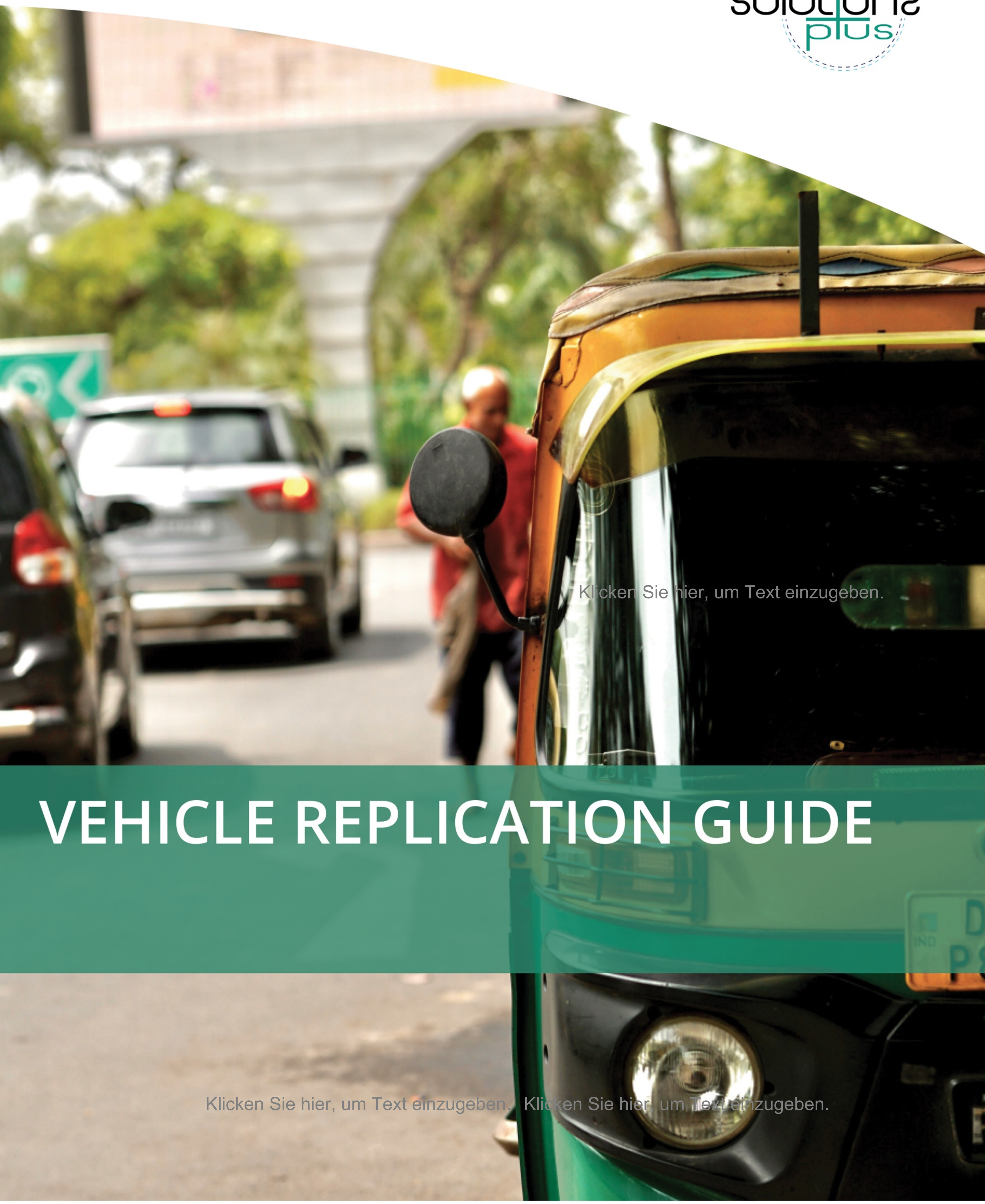


Klicken Sie hier, um Text einzugeben.

VEHICLE REPLICATION GUIDE

Klicken Sie hier, um Text einzugeben. Klicken Sie hier, um Text einzugeben.

This project has received funding from the European Union Horizon 2020 research and innovation Programme under grant agreement no. 875041

AUTHORS

Claus Bertram Bonerz M.Sc.
Mirco Althoff M.Sc.
Tobias Oetermann M.Sc.
Gabriel Salewski B.A.

Dr.-Ing. Dinesh Thirunavukkarasu
Manager Research Area Vehicle Concepts & HMI

Univ.-Prof. Dr.-Ing. Lutz Eckstein
Director

LAYOUT

Maria Giannisi

PHOTO

Amit Rana unsplash

ACKNOWLEDGEMENTS

This document is issued under the SOLUTIONSplus project, which is funded by the European Union’s Horizon 2020 research and innovation programme under Grant Agreement No. 875041.

PROJECT PARTNERS

Contents

Funded by
the European Union

Funded by
the European Union

Funded by
the European Union

1 Introduction

This document is part of the replication guide of the SOLUTIONSplus project. It is the aim of this project to support young companies and start-ups in various model cities in different regions in order to strengthen electromobility in the respective region. In a total of 10 model regions and a few replication regions, electrified vehicles were brought to the various markets. In order to lead other regions, cities and markets into a more sustainable future by strengthening electrified vehicles, the aim of this document is to build on the experiences and findings of the SOLUTIONSplus project and to provide a step-by-step guide for the development of the simplest possible, functional electric micro-vehicle. The guide is intended to help future founders and entrepreneurs to give shape to their vision of a more sustainable future in their individual markets. Of course, the document only provides a basis, which can in no way replace the development of an individual business model and individual research into competitors in the respective markets. Nevertheless, this document can be a great help in overcoming the initial challenges of a young company in order to ensure the company's long-term success on the market.

The vehicles presented in this guide are simple, newly developed electric vehicles whose central components are based on standard, commercially available components. Firstly, a simple, 3-wheeled vehicle, an electric tuktuk, is presented and introduced in chapter 4.1. Subsequently, chapter 4.2 outlines the development of a simple, electric motorcycle for transporting people or goods. In addition to the step-by-step description of vehicle development, further information and findings from the SOLUTIONSplus project are summarized. The relevant vehicles of the various model regions are presented, requirements for the vehicles are derived and target corridors for the vehicle parameters are defined. In addition, some basic design guidelines are presented, which must be taken into account in every development process. Finally, based on the lessons learned from the various companies, recommendations are made as to what needs to be considered when founding a company, developing a business model and selecting the strategic location of the company.

In any case, this document is intended solely as a starting support for setting up a company and can in no way replace detailed research of the respective market conditions. The basic vehicle parameters, the target values of the intended dynamic driving behavior and other use-case-specific factors must always be adapted by the entrepreneur to the specific customer group, the specific target market and the individual business model. However, the document provides a good starting point to support the individual vision of a more sustainable, green future of the individual market by developing electric vehicles.

Funded by
the European Union

2 General design

As a basis for the step-by-step guide of the development of the simple, functional electric micro-vehicles, basic design guidelines are presented below. These guidelines must be taken into account in the vehicle development process. In addition, decision-making support for the design of the two vehicle types is shown for basic concept decisions.

2.1 Design guidelines

It is essential to adhere to certain construction and manufacturing guidelines to ensure safety, durability, and functionality. To do so we have a selection of guidelines that equipe you with the absolute basics about the Materials to choose, basics in Mechanics, Dynamics and Kinematics and basics regarding the production.

Choice of Materials

Selecting the right materials is fundamental to the vehicle's performance and durability. The choice of materials should balance strength and weight. For instance, steel is known for its durability, while aluminum offers light weight and resistance to corrosion, making it a favorable option for various parts of the vehicle. Additionally, it is important to prioritize locally available and cost-effective materials. This approach not only reduces production costs but also supports local industries and minimizes the environmental impact associated with transporting materials over long distances.

Another crucial aspect is implementing measures for corrosion protection. Preventing rust and environmental damage is essential, and this can be achieved through methods such as cavity sealing and painting. Protective coatings not only extend the lifespan of the vehicle, but also maintain its aesthetic appeal.

Mechanics, Dynamics & Kinematics

Ensuring that the mass distribution of the vehicle is as low as possible is key to achieving a low center of gravity, which improves driving stability and handling. Proper mass distribution helps prevent rollovers and enhances overall vehicle performance. This aspect is closely linked to the overall design and structure of the vehicle. Minimizing oscillating masses is another important factor that enhances the vehicle's efficiency and handling. Reducing the weight of moving parts, such as wheels and suspension components, improves performance and responsiveness. By following these interconnected guidelines, individuals can effectively and safely construct a vehicle at home, ensuring that the final product is not only functional and durable but also safe for use.

Production

To effectively work on constructing the vehicle, utilizing the right tools and equipment is essential. Basic tools such as wrenches, screwdrivers, a welding machine and a drill are necessary for assembling and fabricating various parts. Additionally, the use of safety

Funded by
the European Union

equipment, including safety glasses, gloves, and hearing protection, is paramount to prevent injuries during the construction process. Precision is critical in fabrication work, hence measuring tools like calipers, measuring tapes and spirit levels are indispensable for ensuring accurate measurements and maintaining structural integrity.

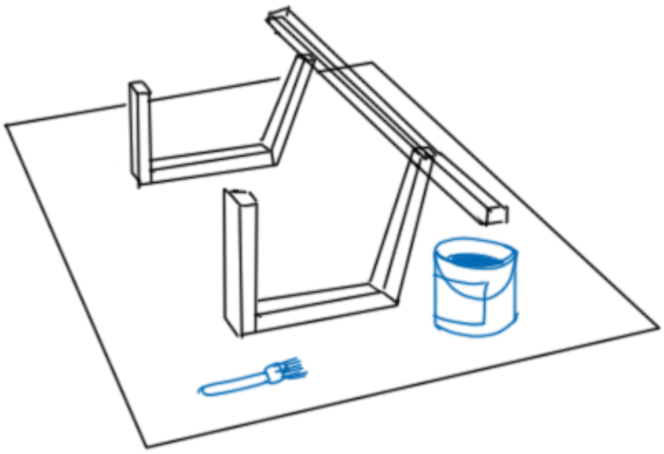
One of the foundational practices is to include deburring as a standard procedure in your manufacturing process. Deburring involves removing sharp edges and burrs from metal or wood parts, enhancing both safety and the quality of the finish.

The design of the vehicle frame plays a significant role in its stability and weight efficiency. Adopting the truss principle in the construction of the frame ensures a stable and lightweight structure. Carefully planning and constructing the joints to efficiently distribute loads is crucial. Strong, well-designed joints contribute significantly to the overall strength and durability of the frame. Utilizing triangular arrangements in the design maximizes structural integrity, as triangles are inherently stable shapes that help evenly distribute stress. Incorporating diagonal bracing further prevents deformation and increases the vehicle's strength, adding rigidity and support to withstand dynamic forces.

Try to develop vehicle components in modular design wherever possible to enable simpler and more efficient assembly and maintenance processes. Modular components can be easily replaced or upgraded without the need for extensive disassembly, reducing downtime and labor costs. This approach increases design flexibility and enables quicker adaptations to different vehicle models or customer requirements.

The following step shows the procedure for corrosion protection of metal components, especially after welding, using anti-corrosion paint.

Funded by
the European Union

Step	Instructions	Visual Assistance
	Components: • Full welded parts Tools: • Clean cloths • Degreaser • Primer • Rust protection paint • Brushes or spray equipment Process: a) Position parts for easy working position. b) Clean parts with degreaser and cloths. c) Follow instructions of paint supplier.	

Joining

There are various ways of joining components together. The simplest method of connecting components is to screw them together. This involves joining two or more components together using a screw connection. To do this, a hole must be drilled in at least one component for the screw to pass through. A hole can also be drilled in the second component and the screw secured on the back with a nut. Alternatively, a hole can be drilled in the second component and then a thread can be cut that directly receives and secures the screw. By tightening the screw, the two components to be joined are pressed against each other, creating a force-fit connection. A thread locker should be used for screw connections of safety-relevant components such as the brakes, chassis, steering, etc. A screw adhesive, self-locking nuts or wire can be used as a screw lock. Alternatively, joints can also be produced by welding. Here, the joining partners are joined by localized melting and the addition of welding filler material. It is important here that only identical materials can be joined. For example, it is not possible to weld aluminum to steel. A lot of heat is introduced into the material during welding, which can lead to distortion. It is therefore a proven procedure to first connect the two joining partners with spot welds in order to be able to react to welding distortions with little effort. After checking the geometry, the joint can be completely welded through. In addition, there is an increased risk of corrosion of the welded joints due to the strong heating during the welding process, which breaks up the passive layer of the steel that protects against rust and thus makes it more susceptible to oxidation. For this reason, the welds in particular should be protected against corrosion. Depending on local availability, adhesive joints are also conceivable, but these are not used in the following due to the difficult availability and time-consuming preparation of the joint.

Wheels

In addition to selecting the tires according to the geometric freedom of the vehicle and the size recommended in the guide, the geometry of the wheel hub must also be taken into account. The wheel hub can have various flanges to accommodate other components. A flange is often used to accommodate a disc brake. In this case, a circular hole pattern with inserted threads with specific bolt circle diameters, angular spacing of the individual holes and thread diameters is specified. This must match the hole pattern of the brake disc. It is also important to ensure that the hub supports the axle standard of the vehicle, as different vehicles can have different axle diameters and types. The installation width of the hub, which is determined by the distance between the inner sides of the dropouts of the frame, is also decisive. In addition, the number of spoke holes in the hub, which create the connection to the rim, influences the stability and load capacity of the wheel. These parameters must be carefully matched to the specific requirements of the vehicle, the intended use and the available materials in order to ensure optimum functionality and safety.

Climate Adaptation

Where necessary or desired, ensure that the heating, ventilation and air conditioning (HVAC) systems are capable of maintaining a comfortable indoor climate in both extremely hot and cold environments. This may involve the use of high-efficiency components, robust insulation and advanced climate control technologies to ensure reliable performance regardless of external weather conditions.

If the vehicle is to be used in rainy or flood-prone areas, technical solutions that can withstand water and moisture should be developed. This includes selecting water-resistant materials, sealing critical components and developing drainage systems that prevent water accumulation. Particular attention should be paid to protecting electrical systems and ensuring that the structural integrity of the vehicle is not compromised by water ingress.

In environments with high levels of dust and particulate matter, it may be advisable to install effective dust filtration systems. These systems should be capable of filtering out fine particles to protect both, the mechanical components of the vehicle and the comfort and health of the occupants. To ensure the longevity and efficiency of the filtration systems, regular maintenance access should also be considered.

2.2 Design decisions

The following is an outline of basic concept decisions relating to the design of the vehicles. The concept decisions are based on calculations and expert assessments. Nevertheless, the

Funded by
the European Union

final definition of the concepts depends on the individual requirements of the potential customers, the markets and local conditions and should be defined urgently taking these into account.

2.2.1 3-wheeler vs. 4-wheeler

With regard to the electrified TukTuk, the fundamental question is whether a three-wheeled or a four-wheeled vehicle concept is more likely to fulfill the requirements and demands typically placed on this vehicle class. Based on a technical comparison of the concept approaches, an analysis and subsequent concept recommendation is provided below.

2.2.1.1 Technical comparison

To establish a quantifiable basis for decision-making between a 3-wheeler and a 4-wheeler, a pairwise comparison of evaluation criteria was initially conducted. This approach facilitates the weighting of the selected criteria shown below.

- Chassis & Body
    - Frame
        - Weight
        - Stiffness
        - Geometry Complexity
    - Suspension & Steering
        - Weight
        - Part Complexity
        - Kinematic Complexity
    - Wheels
        - Size
- Drive train
    - Complexity
- Battery
    - Easy integration
    - Available space
- Body hats
    - Flexibility / available space
- Assembly
    - Complexity
- Maintenance
- Production complexity

The expert team selected the most relevant criteria and listed them in a table for the pairwise comparison (Figure 1).

Funded by
the European Union

Pairwise comparison															
		Frame			Suspension & Steering			Wheels	Drive Train	Battery		Body hats	Assembly		
	with *3… more important* *2… just as important* *1… less important*	Weight (C1)	Stiffness (C2)	Complexity (K3)	Weight (C4)	Part Complexity (C5)	Kinematic Complexity (C6)	Size (C7)	Complexity (C8)	Easy integration (C9)	Available Space (C10)	Flexibility / available space (C11)	Complexity (C12)	Maintenace (C13)	Production Complexity (C14)
Frame	Weight (C1)		1	1	3	1	1	1	1	1	1	1	1	1	1
	Stiffness (C2)	3		3	3	2	2	3	2	2	2	3	3	3	2
	Complexity (K3)	3	1		3	2	1	3	2	2	3	2	2	2	2
Suspension & Steering	Weight (C4)	1	1	1		1	1	2	1	1	1	1	1	1	1
	Part Complexity (C5)	3	2	2	3		2	3	2	3	3	2	2	2	2
	Kinematic Complexity (C6)	3	2	3	3	2		3	2	3	3	3	2	2	2
Wheels	Size (C7)	3	1	1	2	1	1		1	1	1	1	1	1	1
Drive Train	Complexity (C8)	3	2	2	3	2	2	3		3	3	3	2	2	2
Battery	Easy integration (C9)	3	2	2	3	1	1	3	1		2	2	2	2	2
	Available Space (C10)	3	2	1	3	1	1	3	1	2		2	1	1	1
Body hats	Flexibility / available space (C11)	3	1	2	3	2	1	3	1	2	2		1	1	1
Assembly	Complexity (C12)	3	1	2	3	2	2	3	2	2	3	3		2	2
	Maintenace (C13)	3	1	2	3	2	2	3	2	2	3	3	2		2
	Production Complexity (C14)	3	2	2	3	2	2	3	2	2	3	3	2	2	
	Total	37	19	24	38	21	19	36	20	26	30	29	22	22	21
	Weighting	0,1016484	0,0521978	0,0659341	0,1043956	0,0576923	0,0521978	0,0989011	0,0549451	0,0714286	0,0824176	0,0796703	0,0604396	0,0604396	0,0576923

Figure 1: Criteria 3- vs 4-wheeler and pairwise comparison

The weighting shown in Figure 1 was determined through comparing the individual criteria in pairs as objectively as possible. Subsequently, the two concepts, the three-wheeler and the four-wheeler, were evaluated by four different experts regarding the degree to which they met the selected criteria. The results clearly demonstrate the advantage of the three-wheeler over the four-wheeler.

