideration.

  Possible recommendations

  Remeasuring protruding parts

  Determine superfluous material

The main conclusion that can be drawn is the importance of testing the converted vehicle thoroughly. Design flaws and technical inabilities can still be decreased before the introduction of converted vehicle through the use of a conversion company.

The recommended testing is applied to the IMZ-Ural cT in order to determine factors that need further attention before the launch of the product. For the client, the technical specifications regarding the converted IMZ-Ural cT can be considered as the most important factor with regards to the feasibility of the product. Without the desired specifications, the niche product is unlikely to be popular amongst a new market segment, since either the traditional IMZ-Ural cT and competitive electric motorcycles would outperform the conversed vehicle.

The first functional testing for longer distances (excluding the first couple of test drives) is done in the form of an annual tour that is hosted by the importer of IMZ-Ural in the Netherlands. The tour, existing of approximately 100 km, is specialized for sidecar motorcycles. The preliminary data from this tour are promising. The functional prototype was able to complete the tour in its entirety with more than half of a full charge left. The functional prototype has a tested range of around 250 km. Since the range is dependent on factors such as terrain, temperature and acceleration, the expected range is to be between 230 km and 260 km. The range of the traditional IMZ-Ural cT is estimated between 250 km and 300 km. As a result, it can be concluded that the functional prototype has a competitive range to traditional sidecar motorcycles. Consequently, the amount of batteries modules does not have to be increased in order to meet the requirement.

The top speed of the functional prototype is capped at around 80 km/h. While this is significantly lower than the estimated 110 km/h of the traditional IMZ-Ural cT, it is determined by the client that this is more than sufficient for a final product. Due to the compromised directional stability of sidecar motorcycles and the probability to roll over, most drivers actively limit the top speed in order to drive comfortably. Additionally, driving at high speeds with a passenger, while possible, is rather unsafe due to the absence of a seatbelt. For this reason, additional changes with regards to the top speed are not necessary for the final product.

The most important test is passing the RDW examination. The functional prototype has the passed the preliminary examination at the RDW in Lelystad. This pre-approval ensures that the vehicle qualifies for a final and more thorough examination. This definitive RDW examination determines whether the converted vehicle qualifies for a license plate. Unfortunately, the functional prototype has not passed the EMC pre-compliance test. The measurements reveal too much interference with electronic parts. It is therefore recommended to inspect the electronic circuit in order to determine which part is responsible for interference. After the inspection, the cause of the interference can be resolved accordingly following the aforementioned recommendations.

Analyzing the functional prototype with regards to the design elements of the battery case, dimensional issues arise as well. The most notable issue is the height of the battery case with the ground. Due to the positioning of the battery case below the sidecar, the sidecar is actively lowered. While the changes influence the drivability of the IMZ-Ural cT positively, lowering the bottom of the sidecar influence the accessibility of the vehicle to different terrains. In the functional prototype, the height between the skid plate and the ground is 10 cm. While this is enough to clear most speedbumps on the Dutch roads, it can cause hinderance with higher curbs or uneven terrain. Ideally, the dimension between the road and the battery case should be around 15 cm. Recommendations for this issue include adjusting the connection between the sidecar frame and the frame of the motorcycle and changing tires. A more functional and more complete recommendation is to redesign the battery case slightly. In the current prototype, the battery case is suspended directly below the frame. However, there is significant room between the sidecar and the frame of the sidecar. By sinking the battery case into the available space of the frame, the battery case can be thinner and therefore higher from the ground. It is recommended that the design of the final battery case is outsourced in order to provide a strong and calculated design in a more complex shape.

10. CONCLUSION

10.1 DESIGN APPROACH EVALUATION

One of the main goals of this report is to prove whether a converted sidecar motorcycle is a concept that is competitive with a traditional sidecar motorcycle. The roadmap presented as guidance to the creation of a functional prototype has been followed in order to get an understanding of the completeness of the design approach. Based on the results of the functional prototype, it has been proven that the approach is able to produce a functional, converted EV out of a traditional vehicle. In terms of technical specifications, the functional prototype has succeeded in several fronts such as competitive range and top speed. Due to the extensive research with regards to design and style, the distinct style of the vehicle has not been lost in translation.

However, there are aspects of the proposed roadmap that have proven to raise difficulty with the intent of finalizing the vehicle for an eventual product launch. For example, the selection of components have been based mainly on availability and compatibility rather than the most effective components. Because the conversion took place in a timespan of 9 months, the research regarding the ideal combination of components needs to be substantiated. Additionally, the roadmap indicates two main decisions that are based on the two prototypes. After following the roadmap, it can be determined that there are more stages at which decisions that can lead to change management need to be present in the roadmap in order to improve the product. Recommendations with regards to decision-making are to add feedback at the development stage, even before the creation of a quick prototype.