0 for unsatisfactory, 1 for just bearable, 2 for sufficient, 3 for good and 4 for very good										
			Concept 1: 4-wheeler				Concept 2: 3-wheeler			
Criteria (C)		*Weighting*	Score				Score			
			Expert 1	Expert 2	Expert 3	Expert 4	Expert 1	Expert 2	Expert 3	Expert 4
Frame	Weight (C1)	0,10164835	2	1	1	1	3	4	3	3
	Stiffness (C2)	0,0521978	3	2	3	3	3	3	2	2
	Complexity (K3)	0,06593407	2	1	2	3	3	4	3	3
Suspension & Steering	Weight (C4)	0,1043956	2	1	2	2	3	3	3	3
	Part Complexity (C5)	0,05769231	1	1	2	1	3	4	2	3
	Kinematic Complexity (C6)	0,0521978	1	1	2	2	4	4	3	3
Wheels	Size (C7)	0,0989011	3	2	4	4	3	3	3	3
Drive Train	Complexity (C8)	0,05494505	3	2	3	1	3	3	3	3
Battery	Easy integration (C9)	0,07142857	3	3	3	4	3	3	3	4
	Available Space (C10)	0,08241758	3	3	4	4	3	3	3	3
Body hats	Flexibility / available space (C11)	0,07967033	3	2	3	3	3	3	4	3
Assembly	Complexity (C12)	0,06043956	2	1	1	1	3	4	3	3
	Maintenace (C13)	0,06043956	2	1	1	1	3	4	3	3
	Production Complexity (C14)	0,05769231	2	1	1	1	3	4	4	3
Total			2,32967033	1,59340659	2,34065934	2,31043956	3,0521978	3,45604396	3,02747253	3,01923077
Total Weighting			8,574175824				12,55494505			

Figure 2: Concept evaluation 3- vs 4-wheeler

2.2.1.2 Implications

The effects of adapting the concept from a 3-wheeled to a 4-wheeled vehicle are immense. This fact is also highlighted by the experts' technical assessment. The concept adaptation would have the greatest impact on the design and kinematics of the front axle, including the steering. The 3-wheeled vehicle concept has a simple steering layout on the front axle, as is familiar from motorcycles or scooters. Especially for the new development of an electric vehicle, the simplicity of the steering design at this point is a great advantage. A 4-wheeled vehicle, on the other hand, must be implemented in the form of a significantly more complex steering design for the front axle, including more elaborate wheel suspension and kinematics. Along with the significantly more complex design and kinematics of the front axle, this results

Funded by
the European Union

in a significantly higher proportion of relevant components and thus a higher use of resources. This fundamental efficiency disadvantage is increased by the associated increase in vehicle weight, as an increased vehicle weight has an impact on the vehicle's driving resistance, especially the gradient resistance. For this reason, the selection of the drivetrain and the battery capacity would have to be adapted to the different driving resistance to still be able to achieve the required driving parameters (range, top speed, etc.). An increase in the engine power would increase the engine weight and the price of the drivetrain. Due to the increased payload, the battery capacity would also have to be increased in order to realize the same range per swap. Again, the increase in battery capacity has a negative impact on the vehicle weight and the cost structure of the vehicle.

The necessary increase in the power of the drivetrain and the energy capacity of the battery described above would therefore result in a further increase in weight, so that a new recalculation including an increase in the power and energy capacity may be necessary, which is known as the weight loop effect.

2.2.1.3 Recommendations

The choice of vehicle concept is highly dependent on the individual requirements and the needs of the potential target group. Nevertheless, based on the overall objective of this document and the previous implications, a general recommendation can be made which clearly relates to the 3-wheeled vehicle. The most important reason for this is, that the aim of this document is to develop a simple, functional, but above all efficient and environmentally friendly vehicle. Particularly, in view of the fact that the vehicle weight would increase significantly due to the necessary adaptions of the front axle, among other things, and would result in a significant increase in the use of materials, the implementation of a 4-wheeled vehicle must be well considered. The increasing complexity of the front axle design should also be taken into consideration. Based on the intended use case, the power requirement calculations and the axle load distribution, there is no significant advantage of a 4-wheeled vehicle concept for the expectable driving dynamics design of the concept. It is therefore recommended to carefully discuss a conceptual adaptation from 3 wheels to 4 wheels when designing the vehicle in consultation with the potential users of the vehicle, the relevant authorities and the intended business model.

2.2.2 2-seater vs. 3-seater

With regard to the electrified motorcycle, the concept layout is defined against the background of the required payload. Specifically, a concept decision is made based on the question of whether a two-seater or a three-seater vehicle concept seems more appropriate for development. Finally, an assessment is made based on a recalculation of the required vehicle performance, the battery capacity and the need to adapt the concept with regard to the wheelbase.

Funded by
the European Union

2.2.2.1 Power requirement calculation and weight distribution

In contrast to the previous vehicle concept, a technical comparison for the design decision between a 2-seater and a 3-seater vehicle is not appropriate. The reason for this is that the differences between the two variants are less comprehensive compared to the previous vehicle concept. The basic design of the vehicle remains the same, only the payload and weight distribution change. Depending on the vehicle concept, the wheelbase may also change, but there would be no more extensive changes than this. The higher payload does change the driving resistance, in particular the gradient resistance. For this reason, the selection of the drivetrain and the battery capacity would have to be adapted to the different driving resistance.

The following is a calculation of the adapted power requirement of the drivetrain, taking into account the adapted payload for a 3-wheeled vehicle. To understand the power requirement calculation and the calculation of the battery capacity of the vehicle, please also refer to the later chapter 4.2.2.1.1 and 4.2.3.1. For the sake of simplicity, it is initially assumed that the wheelbase of the vehicle does not change. Following the power requirement calculation, a center of gravity calculation is carried out to ensure that the vehicle does not become too light on the front axle, which would result in instability of the vehicle. Finally, based on the results of the analysis, the implications of changing the vehicle concept from a two-seater vehicle to a three-seater vehicle are summarized and a recommendation is made.

<u>*Adapted vehicle parameters:*</u>

Total vehicle weight (including payload): $m = 360\ kg$

All other vehicle parameters remain the same, see chapter 4.2.2.1.1

<u>Calculation:</u>

Rolling resistance force:

$$F_{3\text{-}seat,roll} = 0.01 \cdot 360\ kg \cdot 9.81 \frac{m}{s^2} = 35.316\ N$$

Air resistance force:

$$F_{3\text{-}seat,air} = F_{air} = 116.727\ N$$

Inclination resistance force:

$$F_{3\text{-}seat,inclination} = 360\ kg \cdot 9.81 \frac{m}{s^2} \cdot sin(7°) = 430.394\ N$$

The total resistance force:

$$F_{3\text{-}seat,tot} = 35.316\ N + 116.727\ N + 430.394\ N = 582.437\ N$$

Funded by
the European Union

As described in chapter 4.2.2.1.1 the vehicle is not designed to go the maximum speed at the maximum inclination. For this reason, a distinction is made below between the power requirement on ground level (maximum speed) and the power requirement for the maximum incline (50% of the maximum speed). The higher of the two calculated power demands defines the necessary power of the drivetrain.

The required drive power on ground level:

$$P_{3\text{-}seat,ground} = F_{3\text{-}seat,tot} \cdot v_{max} = \left(F_{3\text{-}seat,roll} + F_{air}\right) \cdot v_{max}$$

$$P_{3\text{-}seat,ground} = (35.316\ N + 116.727\ N) \cdot\ 16.5\frac{m}{s} = 2508.71\ W\ \ \approx 2.5\ kW$$

The required drive power for maximal inclination ($v_{inclination} = 0.5 \cdot v_{max} = 8.25\frac{m}{s}$):

$$P_{3\text{-}seat,inclination} = F'_{3\text{-}seat,tot} \cdot v_{inclination} = \left(F_{3\text{-}seat,roll} + F'_{air} + F_{3\text{-}seat,inclination}\right) \cdot v_{inclination}$$

$$F'_{air} = 29.182\ N$$

$$P_{3\text{-}seat,inclination} = (35.316\ N + 29.182\ N + 430.394\ N) \cdot\ 8.25\frac{\mathrm{m}}{\mathrm{s}} = 4082.859\ W\ \ \approx 4.1\ kW$$

The required motor power $P_{3\text{-}seat,req}$ is now determined using the larger of the required powers $(P_{3\text{-}seat,ground}, P_{3\text{-}seat,inclination})$.

$$P_{3\text{-}seat,req} = \max\left(P_{3\text{-}seat,ground}, P_{3\text{-}seat,inclination}\right) = P_{3\text{-}seat,inclination} = 4.1\ kW$$

The electrical motor output $P_{3\text{-}seat,electr}$ now depends on the efficiency of the motor, which is assumed here to be $\eta = 0.85$.

$$P_{3\text{-}sea,electr} = \frac{P_{3\text{-}seat,inclination}}{\eta} = \frac{4.1\ kW}{0.85} = 4.82\ kW$$

Due to the increased power demand, it is also necessary to adapt the battery layout in order to maintain the same target range.

$$F''_{3\text{-}seat,tot} = F_{3\text{-}seat,roll} + F''_{3\text{-}seat,air} + F''_{3\text{-}seat,inclination}$$

$$F_{3\text{-}seat,roll} = 35.316\ N$$

$$F''_{3\text{-}seat,air} = F''_{air} = 42.875\ N$$

$$F''_{3\text{-}seat,inclination} = 360\ kg \cdot 9.81\frac{m}{s^2} \cdot sin(1.1°) = 67.798\ N$$

$$F''_{3\text{-}seat,tot} = 35.316\ N + 42.875\ N + 67.798\ N = 145.989\ N$$

Funded by
the European Union

$$P''_{3\text{-}seat,req} = F''_{3\text{-}seat,tot} \cdot 10\,\frac{\mathrm{m}}{\mathrm{s}} = 1459.89\ W\ \approx 1.46\ kW$$

$$P''_{3\text{-}seat,electr} = \frac{P''_{3\text{-}seat,req}}{\eta} = \frac{1.46\ kW}{0.85} = 1.72\ kW$$

$$\Delta E_{3\text{-}seat} = P''_{3\text{-}seat,electr} \cdot \Delta t = P''_{3\text{-}seat,electr} \cdot \frac{s}{v} = 1.72\ kW\ \cdot \frac{60\ km}{36\,\frac{km}{h}} = 2.87\ kWh$$

In addition to recalculating the power requirement of the vehicle concept, it is also necessary to consider the distribution of the vehicle weight including the total payload on the two axles. The background to these calculations is to ensure that the vehicle does not become too light on the front axle, which can lead to instability in handling and dangerous driving behavior during the journey. The dangerous riding behavior can arise from the fact that the front wheel can no longer transmit sufficient lateral control forces to achieve the desired maneuver when the front wheel becomes too light. In the following, the weight distribution between the front and rear axles is recalculated by adjusting the payload. Finally, based on the calculations, a decision recommendation is made for the concept decision between a 2-seater and a 3-seater vehicle.

$$m_{vehicle} = \sum m_i = 360\ kg$$

$$x_{gravitycenter} = \frac{\sum m_i \cdot x_i}{m_{vehcile}} \approx\ 1612\ mm$$

$$i_{axleload,rear} = \frac{x_{gravitycenter}}{x_{wheelbase}} \approx\ 87\%$$

$$i_{axleload,front} = 1 - \frac{x_{gravitycenter}}{x_{wheelbase}} \approx\ 13\%$$

2.2.2.2 Implications

As can be seen from the previous chapter, the expansion of a 2-seater to a 3-seater concept has several implications for the vehicle concept. The power requirement calculation shows that based on the higher payload of a 3-seater vehicle, the engine power would have to be increased by 27% to $4.82\ kW$, which in turn increases the engine weight and the price of the drivetrain. Due to the increased payload, the battery capacity would also have to be increased in order to realize the same range per swap. The capacity would have to be increased by 19% to $2.87\ kWh$. Again, the increase in battery capacity has a negative impact on the vehicle weight and the cost structure of the vehicle.

The necessary increase in the power of the drivetrain and the energy capacity of the battery described above would therefore result in a further increase in weight, so that a new recalculation including an increase in the power and energy capacity may be necessary. The described effect of the weight loop is further complicated when considering the weight distribution between the axles of the vehicle. As the adapted calculation of the weight distribution on the front and rear axles of the vehicle shows, there is an essential risk for a 3-seater vehicle that the front wheel will be too light to transfer the necessary dynamic forces to steer the vehicle safely in traffic.

For the reason described above, it would be necessary to extend the wheelbase of the vehicle to the rear in order to adapt the concept from 2 to 3 seats. Extending the wheelbase, on the other hand, requires significant concept adjustments. The adjustments to the concept would result in a significantly increased use of materials in the structure, which in turn would lead to a significant increase in vehicle weight. Based on the increased vehicle weight, it would again be necessary to adapt the drivetrain and the battery in order to still be able to achieve the required driving parameters (range, top speed, etc.).

Overall, the concept adaptations from a 2-seater to a 3-seater concept would therefore have a decisive influence on the vehicle concept, the efficiency of the vehicle and the price.

2.2.2.3 Recommendations

The choice of vehicle concept is highly dependent on the individual requirements and the needs of the potential target group. Nevertheless, based on the overall objective of this document and the previous calculations, a general recommendation can be made which clearly relates to the 2-seater vehicle. The most important reason for this is that the aim of this document is to develop a simple, functional but above all efficient and environmentally friendly vehicle. Particularly, in view of the fact that the vehicle weight would increase significantly due to the necessary increased wheelbase, among other things, and would result in a significant increase in the use of materials, the implementation of a 3-seater vehicle must be well considered. For this reason, it is advisable to consider the use of the vehicle capacity. If the third seat is not occupied by a third person for the majority of journeys, substitution by another solution (possibly use of a second vehicle) is advisable, as the efficiency of the individual vehicles would outweigh in the overall consideration. Of course, depending on the specific application and use case, the added value of a third driver's seat may be essential and cannot be substituted by the use of a second vehicle. In this case, the design of a 3-seater vehicle can be considered. In summary, this decision must be carefully considered and made in close cooperation with the future users and the targeted business model.

Funded by
the European Union

3 Requirements for design decisions

A detailed analysis of the requirements that the product must meet is essential for the product development process. As the product development process progresses, changes and adaptations to the underlying product become exponentially more expensive, so that an early and profound concept decision is necessary. VDI 2221, which describes the classic design process, defines that only the completeness and sufficient depth of detail of the requirements determination can guarantee a successful product development process.

3.1 Overview over the relevant demo vehicles of the SOLUTIONSplus project

The first step is to define the technical target parameters of the vehicle to be developed. This is an essential part of determining the requirements. The target parameters are essentially based on the use case in which the product will be used. In addition to the use case, customer requirements also have a significant influence. This aspect is discussed in detail in chapter 3.2. The following section provides an overview of the vehicles developed and used in the SOLUTIONSplus project as part of the demo activities. It is important to note that this is only a representation of the vehicles that correspond to the vehicle concept envisaged in this development guideline. For this reason, only electric three- and two wheeled vehicles are listed below.

3.1.1 Electric 3-wheeled vehicles

The focus of this guide is on simple but functional three-wheeled vehicles. The targeted vehicle category can be used to transport both people and goods. The vehicles are powered by an electric motor, which is operated by an on-board battery. With regard to the battery, there are different operator approaches for the vehicles, which vary between exchangeable and permanently installed batteries for plug-in charging. The key requirements for the strategy decision are discussed in Chapter 3.2.

3.1.1.1 Kathmandu – Nepal

In Kathmandu, as part of the SOLUTIONSplus project, a market available vehicle, the Safa Tempo, was converted from a conventional internal combustion engine drive to a battery-electric drive train. The drivetrain from Valeo (eAcess technology) was used for the conversion. An overview of the most relevant technical data is listed below.

- Powertrain: Valeo (eAccess technology)
- Motor: 6 kW
- Max. Speed: 45-60 km/h
- Battery: 10 kWh
- Battery Swapping technology
- Driving Range: ~85-130 km

Funded by
the European Union

Three different derivatives of the vehicle have been built, a passenger EV as a cab or for the local transportation, a municipal waste e-trike and a cargo e-trike.

Figure 3: Kathmandu demo vehicle remodeled Safa Tempo

3.1.1.2 Dar es Salaam – Tanzania

In Dar es Salaam, new vehicles were built by a total of 4 different local companies as part of the SOLUTIONSplus project. The vehicles are mostly new developments and partly converted from market-available vehicles. The vehicles have a comparable range of technical specifications. An overview of the range is given below.

- Motor: 3-4 kW
- Max. Speed: 45-60 km/h
- Battery: 5.46-12 kWh (mostly around 7.2 kWh)
- Partly Battery Swapping technology, partly change in Strategy: From Battery swapping to Plug-In Only (due to driver's demand)
- Driving Range: 80-150 km (mostly around 100 km)

Figure 4: Dar es Salaam demo vehicle

3.1.1.3 Montevideo – Uruguay

The three-wheeled vehicle, which was used in Montevideo as part of the SOLUTIONSplus project, takes a different conceptual approach compared to the vehicles presented above. In contrast to these, the two-wheeled axle is not located at the rear of the vehicle, but at the front. The single rear wheel of the vehicle is driven. The vehicle concept results in a significantly higher complexity of the front axle and the steering design of the vehicle. In addition, compared to the previous vehicles, the transport volume of the vehicle is severely limited, both in terms of transporting people and goods. For the reasons mentioned, especially with regard to the greater complexity of the overall concept, the concept design does not fall within the scope of this guide and is therefore not considered further.

Funded by
the European Union

Figure 5: Montevideo demo vehicle

3.1.1.4 Summary of technical specifications of the demo vehicles

	Kathmandu – Nepal		
Parameters	**Passenger EVmini Safa Tempo**	**Municipal waste etrike**	**Cargo e trike**
L*W*H (mm)	3500*1330*1770	3500*1330*1770	3800*1600*2100
Gross vehicle weight (kg)	1200	1200	1200
Wheelbase (mm)	2600 mm	2600 mm	2600 mm
Motor (kW)	6 (Valeo eAccess technology)	6 (Valeo eAccess technology)	6 (Valeo eAccess technology)
Max. speed (km/h)	60	45	45
Payload (kg)	630	500	350
Battery (kWh)	10 (Li-fe4)	10 (Li-fe4)	10 (Li-fe4)
Driving range (km)	130	85	85
Charging time (h)	5	4	4
Climbing ability (%)	12	12	12
Ground clearance	175mm	175mm	175mm
Transmission	Single speed reducer	Single speed reducer	Single speed reducer
Front brake	Disc brake	Disc brake	Disc brake
Rear brake	Oil brake	Oil brake	Oil brake
Front suspension	Coil Spring and Shock Absorber	Coil Spring and Shock Absorber	Coil Spring and Shock Absorber
Rear suspension	Coil Spring and Shock Absorber	Coil Spring and Shock Absorber	Coil Spring and Shock Absorber
Roof type	NA	NA	NA
Tires	Front 4.00-12/Rear 4.00-12	Front 4.00-12/Rear 4.00-12	Front 4.00-12/Rear 4.00-12

Funded by
the European Union

	Dar es Salaam – Tansania			
Parameters	**Company: TRI Strategy: Battery Swapping**	**Company: Ekoglobe Change in Strategy: No Battery Swapping**	**Company: Sescom**	**Company: AutoTruck**
L*W*H (mm)	2700*1300*1780	2650*1300*1700	NA	NA
Gross vehicle weight (kg)	400	430	NA	900
Wheelbase (mm)	NA	NA	NA	NA
Motor (kW)	4	4 (PSMS)	3	3
Max. speed (km/h)	60	55	NA	NA
Payload (kg)	NA	NA	NA	500-600
Battery (kWh)	7.2 (LFP) 72V100A (swappable)	7.4 (Lithium) (1. Shipment) 12 (LFP) (2.Shipment)	7.56 (Lithium 72VDC)	5.46 (72V90AH Lithium)
Driving range (km)	90-100	100 (1.Shipment) 150 (2.Shipment)	100	80-100
Charging time (h)	2.5-8	2-5.5	NA	NA
Climbing ability (%)	13	NA	NA	NA
Ground clearance	NA	NA	NA	NA
Transmission	NA	direct drive - transmission	NA	NA
Front brake	Drum (170mm oil drum)	Hydraulic Powered + Drum Brake	NA	NA
Rear brake	Drum (170mm oil drum)	Hydraulic Powered + Drum Brake	NA	NA
Front suspension	Independent	Double Trailing Arm Independent Suspension	NA	NA
Rear suspension	Independent	Double Trailing Arm Independent Suspension	NA	NA
Roof type	NA	Canvas	NA	NA
Tires	NA	4:00-10 Radial universal tires	NA	NA

3.1.2 Electric 2-wheeled vehicles

Two-wheeled electric motorcycles are another relevant vehicle category for this guide. In this case, the focus is on a structure that is as uncomplex and functional as possible again. For the two-wheeled vehicle, the focus is also on a cab and a cargo variant. In contrast to the three-wheeled vehicles, a battery swap strategy is consistently pursued for the two-wheeled vehicles. The arguments for the strategy decision can be found in chapter 3.2.

Funded by
the European Union

3.1.2.1 Hanoi – Vietnam

A market-available electric scooter has been used in Hanoi as part of the SOLUTIONSplus project. As part of the project, an on-board unit was developed that enables professional operation of the scooter via an app (fleet management, vehicle rental, bookings, etc.). The scooter itself has replaceable batteries and is distributed by Vinfast. The technical data of the vehicle is shown below.

- Motor: 1.1 kW
- Max. Speed: 35 km/h
- Battery: 22 Ah
- Battery swapping technology
- Driving Range: 75 km

Figure 6: Hanoi demo vehicle VinFast Ludo

3.1.2.2 Kigali – Ruanda

In Kigali, the SOLUTIONSplus project supported a start-up (Ampersand) that has developed and is building its own motorcycle with an electric drive and replaceable battery. The vehicles are rented out to drivers via an app for the local transportation of people. An overview of the vehicle's technical data is provided below.

- Motor: 5 kW (nominal), 8 kW (peak)
- Max. Speed: 80 km/h
- Battery swapping technology
- Driving Range: 65 km

Figure 7: Hanoi demo vehicle Ampersand

Funded by
the European Union

3.1.2.3 Summary of technical specifications of the demo vehicles

	Hanoi – Vietnam	Kigali – Ruanda
	VinFast Ludo	**Ampersand**
Length x Width x Height (mm)	1700 x 715 x 1070	NA
Wheelbase (mm)	1157	NA
Weight (kg)	68	NA
Max. occupancy	2 persons	NA
Payload (kg)	140	NA
Motor (kW)	1.1	5 (nominal) 8 (peak)
Power unit	Bosch brushless DC motor	Brushless DC motor
Max. torque	NA	67
Range (km)	75	65
Charging time (h)	4.8	NA
Top speed (km/h)	35	80
Battery type	Swappable lithium-ion	Swappable lithium-ion
Battery capacity (Ah)	22	NA
Further battery details	Power: 1.2 kW IP57	IP67 battery enclosure, modular battery system with onboard safety and intelligence
Front brake	Disc brake	Hydraulic disc brakes; 2kW onboard regenerative breaking
Rear brake	Drum brake	Hydraulic disc brakes; 2kW onboard regenerative breaking
Front shock absorbers	Oil spring dampers	NA
Rear shock absorbers	Double shock absorber	NA
Tires	70/90 - 14; 80/90 - 14	NA
Others		Field orientation control custom controller Built in telematics recording up to 50 data points/sec 40W LED high-power front light

Funded by
the European Union

3.2 Definition of Requirements

According to Feldhusen and Grote[1], documents, products and persons can generally be identified as sources of requirements, see Figure 8.

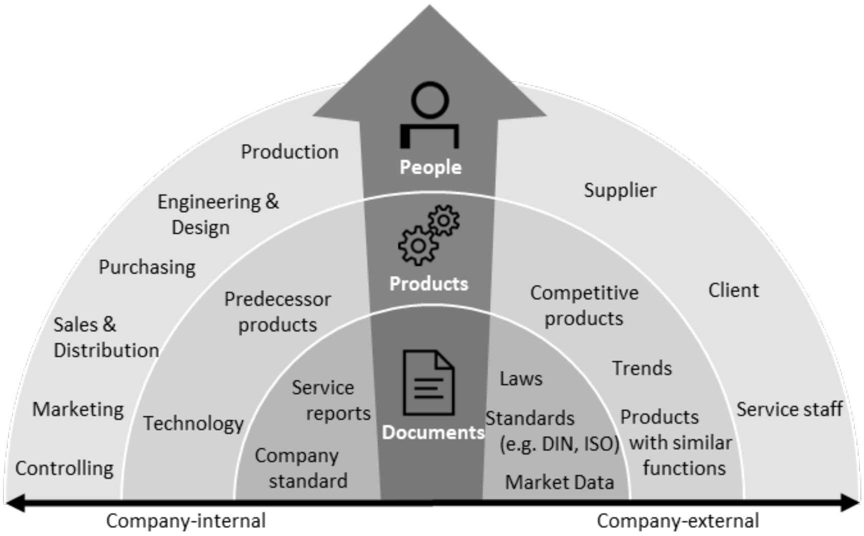


Figure 8: Presentation of possible sources of requirements[1]

Relevant documents in the form of standards and laws are to be given priority as documents. Some legislative requirements that had to be taken into account when implementing the individual vehicle concepts are known from the various model regions of the SOLUTIONSplus project. Unfortunately, however, it is not possible to make generic statements on legislative requirements from the findings, as the conditions in the various countries differ greatly from one another. It is therefore only possible to give a general indication that detailed research should be carried out into the standards and legislation relevant to the concept in the respective target market before the actual conceptual phase of the individual vehicle concept begins. In any case, it is advisable to inform the regulatory authorities about the planned development at an early stage and to seek advice in this regard. In many cases, it is in the government's interest to support young entrepreneurs in their projects, especially if they want to contribute to a more sustainable future for the region in question with innovative electrified vehicle concepts. Since infrastructure adjustments beyond vehicle concept development will have to be made anyway, especially against the background of a potential charging infrastructure, a strategic partnership with the relevant government departments is advisable. Under certain circumstances, cooperation with the relevant government authorities can also make it possible to use funding to cover the initial costs of setting up a business. The following is an overview of potential document types that should be taken into account in the individual research:

---

[1] FELDHUSEN, J., GROTE, K.-H.
Pahl/Beitz Konstruktionslehre
Springer Berlin Heidelberg, Berlin, Heidelberg 2013

Funded by
the European Union

- Regulations for the general approval of vehicles
- Regulations for approval of electric vehicles
- Regulations for approval of lightweight vehicles
- National Climate Change Strategies
- National Sustainable Development Strategies
- National Green Growth Strategies
- Environmental Protection Laws

Requirements based on relevant products can be obtained in the first instance from the overview of developed or converted vehicles from the model regions of the SOLUTIONSplus project. A detailed description of the relevant vehicles from the various model regions has been provided in chapter 3.1. Based on the reference vehicles shown and some general design decisions for simplicity reasons, a rough target corridor for individual vehicle parameters can be derived for the target vehicles, the 3-wheeled vehicle and the 2-seater motorcycle. The overview is shown below. **Note: The following list is only a rough identification of target corridors for the vehicle parameters. In each individual case, it must be checked which vehicle parameters must be selected for the individual concept in order to achieve the individual requirements and target customer values.**

Target corridor: Electric 3-wheeled vehicle

Parameters	Target corridor for vehicle parameters
L*W*H (mm)	3000*1200*1700
Wheelbase (mm)	2100
Gross vehicle weight (kg)	1100
Motor (kW)	5-6
Max. speed (km/h)	50
Payload (kg)	600
Battery (kWh)	10
Driving range (km)	100
Climbing ability (%)	12
Ground clearance (mm)	170
Transmission	Single speed reducer
Front brake	Disc brake
Rear brake	Disc brake
Front suspension	Fork
Rear suspension	Leaf springs

Funded by
the European Union

Target corridor: Electric 2-wheeled vehicle

Parameters	Target corridor for vehicle parameters
Length x Width x Height (mm)	2000*700*1000
Wheelbase (mm)	1500
Weight (kg)	100
Max. occupancy	2 persons
Payload (kg)	180
Motor (kW)	3-4
Range (km)	60 (per swap)
Top speed (km/h)	60
Battery type	Swappable lithium-ion
Battery capacity (kWh)	2-3
Front brake	Disc brake
Rear brake	Disc brake
Front shock absorbers	Fork
Rear shock absorbers	Oil spring dampers

It is crucial to consider the available local infrastructure. Existing workshops and garages can be utilized, and partnerships with local entities can be formed to provide additional resources. For example, for painting tasks, it is necessary to identify clean and dust-free areas to ensure high-quality surface coatings. Parallelizing workflows through efficient use of available spaces can increase productivity.

Another essential element is the availability of machinery. If specific machines are not available, creative alternatives must be developed. For instance, a pipe bending machine can be replaced with a homemade device using a car jack. Alternatively, various profile shapes can be achieved by cutting, bending and then welding profiles. Equally important is the availability of tools. If a welding machine is missing, bolted connections can be used to ensure stable joints. Recycling opportunities for production waste also offer cost-saving and environmentally friendly production possibilities. Scrap metal can be used for non-structural parts, providing both ecological and economic benefits.

The use of alternative energy sources is also significant. Solar panels can be used to power small machines, leading to independence from unstable power grids and promoting the use of renewable energy.

Funded by
the European Union

The number and expertise of available personnel play a central role. Task parallelization can enhance efficiency. If sufficient expertise is not available, it can be built through training. It is advisable to establish partnerships with local vocational schools to further educate the employees.

The procurement of materials and components is another important aspect. Local resources such as bicycles or carts can be utilized to reduce costs and increase efficiency. Collaborations with local transport providers can also be advantageous.

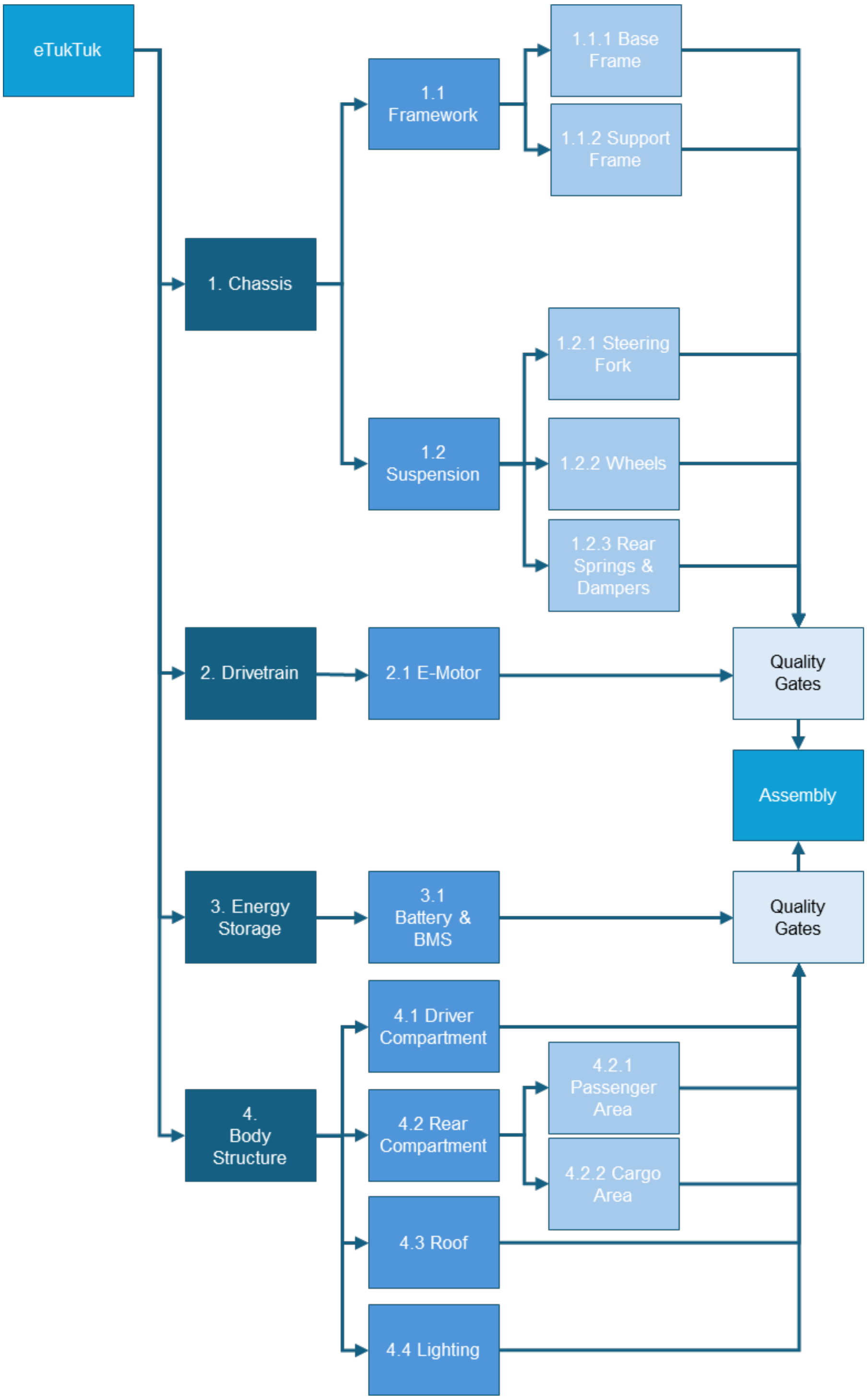
When selecting suppliers, import duties and restrictions must be considered. The availability and cost of locally available raw materials must also be taken into account in planning. For example, steel is easy to weld and process, whereas aluminum is easy to process but difficult to weld. Natural materials like wood are extremely easy to process and cheaply available, but are susceptible to structural damage due to decay.

Funded by
the European Union

4 Step-by-Step instruction guide

This is the Step-by-Step instruction guide for the eTukTuk. It is divided into four main categories that structure the following chapters of the document. The guide takes you through all the necessary processes for manufacturing, selecting and assembling all the necessary parts and components to develop your own eTukTuk.

4.1 eTukTuk



Funded by the European Union

The basis of some of the following chapters is the calculation of the weight distribution of the vehicle weight on the front and rear axle. Knowledge of the weight distribution between the front and rear axles is essential for the chapters on designing the suspension and damping of the vehicle. The following is a schematic representation of how a basic calculation of the axle load distribution can be carried out. A corresponding calculation is then carried out for the vehicle concept presented, thus laying the foundation for further calculations.

ATTENTION: The following calculations depend heavily on the individual vehicle concept, the weights of the individual components as well as the choice of materials, the wheelbase, etc. It is therefore essential that a calculation adapted to the individual concept is carried out, which serves as the basis for the design of the spring and damper system.