Lastly, the roadmap exists of a variety of processes that happen simultaneously. As a result, the report seems mostly sequentially, while most of the development phase is dependent on cooperation between the tasks. For example, the location of the battery case is highly dependent on the type of battery selected. However, the amount of battery modules is dependent on the available space. Consequently, the design parameters are less strict than they appear in the approach. More collaboration between the tasks is therefore inevitable and recommended.

In conclusion, the design approach that has been established at the beginning of the project can be perceived as an idealized vision of the design process. Several steps take place simultaneously and are executed by different experts. However, it is an insightful overview that has proven to produce a functional proof-of-concept.

10.2 FINAL THOUGHT

Over the course of 9 months, a functional prototype of an converted EV is created that has proven to be competitive with the original vehicle. This result, while planned, was a massive undertaking in which various processes regarding conversion have been explored. While sometimes the focus of the project has shifted a bit to a more global view with regards to design and marketing. However, As mentioned in the scope of the report, the final deadline is the introduction of the motorcycle at the Dutch Design Week 2022 (DDW22). A significant portion of the DDW22, is branding and therefore the exploration of this side of the project has been very relevant for the process and for the client.

In conclusion, the report has proven that it is possible to produce a functional prototype in a short timespan that can be publicly displayed and validated. As a proof-of-concept, this approach has succeeded and is a sufficient starting point for a company, such as the client of this report, to proof that the conversion of a sidecar motorcycle is not only possible from a technical point of view but from a stylistic point of view as well.

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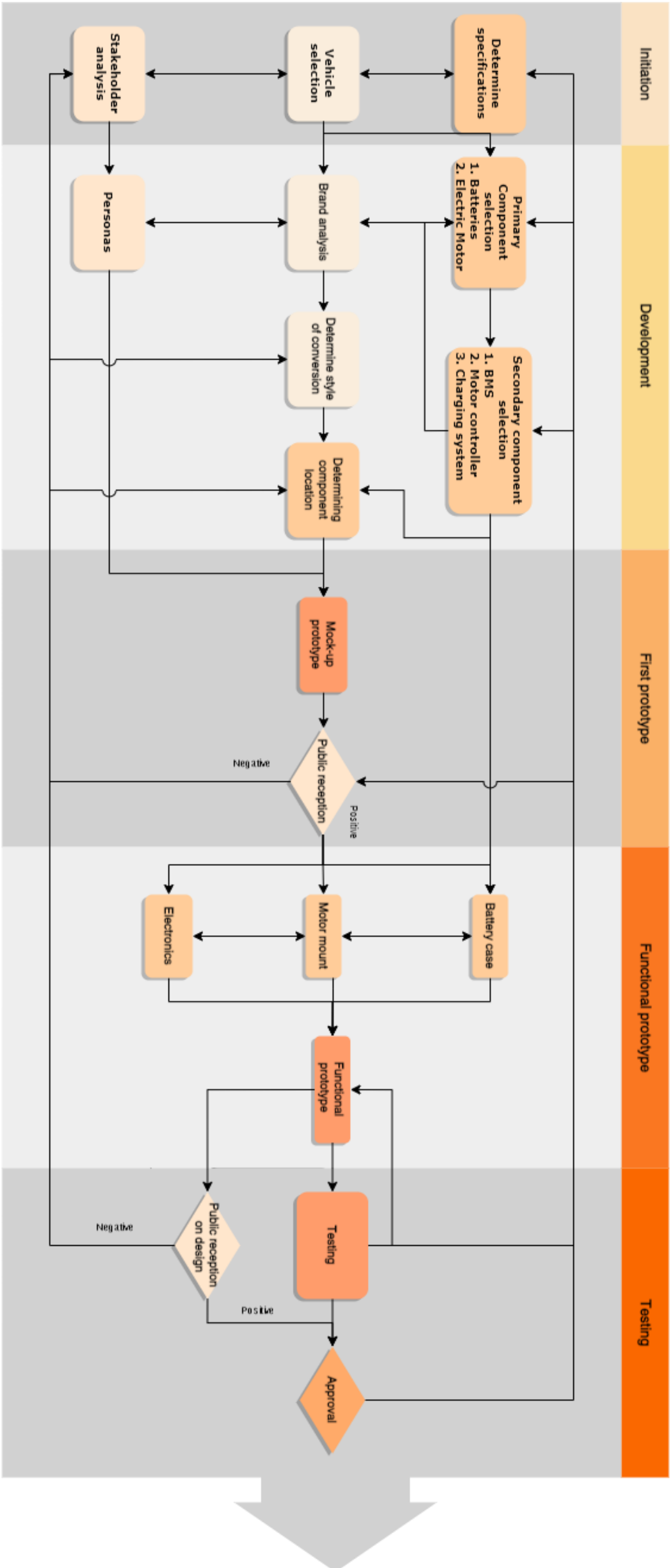
12. APPENDICES