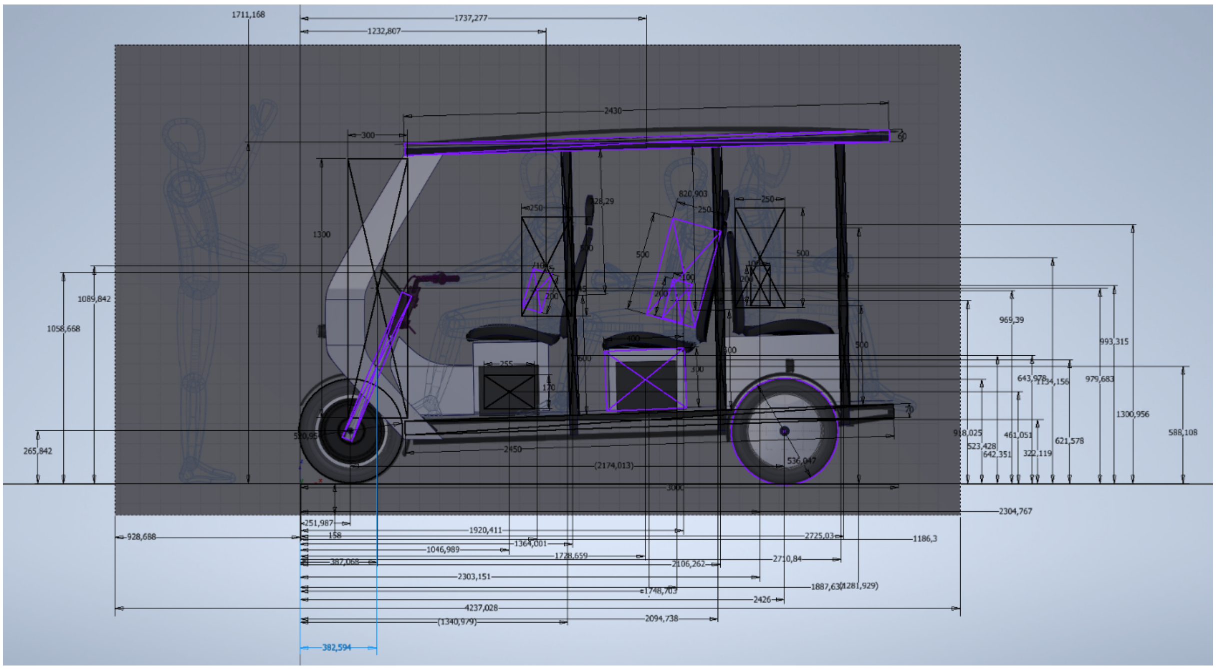


Figure 9: Concept Sketch of the eTukTuk

To calculate the axle load distribution, the parts and components relevant to the vehicle weight are required with their respective position in relation to a reference point (in this case the front of the vehicle) and the individual weight. An individual, geometric center of gravity (geometric center of the components) must be assumed for the individual parts and components. From this individual center of gravity, the position in relation to the reference point is calculated. The position of the center of gravity results from a summation of the individual weights and distances from the reference point divided by the total weight of the relevant component. A comparison with the position of the center of gravity and the wheelbase then results in the required axle load distribution. In this case, only the position of the center of gravity in x direction (longitudinal direction of the vehicle) is important for the axle load distribution.

Funded by
the European Union

$$m_{vehicle} = \sum m_i = 1100\ kg$$

$$x_{gravitycenter} = \frac{\sum m_i \cdot x_i}{m_{vehcile}} \approx\ 1745\ mm$$

$$i_{axleload,rear} = \frac{x_{gravitycenter}}{x_{wheelbase}} \approx\ 79\%$$

$$i_{axleload,front} = 1 - \frac{x_{gravitycenter}}{x_{wheelbase}} \approx\ 21\%$$

4.1.1 Chassis eTukTuk

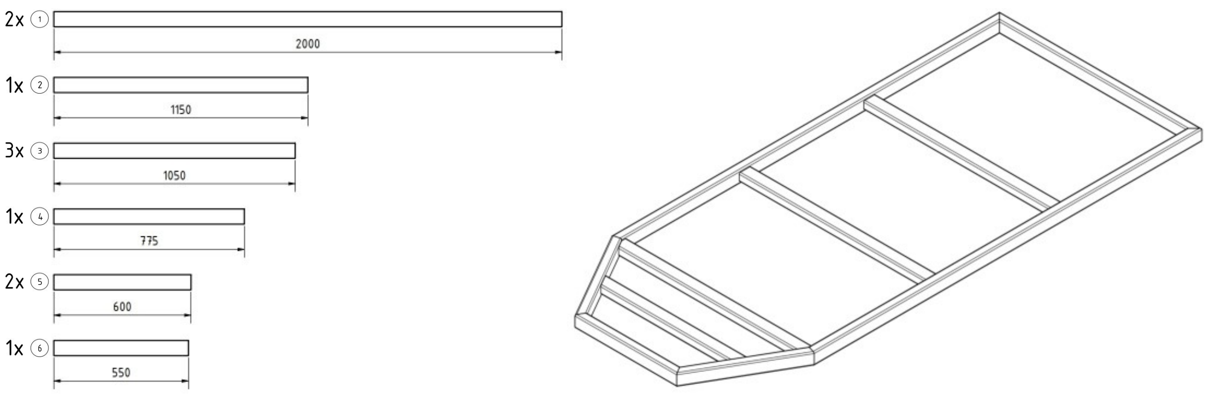
The following chapters will provide you with all the necessary information to build up the chassis of the eTukTuk which will be the main assembly for works done at a later stage.

4.1.1.1 Framework

The framework forms the entire basic structure of the eTukTuk, on which various components such as the chassis, body, ... are mounted.

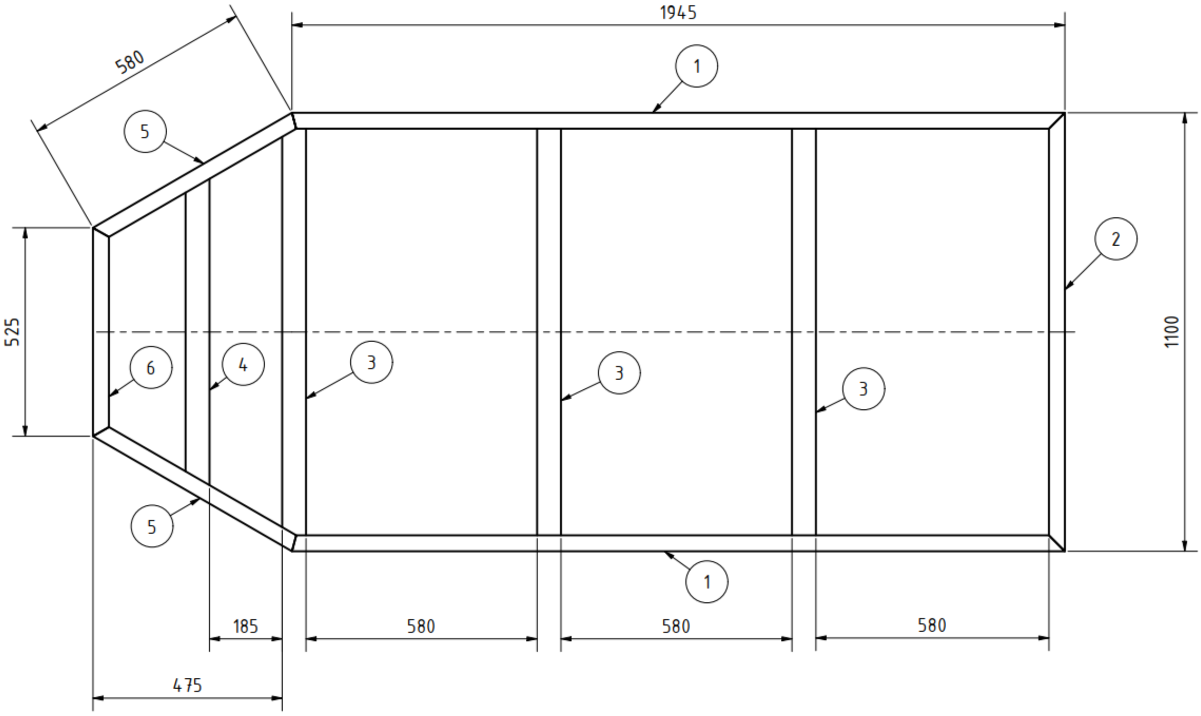
4.1.1.1.1 Base Frame

The base frame for an eTukTuk is manufactured to form the basic structure of the entire vehicle. The base frame significantly influences the stability and structural integrity of the eTukTuk. In the overall vehicle production process, the base frame is one of the first components to be assembled and serves as the basis for the further assembly of the vehicle parts.

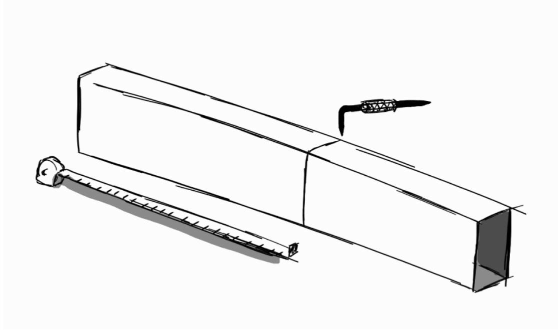
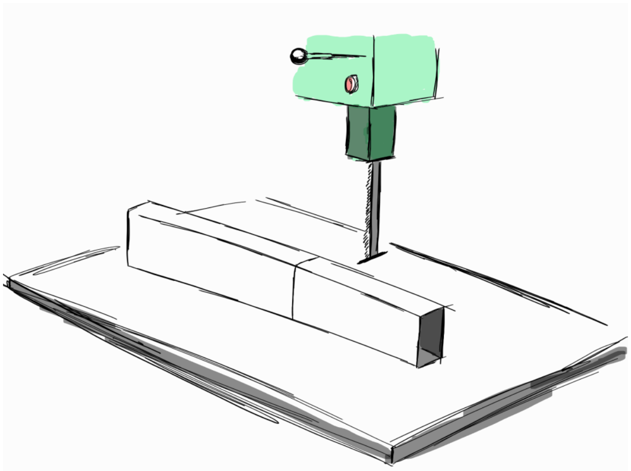


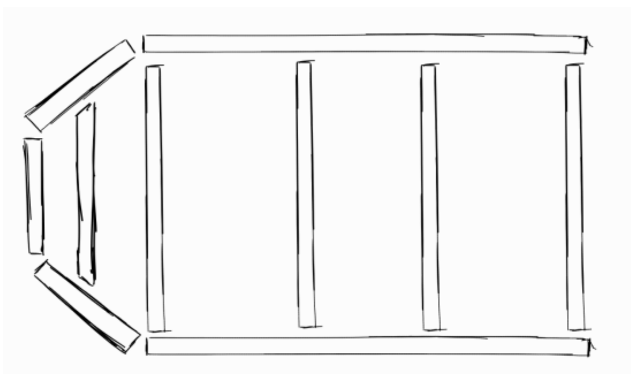
Funded by
the European Union

1.1.1-1 Saw profiles to length → 1.1.1-2 Put together Base Frame → 1.1.1-3 Saw profiles to mitre → 1.1.1-4 Put together Base Frame → 1.1.1-5 Tack weld Base Frame → 1.1.1-6 Check Geometry → 1.1.1-7 Weld the Base Frame → Quality Gate: Check welds and distortions

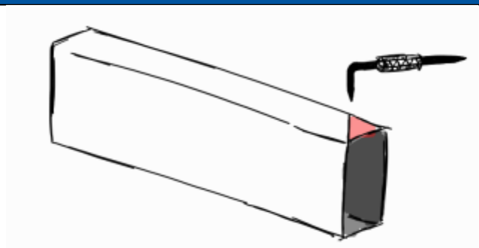
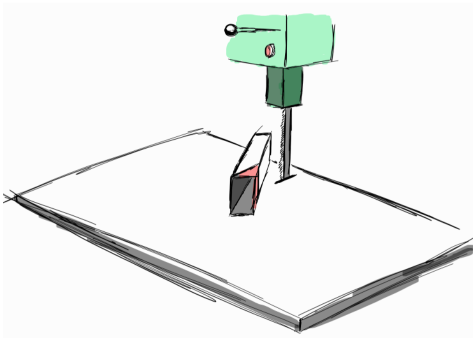
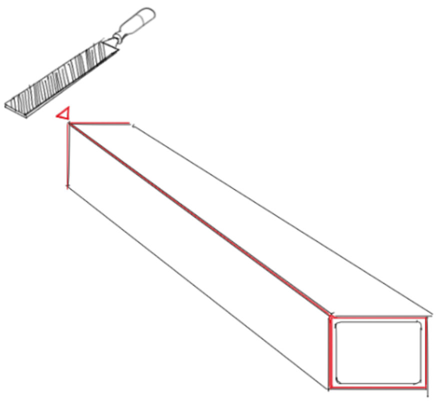


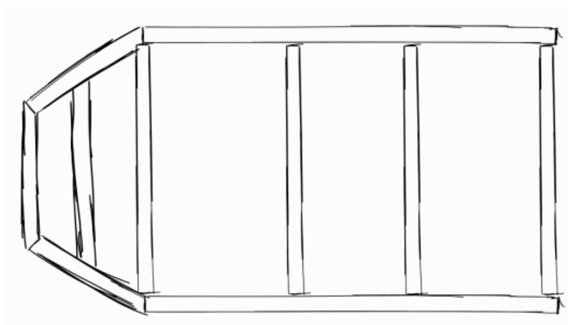
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.1.1-1	Components: • Rectangular profiles 60 mm x 30 mm; t = 3 mm Tools: • Tape Measure • Scriber • Saw (preferably band saw) • File (used for deburring) Process: a) Measuring profiles b) Mark profile length according to plan c) Saw profile d) Deburr cutting edges	 

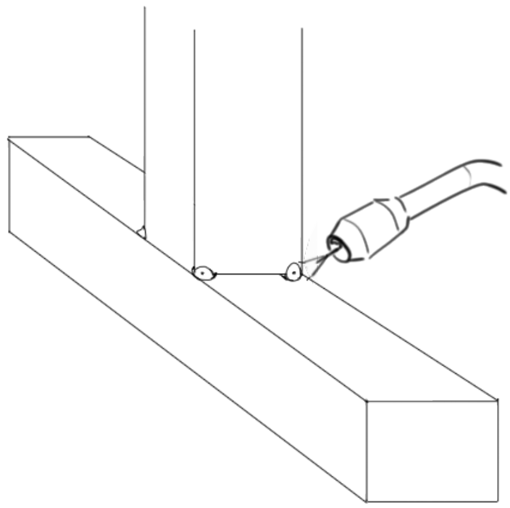
Step	Instructions	Visual Assistance
Step 1.1.1-2	Components: • Cut Rectangular profiles Tools: • None Process: a) Placing cut profiles according to plan b) Check layout	

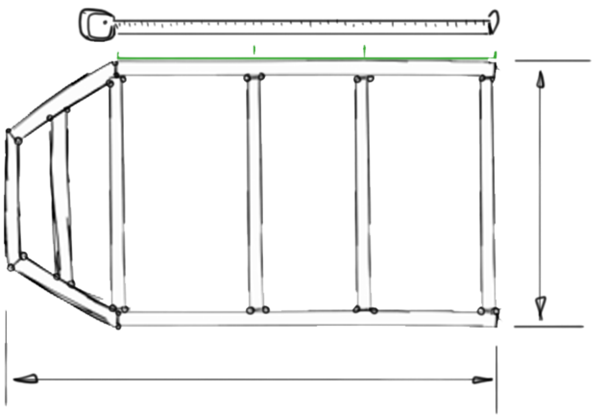
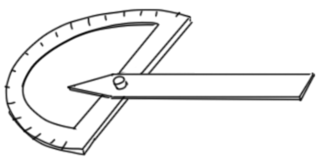
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.1.1-3	Components: • Cut rectangular profiles Tools: • Saw (preferably band saw) • File (used for deburring) • Tape Measure • Scriber Process: a) Mark profile length according to plan b) Saw profile to mitre c) Deburr cutting edges	  

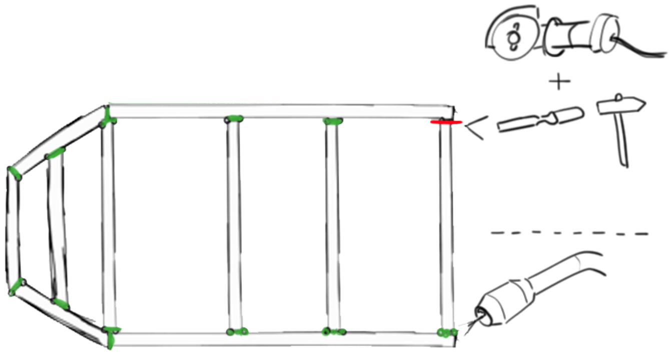
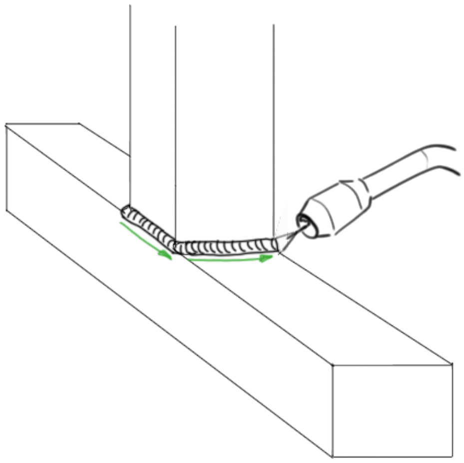
Step	Instructions	Visual Assistance
Step 1.1.1-4	Components: • Cut to mitre rectangular profiles Tools: • None Process: a) Placing cut profiles according to plan b) Check layout	

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.1.1-5	Components: • Cut to mitre rectangular profiles Tools: • MIG welding machine Process: a) Tack weld the edges of the profile together b) Use at least 4 tacks at each joint	

Step	Instructions	Visual Assistance
Step 1.1.1-6	Components: • Tack welded Base Frame Tools: • Tape measure • Protector • Spirit level Process: a) Measure if the tack welded Base Frame is according to the measurement plans. b) If measurements are correct, proceed with step 1.1.1-7. c) If measurements are incorrect, separate the tack welds and start again at step 1.1.1-5.	 