12.1 APPENDIX A

12.1.1 Design approach roadmap



12.2 APPENDIX B

12.2.1 Full Questionnaire

Twentlantis: Ural Electric

Met Twentlantis: Ural Electric zijn wij bezig met het ombouwen van een traditionele IMZ-Ural CT met zijspan naar een EV (Elektrisch Voertuig). Deze enquête is bedoeld om inzicht te krijgen in de beleving van elektrische voertuigen zoals de Ural Electric Project. De eerste sectie bestaat uit een aantal persoonlijke vragen met betrekking tot elektrisch rijden. Antwoorden vanuit de enquête zullen anoniem blijven en enkel gebruikt worden als ondersteuning van het project. De enquête duurt niet langer dan ~5 minuten.

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* Required

Ik ben een.. *

- Vrouw
- Man
- Other: ______

Een elektrisch voertuig moet er voor mij *

	1	2	3	4	5	
Traditioneel uitzien	○	○	○	○	○	Futuristisch uitzien

Ik rij momenteel een elektrisch voertuig *

- Ja
- Nee

Twentlantis: Ural Electric

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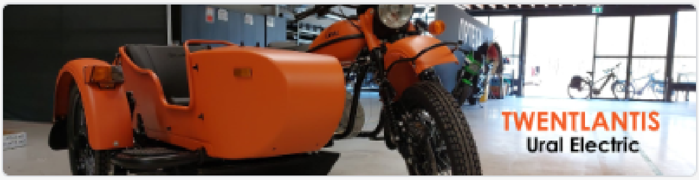
Motivatie elektrisch rijden

Om beter inzicht te krijgen in de reden waarom mensen tegenwoordig elektrisch willen rijden, volgt er een vraag met betrekking tot de motivatie waarom u elektrisch bent gaan rijden.

Kies uit de volgende opties waarom u elektrisch bent gaan rijden.

- ☐ Minder geluid
- ☐ Benzine/Diesel prijzen
- ☐ Milieu/CO2 uitstoot
- ☐ Thuis kunnen opladen
- ☐ Subsidies/Vrijstelling BPM
- ☐ Sneller optrekken
- ☐ Restricties omtrent brandstofmotoren vanuit de overheid
- ☐ Other: ______



Twentlantis: Ural Electric

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Motivatie om eventueel elektrisch te gaan rijden

Deze sectie is bedoeld om inzicht te krijgen in een eventuele keuze

Ik zou overwegen om ooit later een elektrisch voertuig aan te schaffen

	1	2	3	4	5	
Nee, dat zou ik nooit doen	○	○	○	○	○	Ja, dat zou ik direct doen

Kies uit de volgende opties wat voor u een reden kan zijn om ooit elektrisch te gaan rijden

- ☐ Minder geluid
- ☐ Benzine/diesel prijzen
- ☐ Milieu/CO2 uitstoot
- ☐ Thuis kunnen opladen
- ☐ Subsidies/Vrijstelling BPM
- ☐ Sneller optrekken
- ☐ Restricties omtrent brandstofmotoren vanuit de overheid
- ☐ Ik zie geen reden om elektrisch te gaan rijden
- ☐ Other: ____________

Licht hier eventueel toe waarom u liever niet elektrisch zou willen rijden of wat er voor nodig is om later te overwegen om elektrisch te rijden

Your answer

Twentlantis: Ural Electric

Saving disabled

* Required

Ombouwen van een regulier voertuig

Deze laatste sectie gaat over de keuze tussen het ombouwen van een regulier voertuig naar een EV (Elektrisch Voertuig. Dit project houdt zich bezig met het ombouwen van een voertuig met een reguliere brandstof motor naar een omgebouwde EV (Elektrisch Voertuig). Doordat hierbij geen aanpassingen worden gemaakt aan het frame, zal de omgebouwde EV dezelfde stijl behouden als het originele model. Op deze manier is het mogelijk om een EV te rijden terwijl de stijl nog steeds overeenkomt met oudere merken.

Als ik een voertuig zou willen ombouwen naar een elektrisch voertuig wil ik dat... *

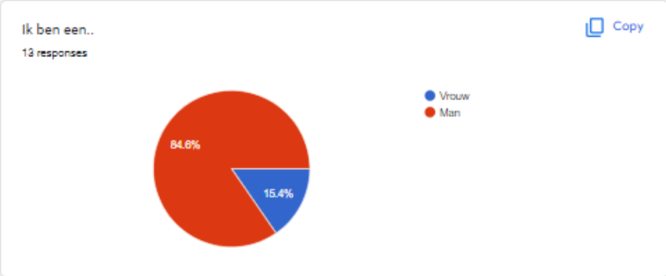
	1	2	3	4	5	
Zelf doen (alle componenten + instructies worden geleverd)	○	○	○	○	○	Laten doen door een extern bedrijf

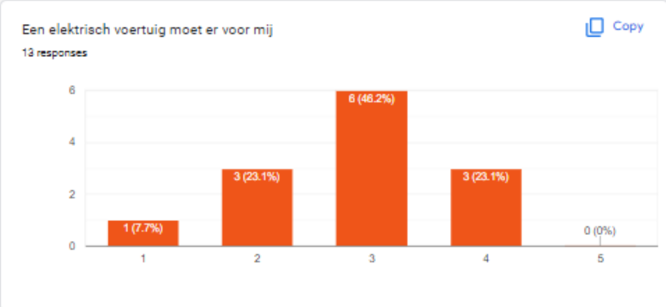
Als ik de optie had om te kiezen tussen een reguliere uitvoering en een elektrische uitvoering zou ik overwegen om de elektrische uitvoering aan te schaffen. *

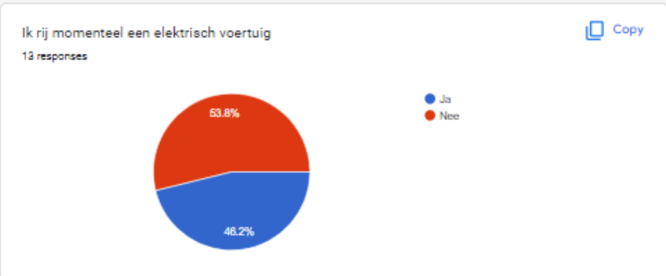
Bij de aanschaf van een nieuwe motor met zijspan is het mogelijk om deze aan te schaffen zonder motorblok. Hierdoor kunnen kosten bespaard worden. Dit in combinatie met de subsidies die aangevraagd kunnen worden zal de prijs niet heel veel duurder worden bij het aanschaffen van een nieuw model. De additionele kosten zullen maximaal €5.000 zijn bij aankoop.