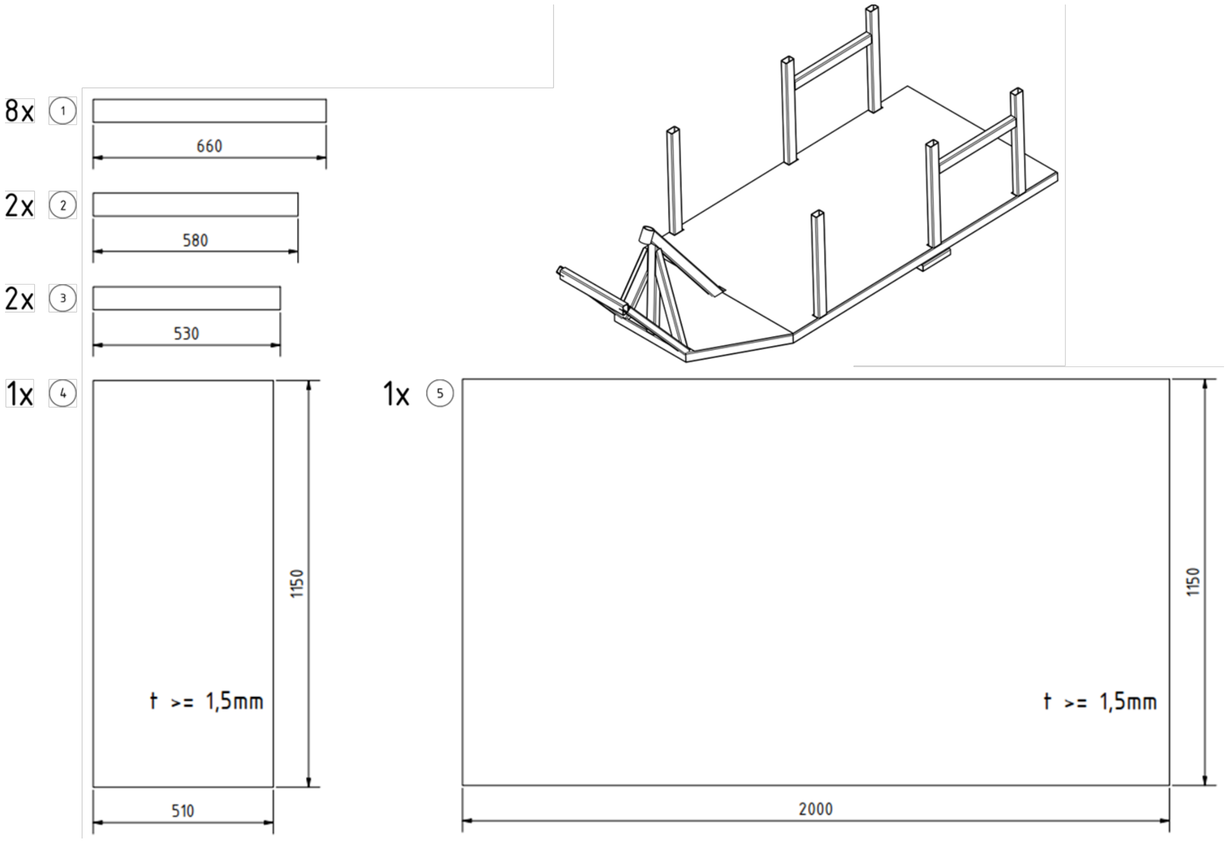
Funded by
the European Union

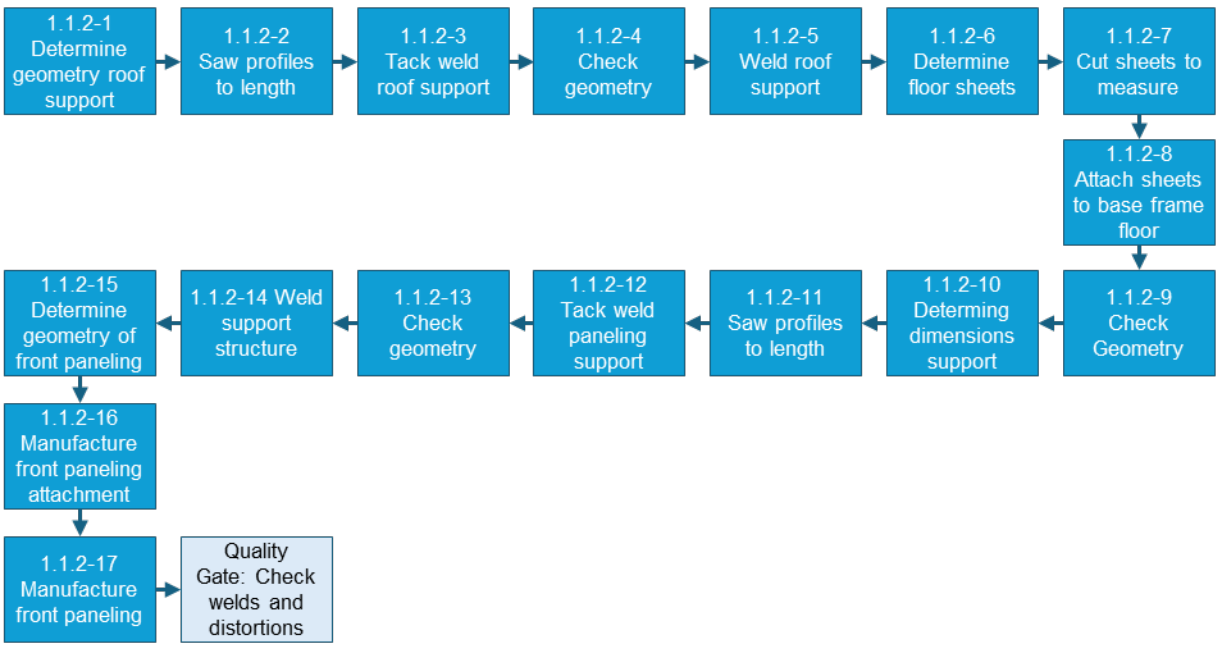
Step	Instructions	Visual Assistance
Step 1.1.1-7	Components: • Tack welded Base Frame Tools: • MIG welding machine Process: a) Fully weld all joints of the Base Frame	 
Quality Gate	Check the welding seams and the Base Frame regarding welding distortions	

Funded by
the European Union

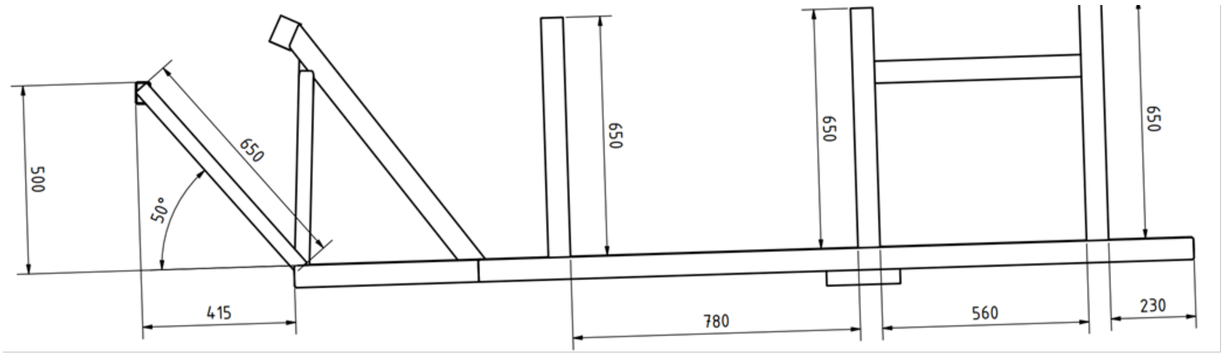
4.1.1.1.2 Support Frame

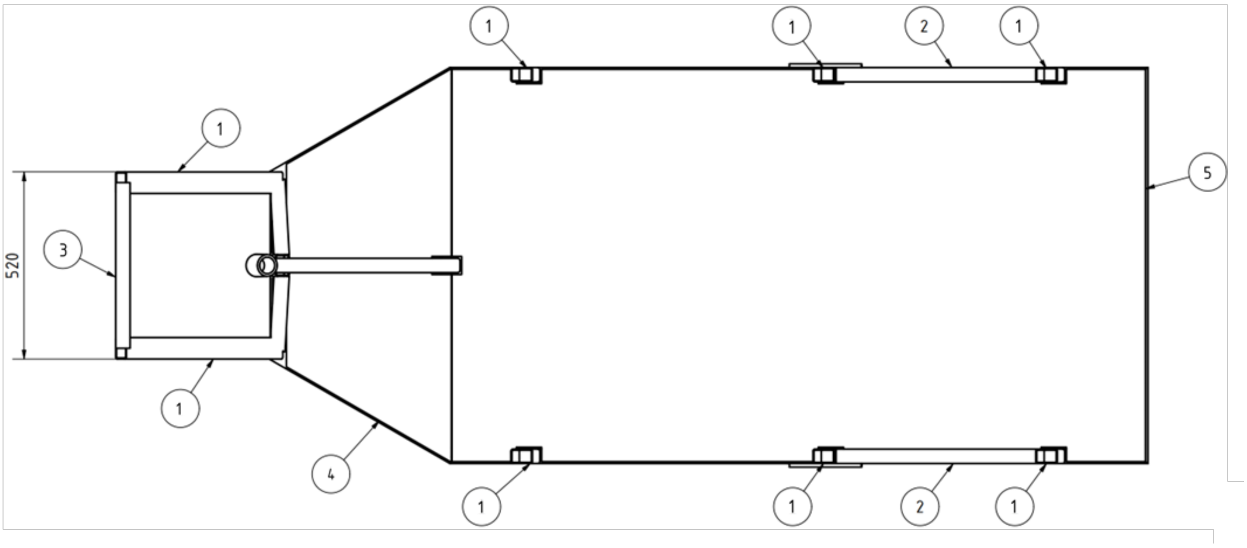
The Support Frame forms the basic framework for the outer paneling and the roof. The support frame is attached to the base frame of the vehicle, increasing the structural strength and stability of the exterior paneling and roof, which improves overall safety and occupant protection.

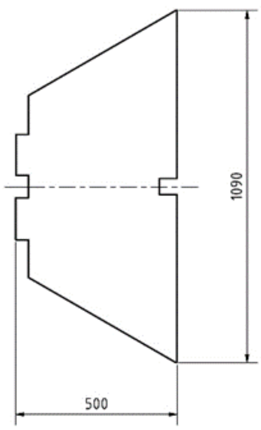


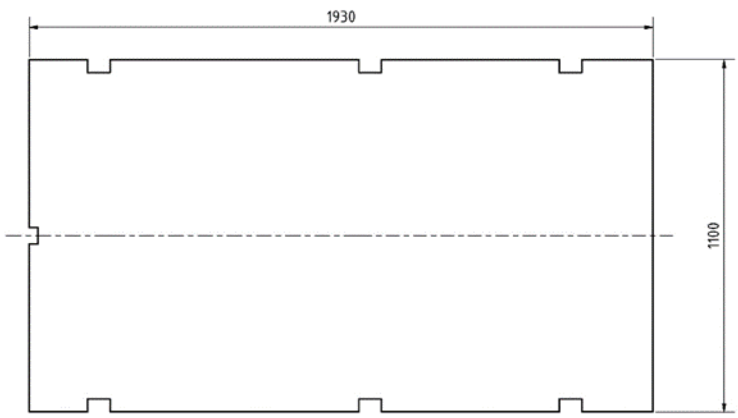


Funded by
the European Union

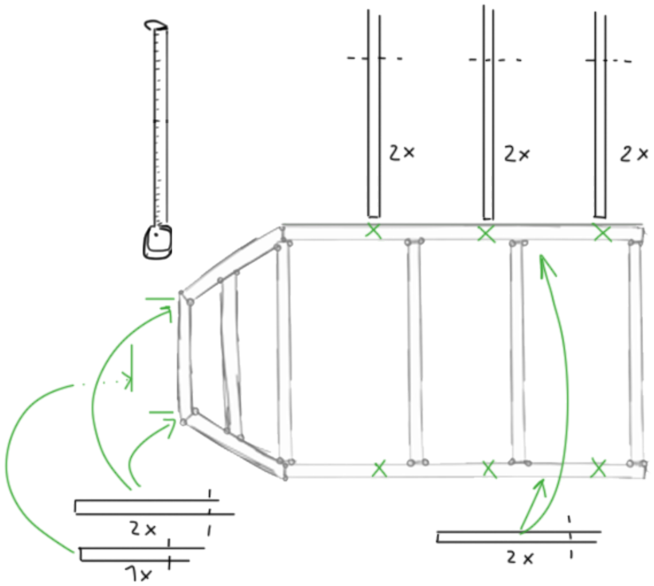




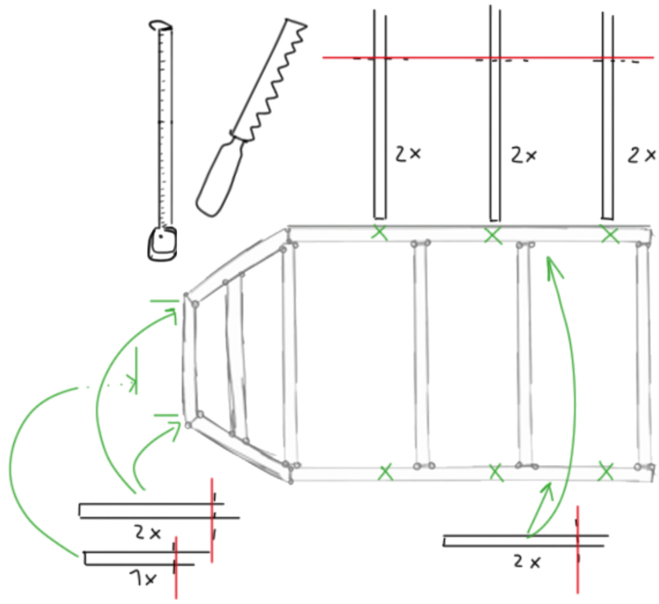
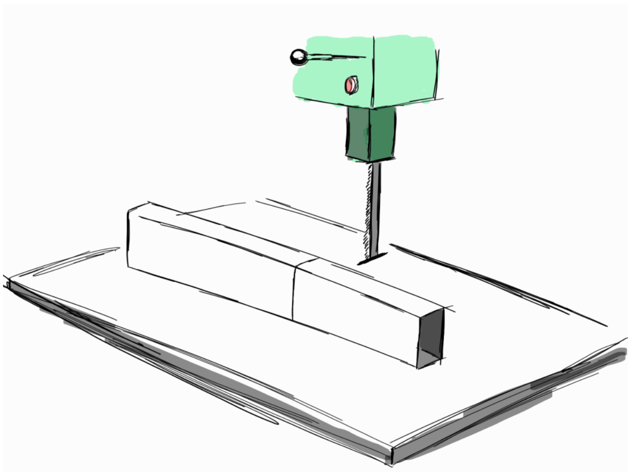
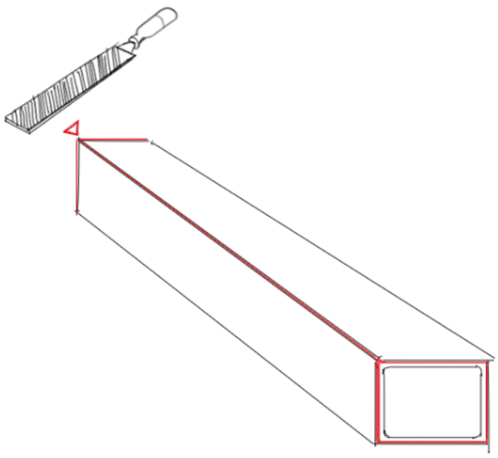




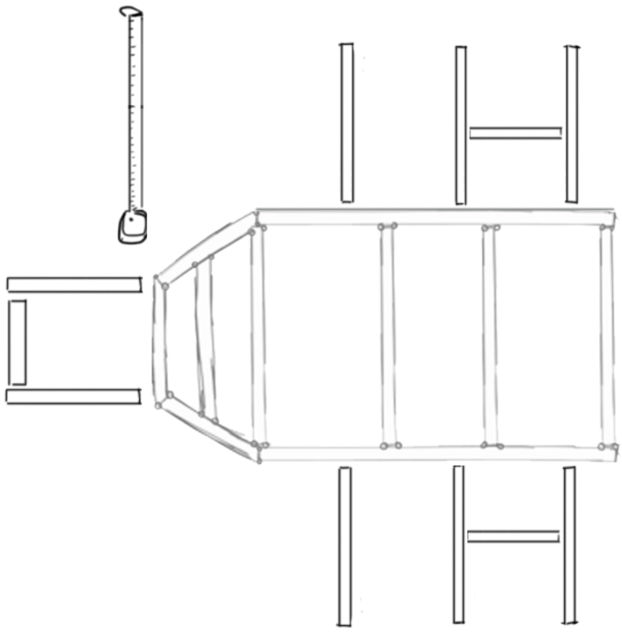
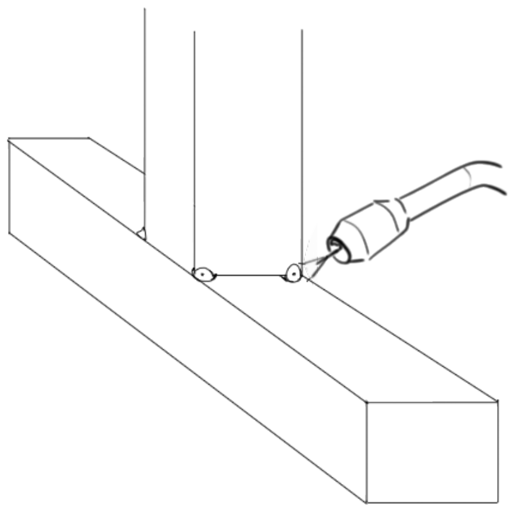
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.1.2-1	Components: • Rectangular profiles 60 mm x 30 mm; t = 3 mm Tools: • Measuring tape Process: a) Determine geometry from roof support	

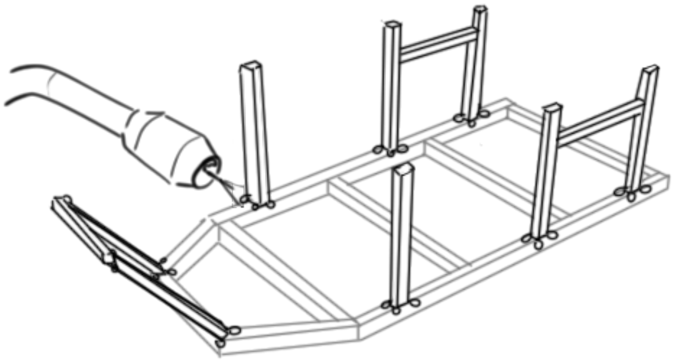
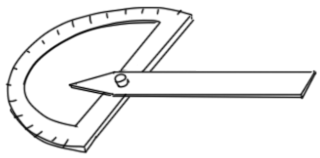
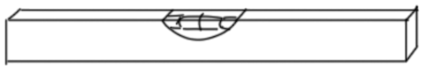
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.1.2-2	Components: • Rectangular profiles 60 mm x 30 mm; t = 3 mm Tools: • Tape Measure • Scriber • Saw (preferably band saw) • File (used for deburring) Process: a) Measuring profiles b) Mark profile length according to plan c) Saw profile d) Deburr cutting edges	  

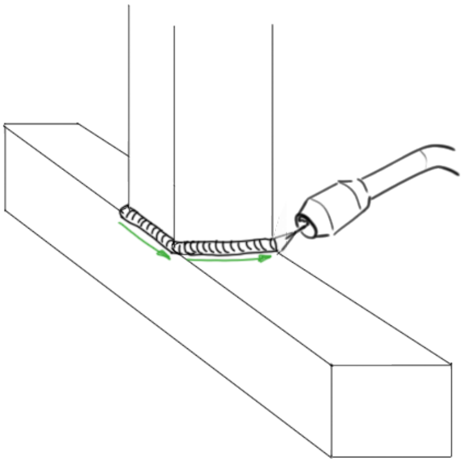
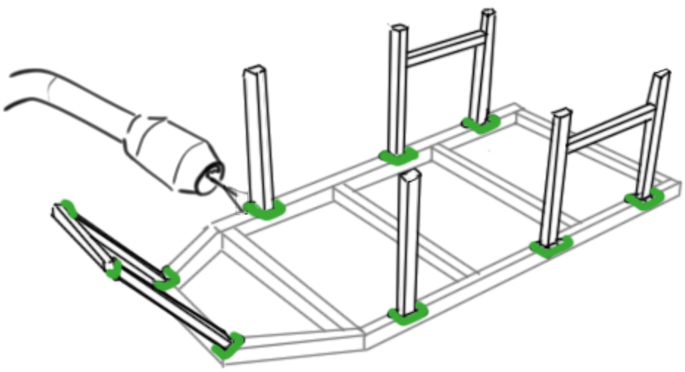
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.1.2-3	Components: • Trimmed rectangular profiles 60 mm x 30 mm; t = 3 mm Tools: • MIG welding machine Process: a) Tack weld the edges of the profile together. b) Use at least 4 tacks at each joint.	 