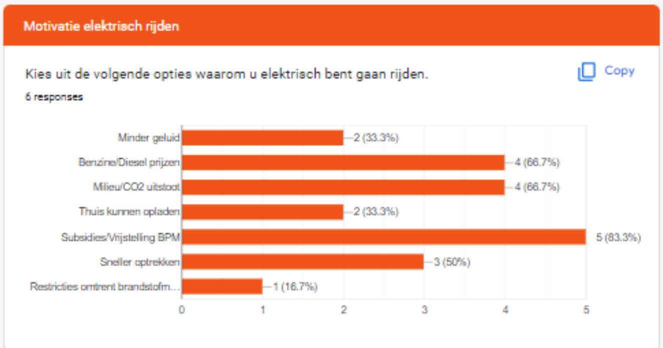
- ○ Ja
- ○ Nee

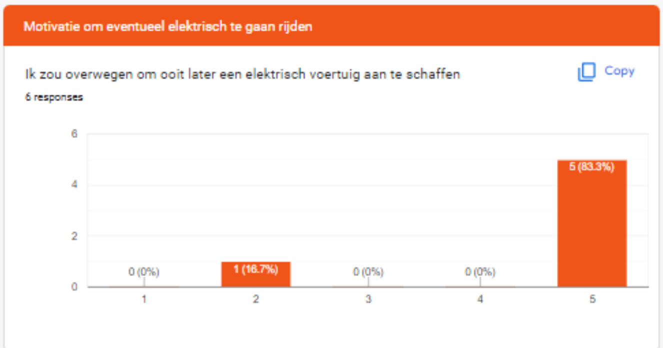
12.2.2 Questionnaire respondents





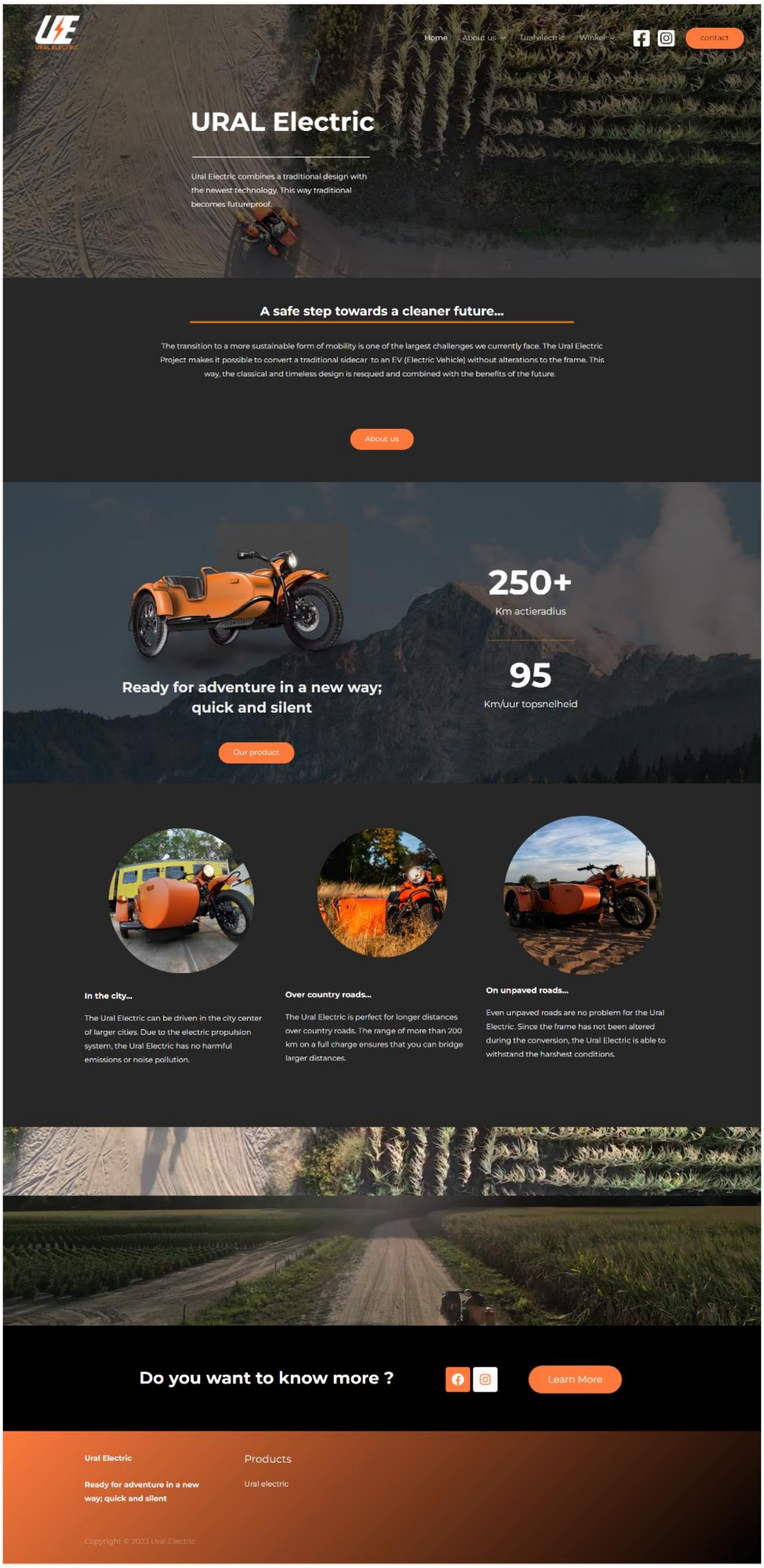


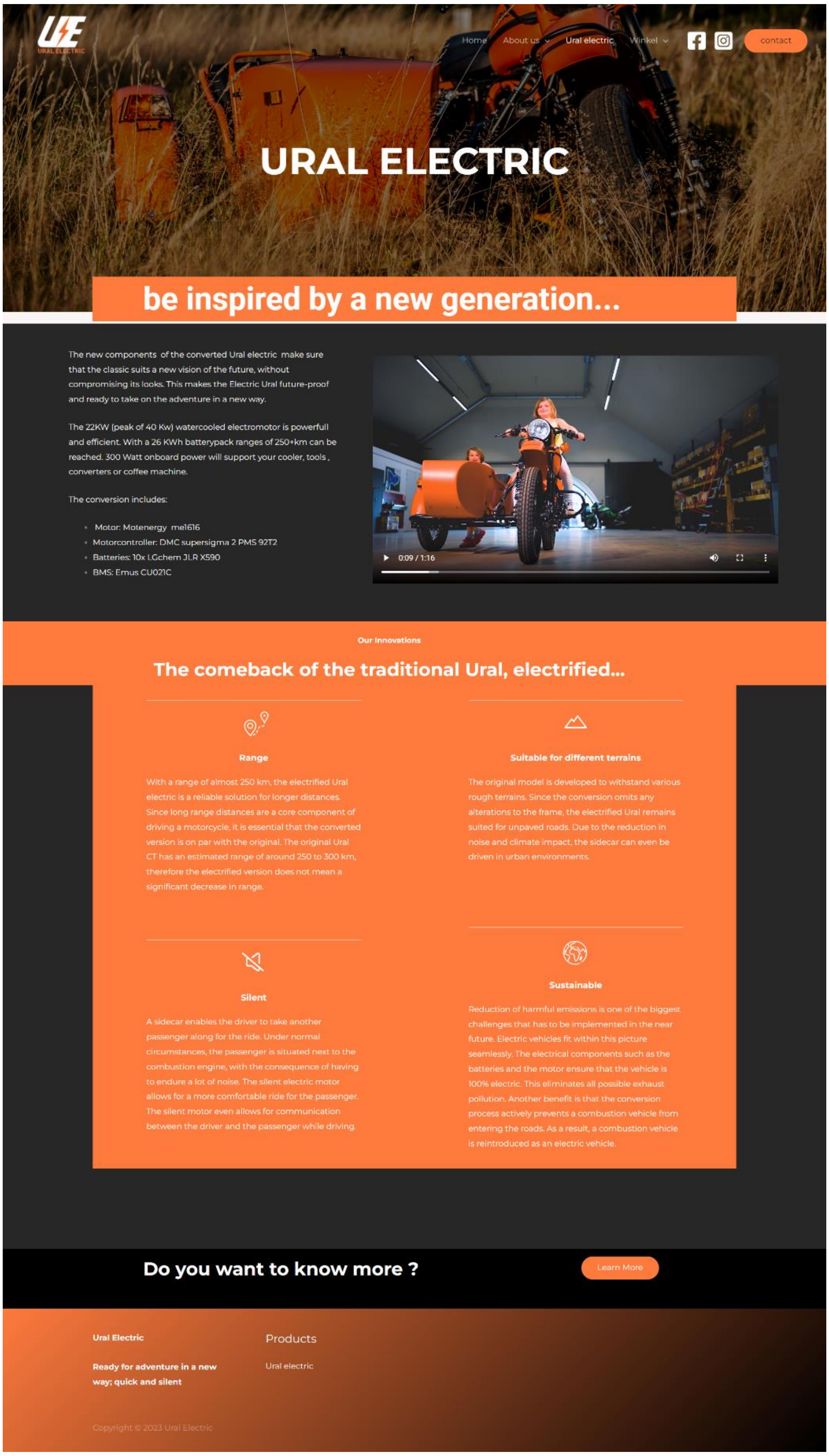




12.3 APPENDIX C

12.3.1 Designed Website




Home
About us
Ural electric
Winkel
contact
URAL ELECTRIC
be inspired by a new generation...
The new components of the converted Ural electric make sure that the classic suits a new vision of the future, without compromising its looks. This makes the Electric Ural future-proof and ready to take on the adventure in a new way.
The 22KW (peak of 40 Kw) watercooled electromotor is powerfull and efficient. With a 26 KWh batterypack ranges of 250+km can be reached. 300 Watt onboard power will support your cooler, tools , converters or coffee machine.
The conversion includes:
Motor: Motenergy me1616
Motorcontroller: DMC supersigma 2 PMS 92T2
Batteries: 10x LGchem JLR X590
BMS: Emus CU021C
0:09 / 1:16
Our Innovations
The comeback of the traditional Ural, electrified...
Range