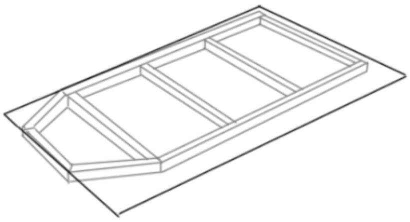
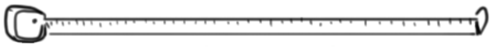
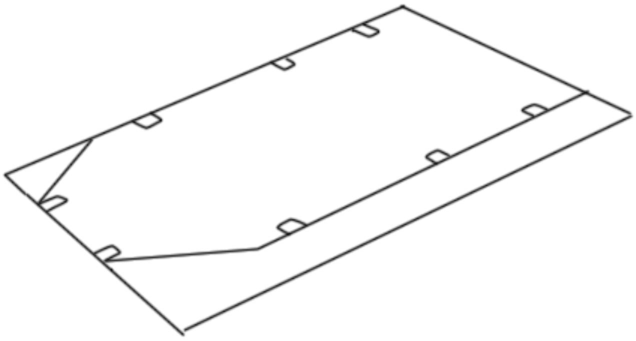
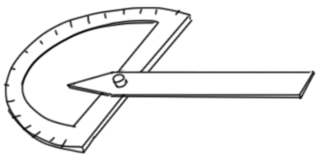
Funded by the European Union

Step	Instructions	Visual Assistance
Step 1.1.2-4	Components: • Tack welded profiles Tools: • Tape measure • Protractor • Spirit level Process: a) Measure if the tack welded Base Frame is according to the measurement plans. b) If measurements are correct, proceed with step 1.1.2-5. c) If measurements are incorrect, separate the tack welds and start again at step 1.1.2-3.	   

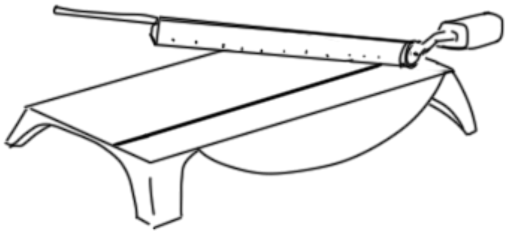
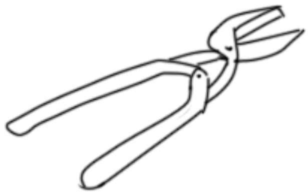
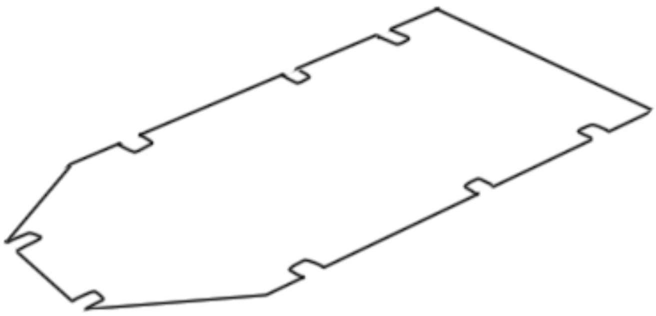
Funded by
the European Union

<table>
<tr><th>Step</th><th>Instructions</th><th>Visual Assistance</th></tr>
<tr><td>Step 1.1.2-5</td><td>Components:
• Tack welded profiles
Tools:
• MIG welding machine
Process:
a) Fully weld all joints of the roof support.</td><td>
</td></tr>
</table>

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.1.2-6	Components: • Base frame with roof support • Sheet metal t_{min} >= 1,5 mm Tools: • Scriber needle • Scribing angle • Measuring tape Process: a) Transfer the base area of the frame and the cut-outs for example for the roof support and steering connection to one or several metal sheets. Ensure sufficient distance for welding seams. (~ 5 mm)	   

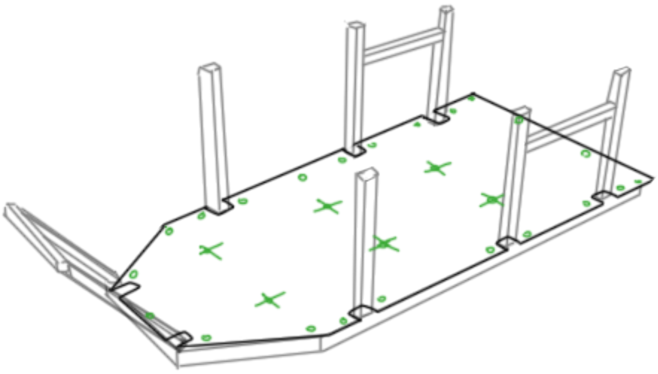
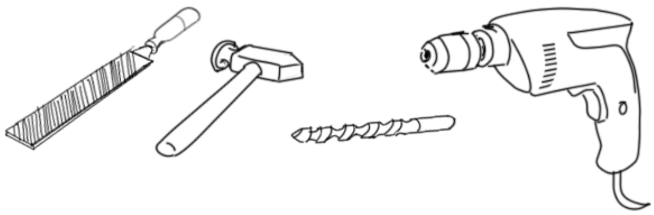
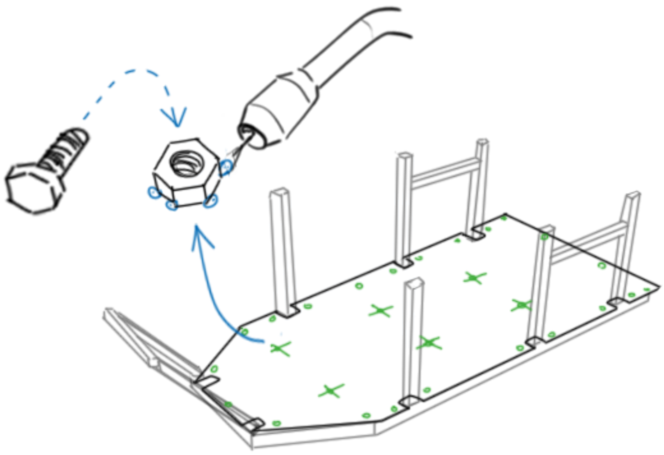
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.1.2-7	Components: • Scribed sheet metal Tools: • Tin snips • File (used for deburring) • Drilling machine • Center punch • Hammer Process: a) Use the tin snips to cut out the scribed base of the base frame. b) Center punch and drill out the corners of the cut-outs from the sheet metal. c) Deburr all sharp edges with a file.	  

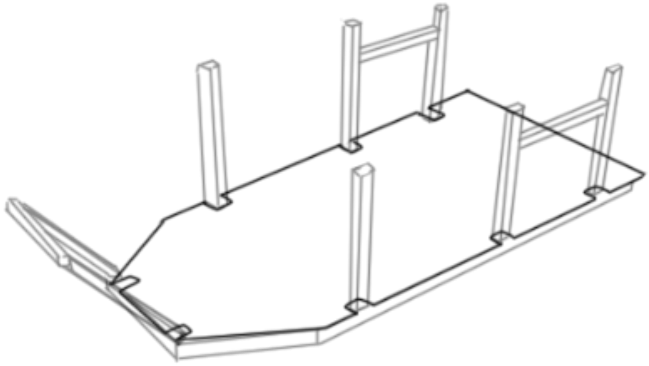
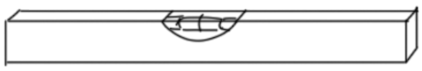
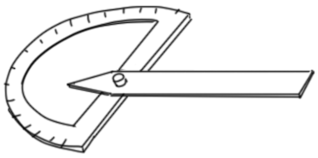
Funded by the European Union

<table>
<tr><th>Step</th><th>Instructions</th><th>Visual Assistance</th></tr>
<tr><td>Step 1.1.2-8</td><td>Components:
• Base frame with support structure
• Sheet metal with cut-outs
• Screws, if not welded

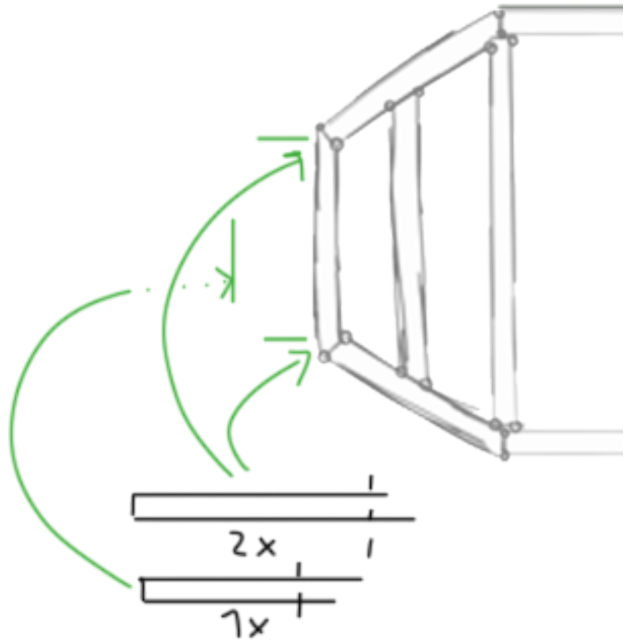
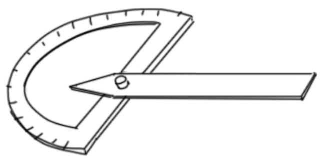
Tools:
• File
• MIG welding machine / Screws
• Drilling machine
• Tap
• Hammer
• Center punch

Process:
a) Mark the joints between the floor panel and the base frame. Use a connection point at least every 15 cm.
b) Connect the base plate to the base frame by welding or bolting. To screw the base plate to the base frame, the connection points must be center punched, drilled and a threaded. Instead of cutting a thread, nuts can be used, which can be welded on for easier installation. After that connect the base plate with the base frame with screws.</td><td>

</td></tr>
</table>

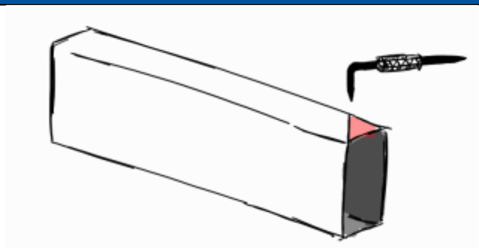
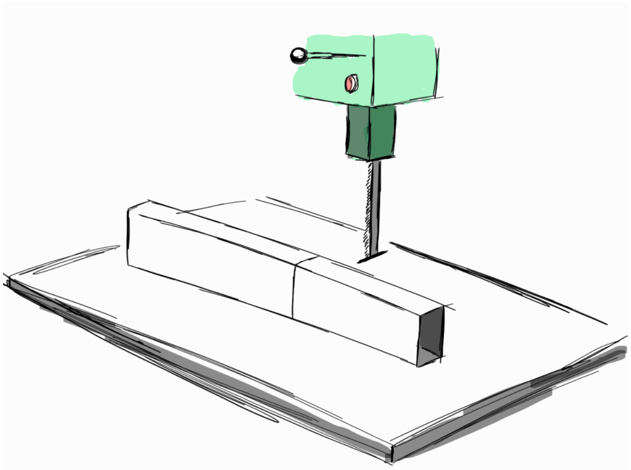
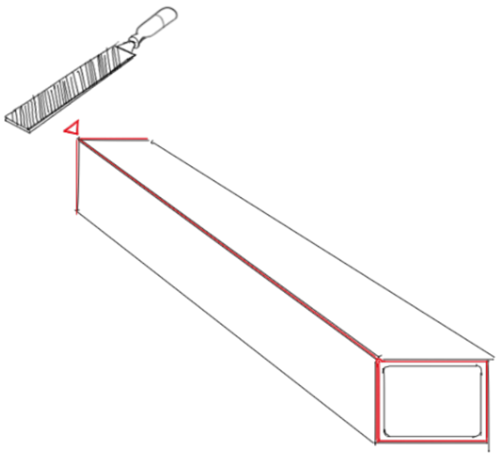
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.1.2-9	Components: • Base frame with support and connected base plate. Tools: • Tape measure • Protractor • Spirit level Process: a) Measure if the tack welded Base Frame is according to the measurement plans. a) If measurements are correct, proceed with step 1.1.2-10. b) If measurements are incorrect, separate the base frame and start again at step 1.1.2-8.	   

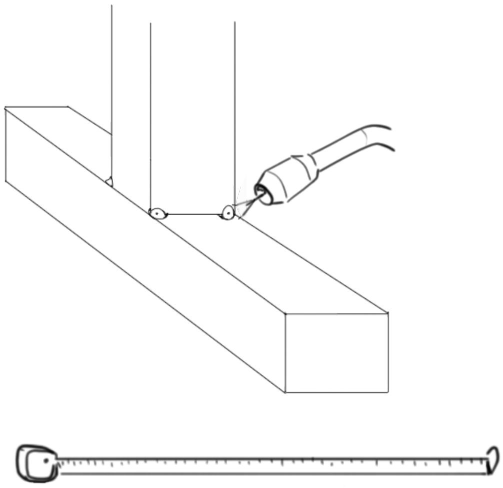
Funded by
the European Union

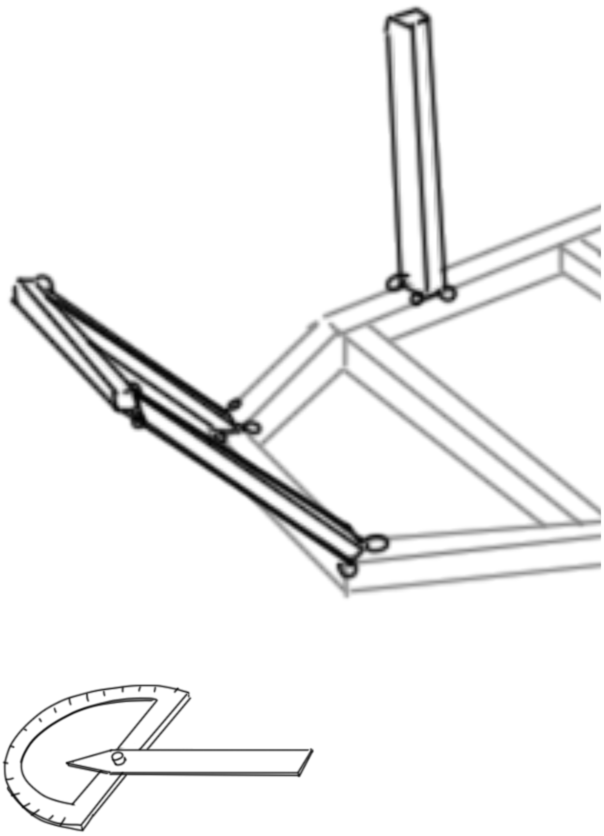
Step	Instructions	Visual Assistance
Step 1.1.2-10	Components: • Rectangular profiles 60 mm x 30 mm; t = 3mm Tools: • Measuring tape Process: a) Determination of the geometry from the front panel support. The profiles form the attachment points for the front panel. The profiles are attached to the support structure for the head tube from chapter 4.1.1.1.1 step 1.1.1-7.	  

Funded by
the European Union

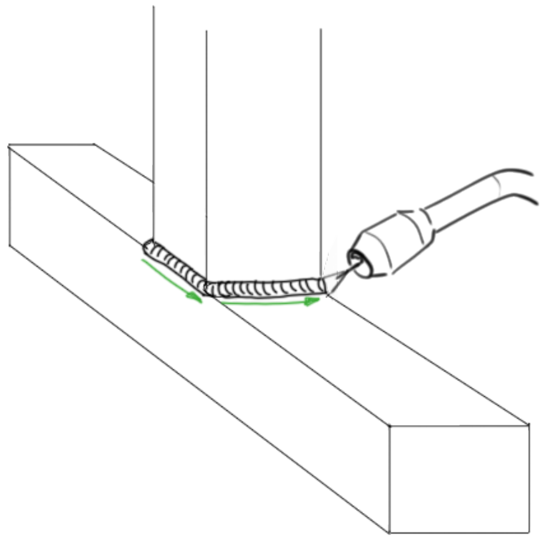
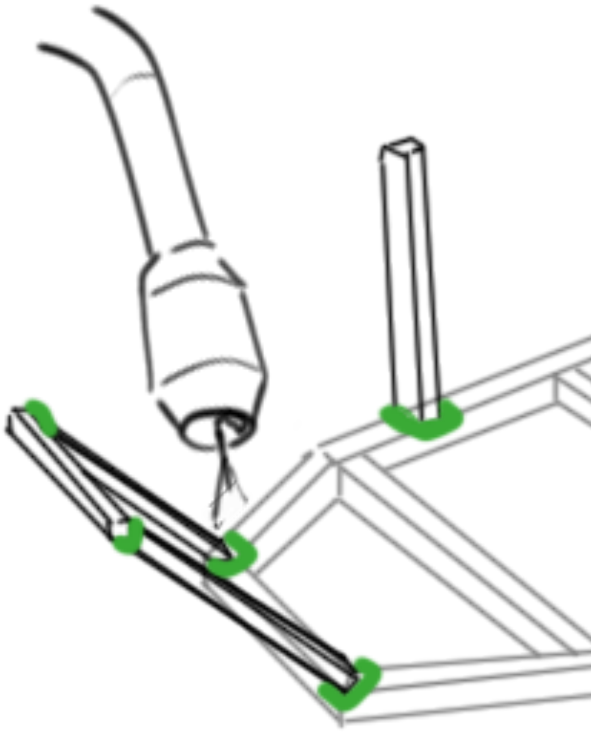
Step	Instructions	Visual Assistance
Step 1.1.2-11	Components: • Rectangular profiles 60 mm x 30 mm; t = 3 mm Tools: • Tape Measure • Scriber • Saw (preferably band saw) • File (used for deburring) Process: a) Measuring profiles b) Mark profile length according to plan c) Saw profile d) Deburr cutting edges	  

Funded by the European Union

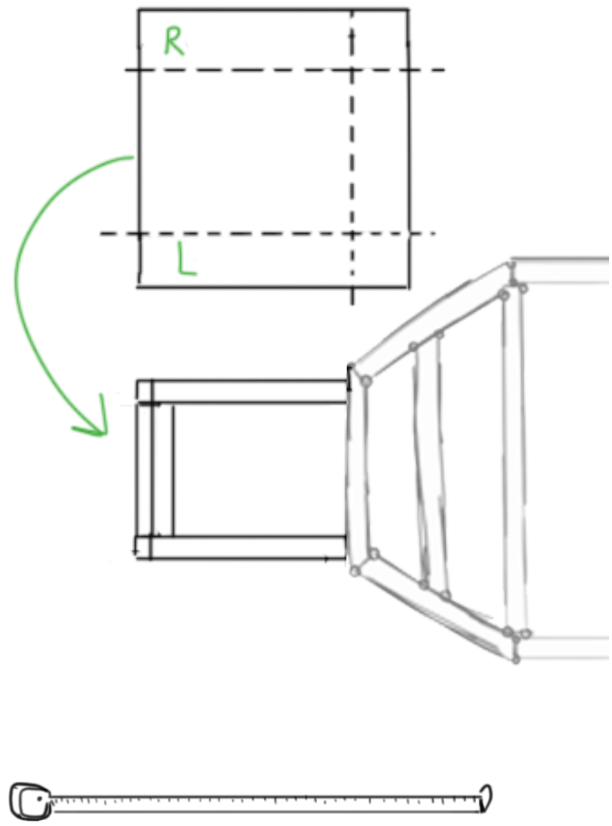
Step	Instructions	Visual Assistance
Step 1.1.2-12	Components: • Trimmed rectangular profiles 60 mm x 30 mm; t = 3mm Tools: • MIG welding machine Process: a) Tack weld the edges of the profile together b) Use at least 4 tacks at each joint	

Step	Instructions	Visual Assistance
Step 1.1.2-13	Components: • Tack welded profiles on head tube support. Tools: • Tape measure • Protractor • Spirit level Process: a) Measure if the tack welded profiles are according to the measurement plans. b) If measurements are correct, proceed with step 1.1.2-14. c) If measurements are incorrect, separate the base frame and start again at step 1.1.2-12.	

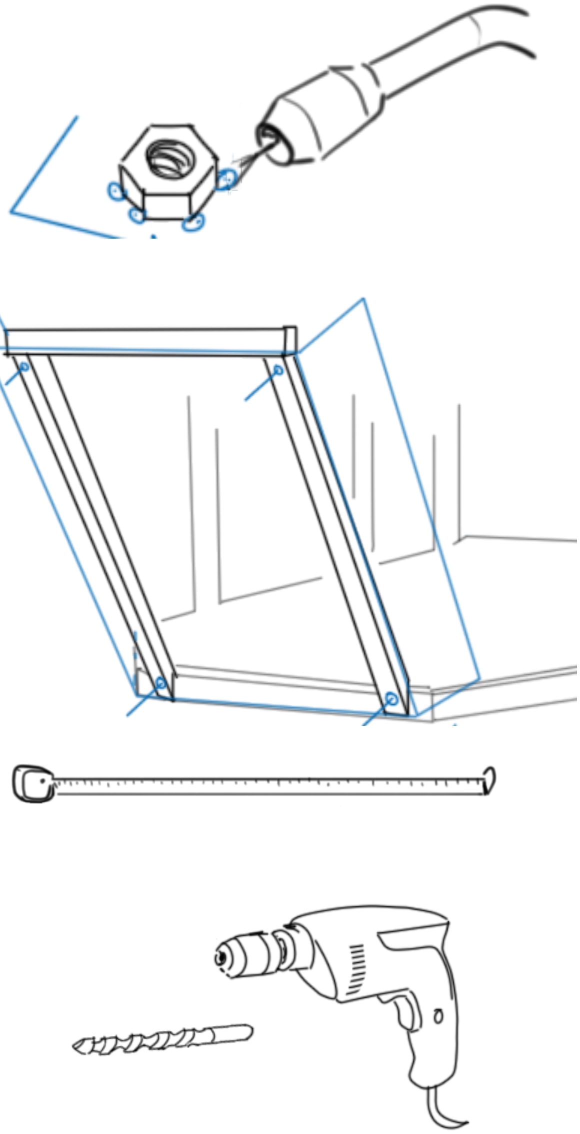
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.1.2-14	Components: • Tack welded profiles Tools: • MIG welding machine Process: a) Fully weld all joints of the paneling support.	 

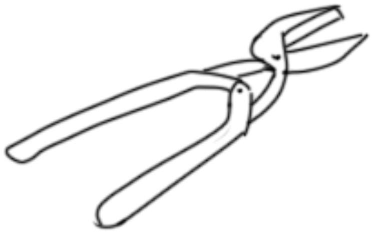
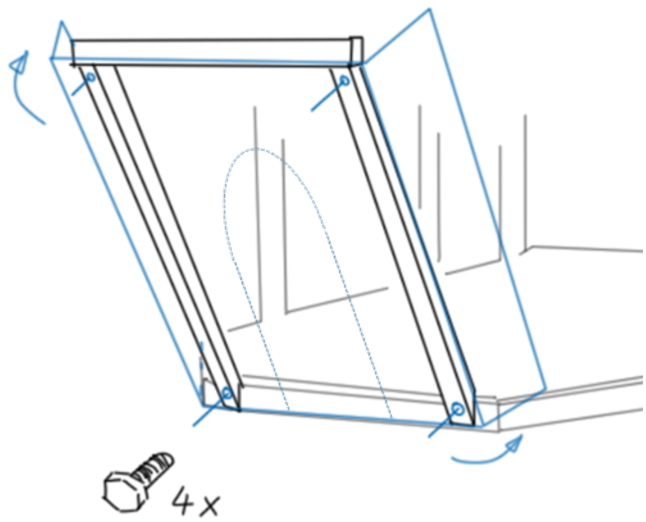
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.1.2-15	Components: • Paneling support Tools: • Use cardboard, wood or metal strips as stencil • Measuring tape • Profile as a straight gauge a) Use cardboard, wood scraps or metal strips to model the front panels. b) Cut the template according to the desired contour.	

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.1.2-16	Components: • (Nuts) • Panel support structure Tools: • Drilling machine, Tap or MIG welding machine Process: a) If preferred for easier installation, weld nuts or drill holes and cut a thread to the desired fastening points at the panel support structure for the front panel.	

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.1.2-17	Components: • Front panel support • Material for front panel freely selectable • Plastic metal fabric Tools: • Tin snips, scissors • Hammer / Bending machine • File (for deburring) Process: a) Shape the front paneling according to the attachment points. When covering with a fabric, it is helpful to make a wooden structure for covering. b) Provide an opening for the front wheel.	  
Quality Gate	Check welds and distortions and correct them if necessary.	

4.1.1.2 Suspension

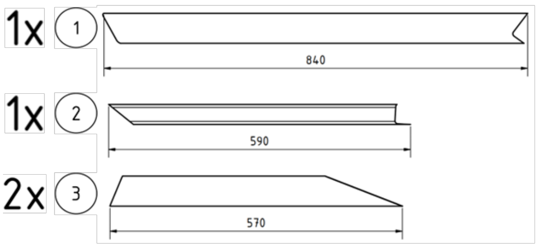
The suspension, including the shock absorber, springs, wheels and axle is designed, selected and installed below. The suspension is attached to the base frame and improves the ride comfort and road holding of the vehicle by absorbing shocks and vibrations. The front

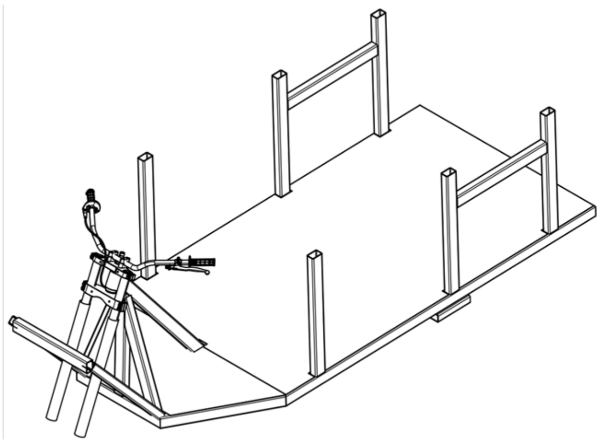
Funded by
the European Union

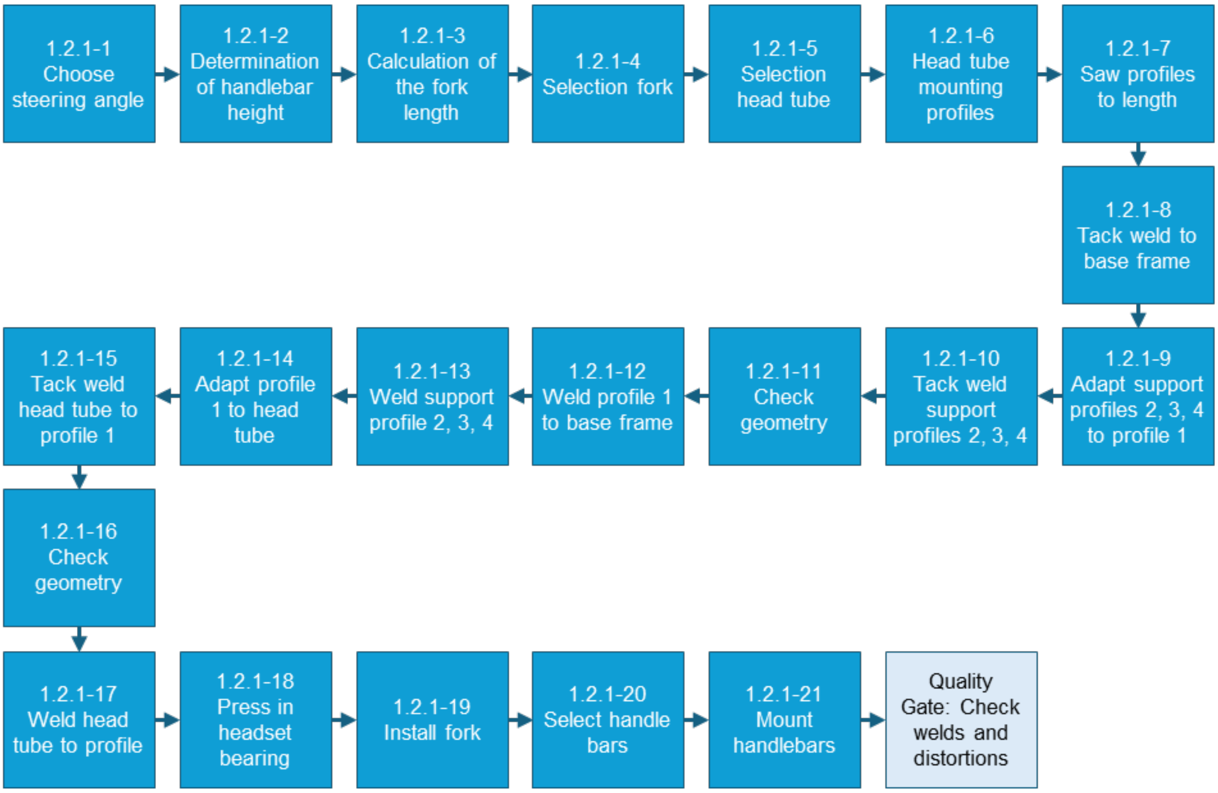
suspension provides the steering function. In the overall vehicle manufacturing process, the rear suspension is installed, the base frame is assembled and plays a crucial role in the vehicle's driving dynamics and safety.

4.1.1.2.1 Steering / Fork

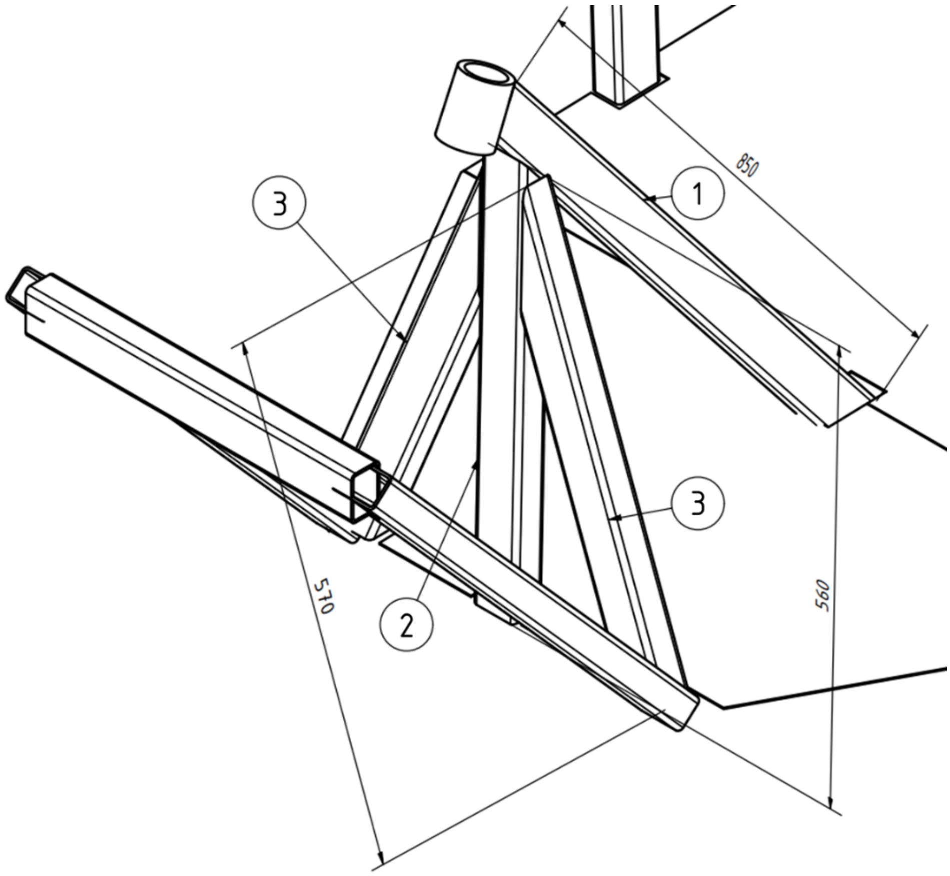
The steering system, including the suspension fork, is designed and installed below. The steering system and suspension fork are installed at the front of the base frame and enable the vehicle to change direction. This System contributes significantly to driving stability and safety. In the overall vehicle production process, the steering and suspension fork are installed after the base and support frames have been assembled.