With a range of almost 250 km, the electrified Ural electric is a reliable solution for longer distances. Since long range distances are a core component of driving a motorcycle, it is essential that the converted version is on par with the original. The original Ural CT has an estimated range of around 250 to 300 km, therefore the electrified version does not mean a significant decrease in range.
Suitable for different terrains
The original model is developed to withstand various rough terrains. Since the conversion omits any alterations to the frame, the electrified Ural remains suited for unpaved roads. Due to the reduction in noise and climate impact, the sidecar can even be driven in urban environments.
Silent
A sidecar enables the driver to take another passenger along for the ride. Under normal circumstances, the passenger is situated next to the combustion engine, with the consequence of having to endure a lot of noise. The silent electric motor allows for a more comfortable ride for the passenger. The silent motor even allows for communication between the driver and the passenger while driving.
Sustainable
Reduction of harmful emissions is one of the biggest challenges that has to be implemented in the near future. Electric vehicles fit within this picture seamlessly. The electrical components such as the batteries and the motor ensure that the vehicle is 100% electric. This eliminates all possible exhaust pollution. Another benefit is that the conversion process actively prevents a combustion vehicle from entering the roads. As a result, a combustion vehicle is reintroduced as an electric vehicle.
Do you want to know more ?
Learn More
Ural Electric
Ready for adventure in a new way; quick and silent
Products
Ural electric
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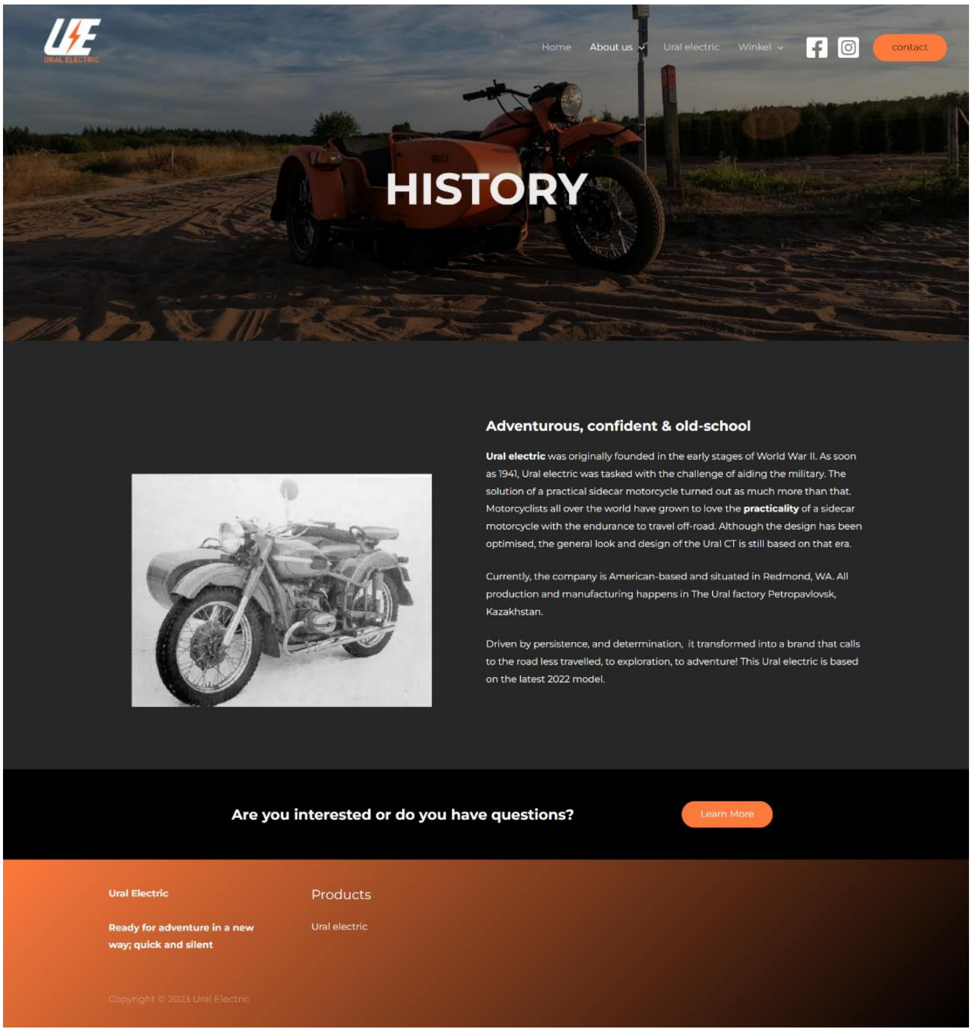
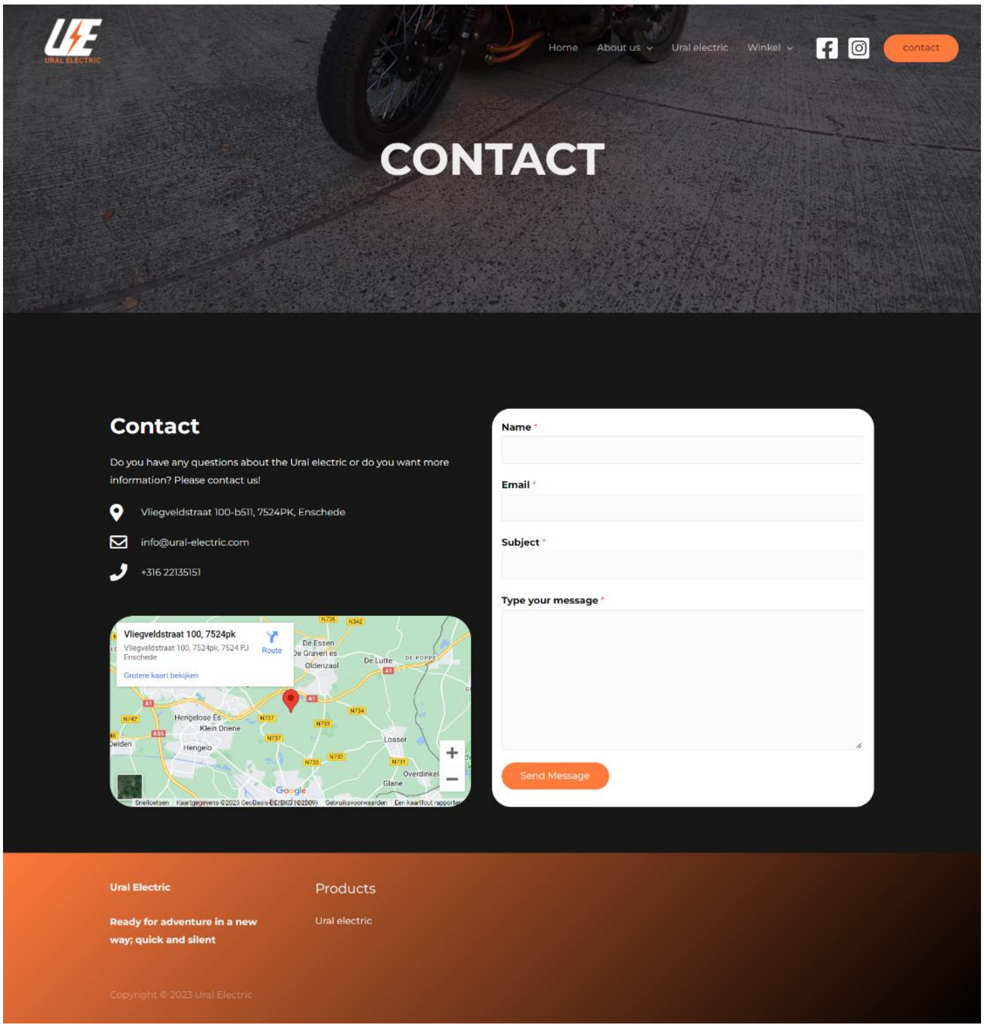

URAL ELECTRIC
Home
About us
Ural electric
Winkel
contact
HISTORY
Adventurous, confident & old-school
Ural electric was originally founded in the early stages of World War II. As soon as 1941, Ural electric was tasked with the challenge of aiding the military. The solution of a practical sidecar motorcycle turned out as much more than that. Motorcyclists all over the world have grown to love the practicality of a sidecar motorcycle with the endurance to travel off-road. Although the design has been optimised, the general look and design of the Ural CT is still based on that era.
Currently, the company is American-based and situated in Redmond, WA. All production and manufacturing happens in The Ural factory Petropavlovsk, Kazakhstan.
Driven by persistence, and determination, it transformed into a brand that calls to the road less travelled, to exploration, to adventure! This Ural electric is based on the latest 2022 model.
Are you interested or do you have questions?
Learn More
Ural Electric
Ready for adventure in a new way; quick and silent
Products
Ural electric
Copyright © 2023 Ural Electric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info@ural-electric.com
+316 22135151
Vliegveldstraat 100, 7524pk
Route
Grotere kaart bekijken
Hengelo
Oldenzaal
De Lutte
Losser
Overdinkel
Glane
Name *
Email *
Subject *
Type your message *
Send Message
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