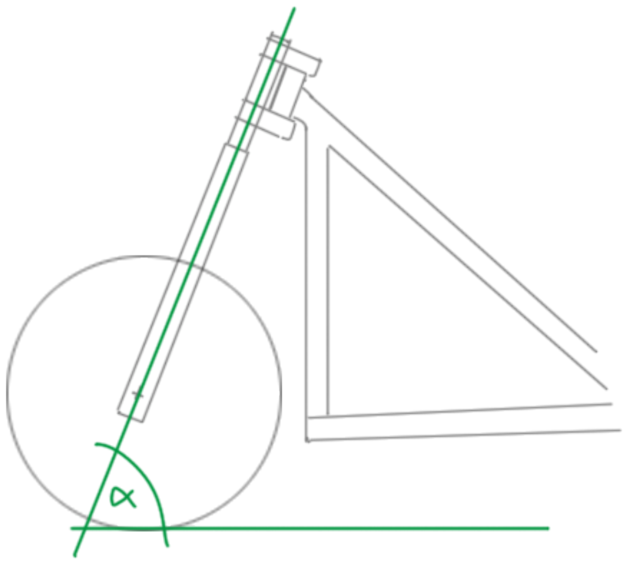




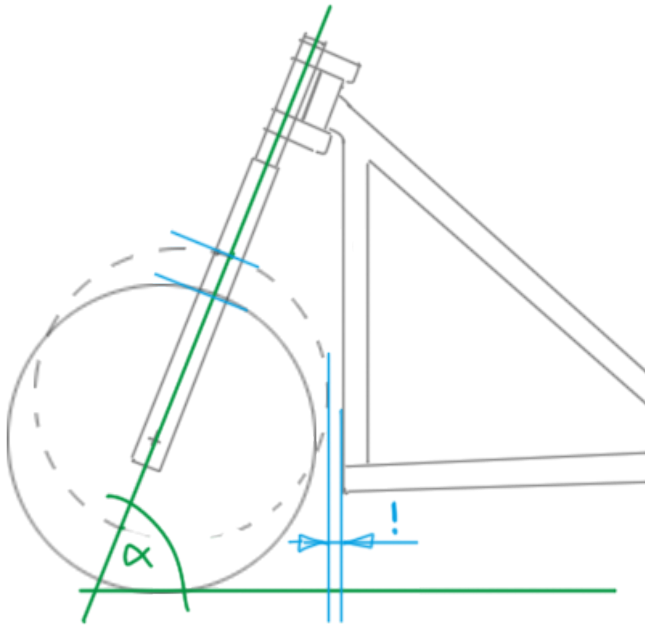


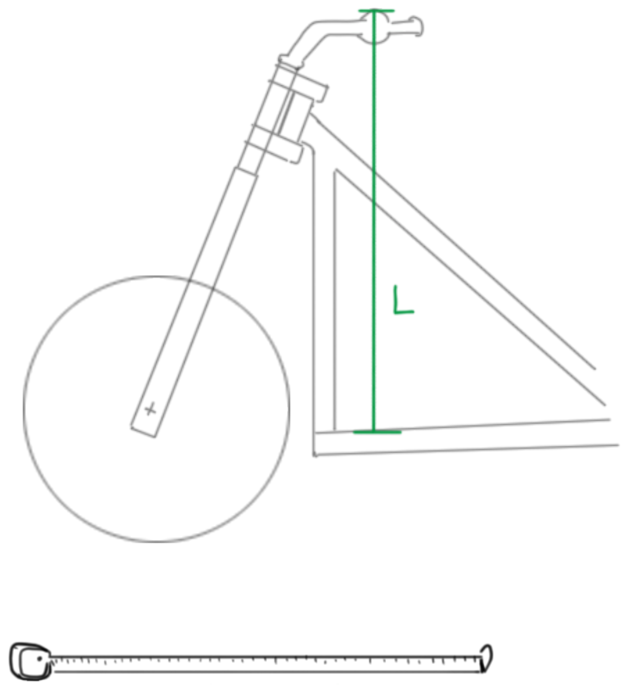
Funded by
the European Union



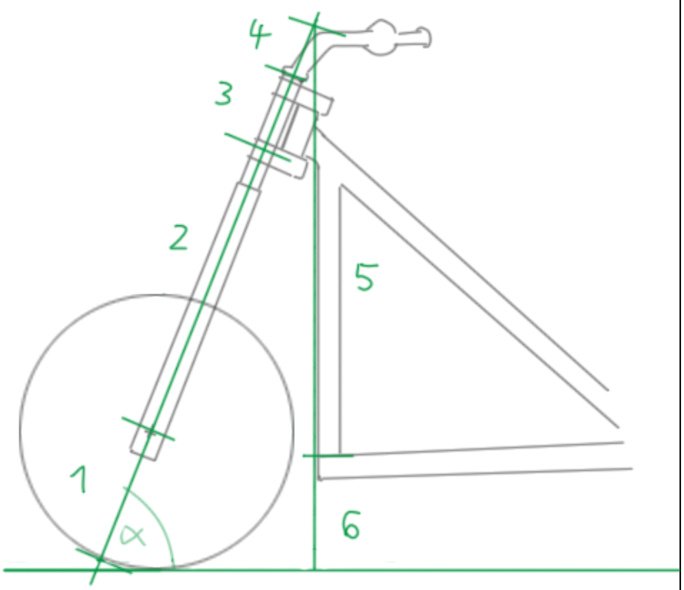
Step	Instructions	Visual Assistance
Step 1.2.1-1	Components: • None Tools: • Calculator • Pencil • Sheet of paper Process: a) Typical steering angles for TukTuks are 45° - 60°. b) Select a steering angle that fits well with the prepared base frame. Ensure that the front wheel has sufficient clearance in	

Funded by the European Union

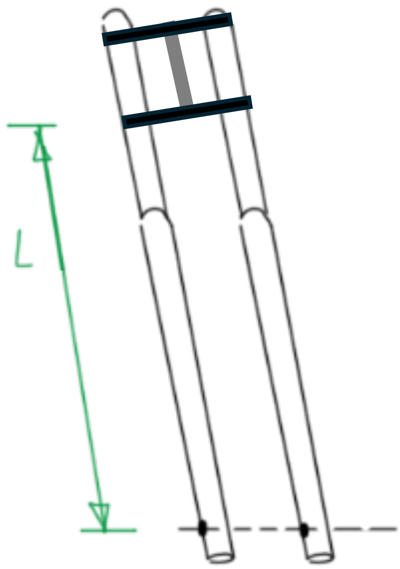
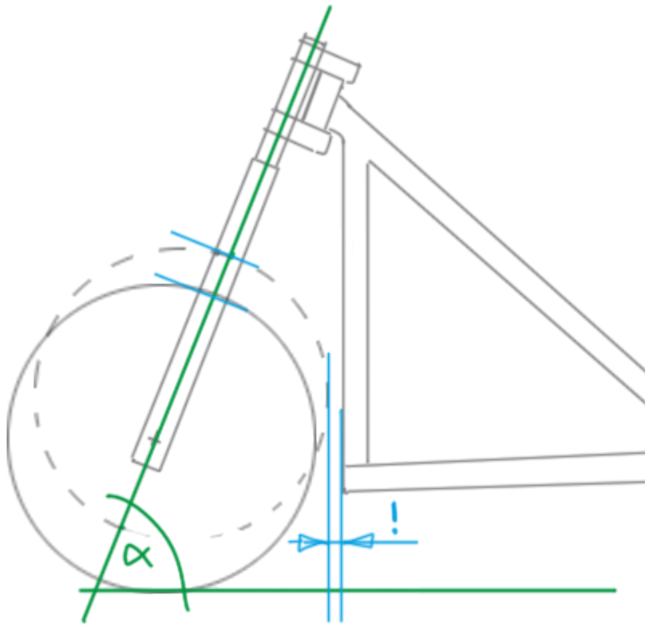
	compressed state to components in the steering area. For example, dirt build-up can reduce the clearance, which can lead to unwanted grinding marks, wear and dangerous influences on the steering, drive or brakes.	

Step	Instructions	Visual Assistance
Step 1.2.1-2	Components: • None Tools: • Measuring tape Process: a) Determining the height of the handlebar within the range of 600 – 700 mm. b) Check the defined value for ergonomic plausibility and adjust it as required.	

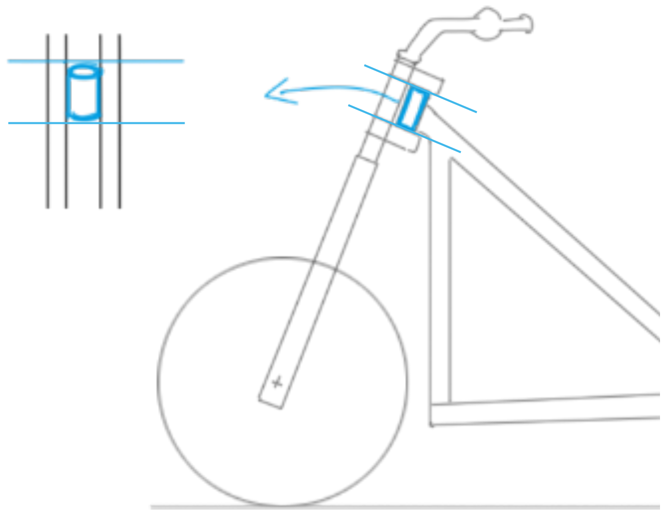
Funded by
the European Union

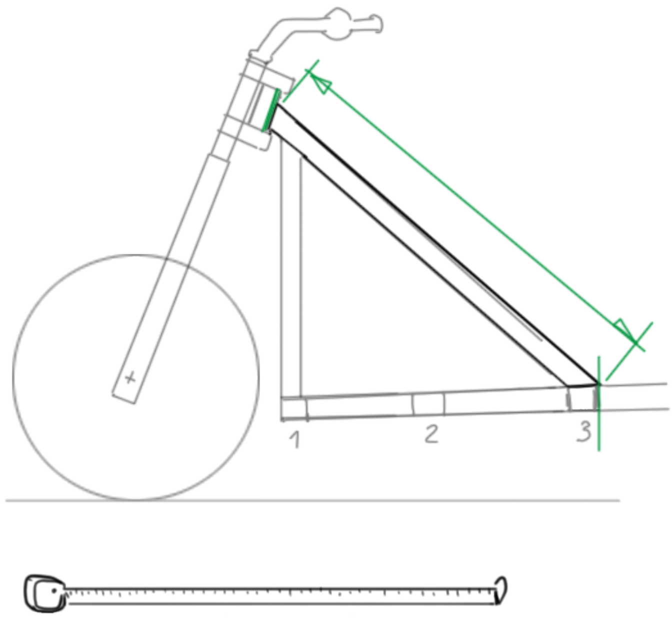
Step	Instructions	Visual Assistance
Step 1.2.1-3	Components: • None Tools: • Calculator Process: a) The installation length (L_2) of the suspension fork can be calculated by specifying the handlebar height (L_5), selecting a front wheel with radius XY (L_1), specifying the ground clearance (L_6) and the steering angle (alpha). Additionally, the possible range (L_3) of the triple clamp spacing and the distance between handlebars and the top triple clamp (L_4) must be taken into account, which varies depending on the fork and handlebar model. b) The length L_2 is calculated as follows: $L_2 = \frac{L_5 + L_6}{\sin(\alpha)} - L_1 - L_3 - L_4$	

Funded by
the European Union

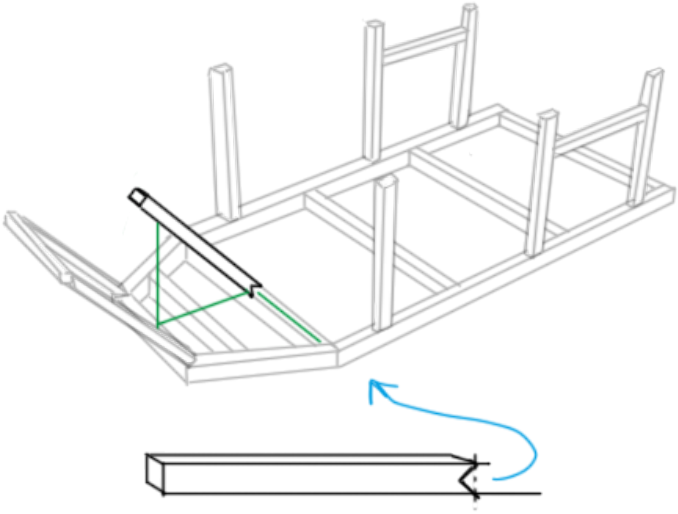
Step	Instructions	Visual Assistance
Step 1.2.1-4	Components: • None Tools: • Calculator Process: **Consider deflection:** **When the suspension is compressed, the distance between the wheel and the frame is reduced; note the impact of the mudguard** a) Selection of a suitable suspension fork based on minimum installation length (L), suspension travel and spring rate. The spring rate is calculated in chapter **Error! Reference source not found.**	  

Funded by
the European Union

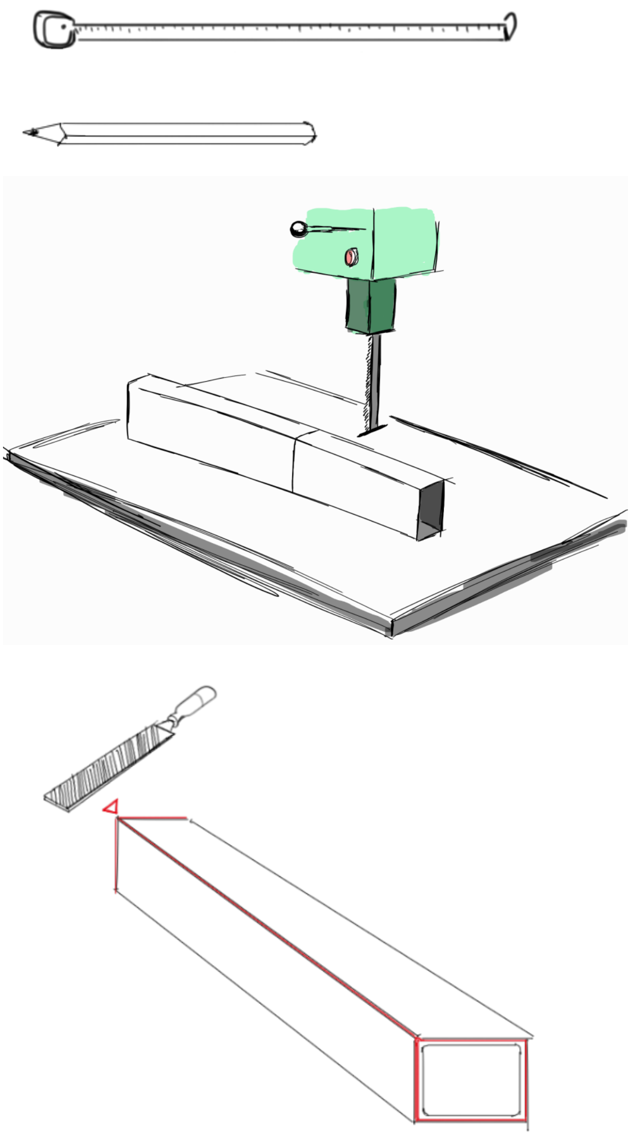
Step	Instructions	Visual Assistance
Step 1.2.1-5	Components: • None Tools: • None Process: a) Select a head tube that fits within the recommended spacing between the triple clamps and has an inner diameter that fits with the recommended bearing for the fork shaft.	

Step	Instructions	Visual Assistance
Step 1.2.1-6	Components: • Rectangular profiles 60 mm x 30 mm; t = 3 mm rectangular profile Tools: • Tape Measure Process: a) Selection of a rectangular profile (60 mm x 30 mm; t = 3 mm) to fix the head tube at the specified position. b) The rectangular tube is connected to the third strut of the base frame.	

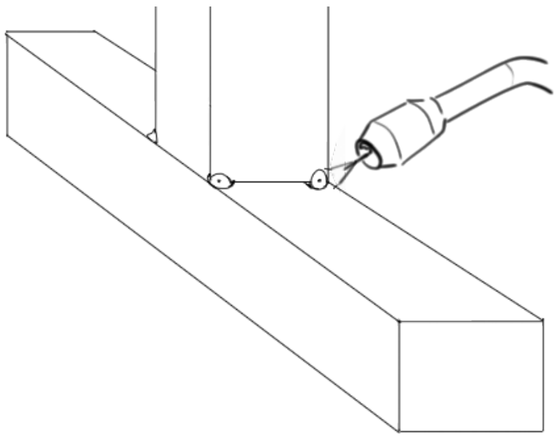
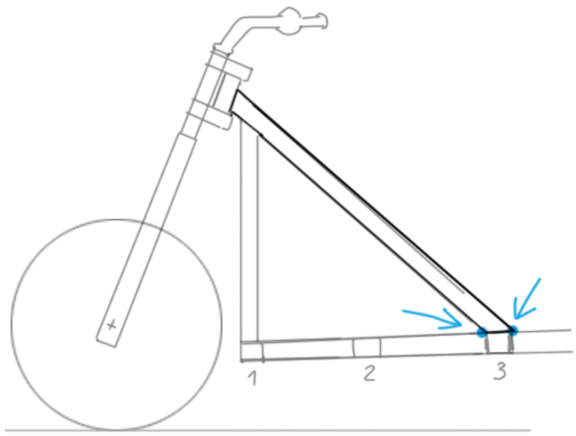
Funded by
the European Union

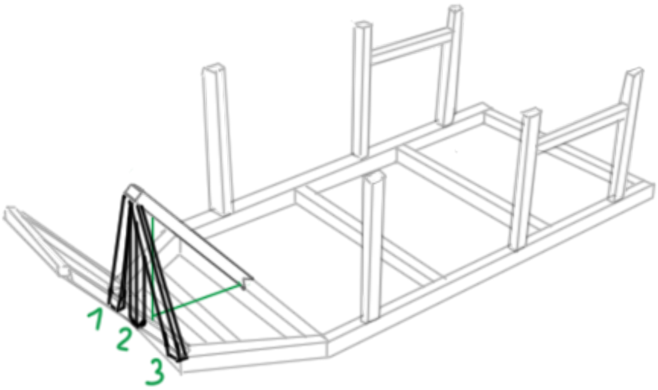
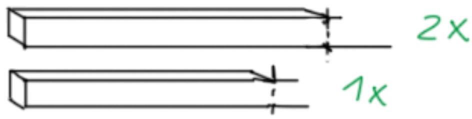
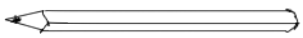
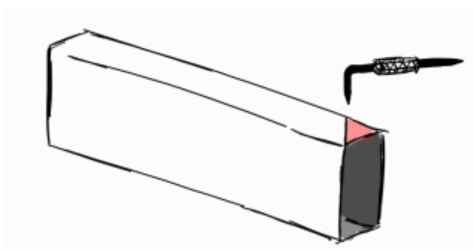
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.1-7	Components: • Rectangular profiles 60 mm x 30 mm; t = 3 mm Tools: • Tape Measure • Scriber • Saw (preferably band saw) • File (used for deburring) Process: a) Measuring profiles b) Mark profile length according to plan c) Saw profile d) Deburr cutting edges	

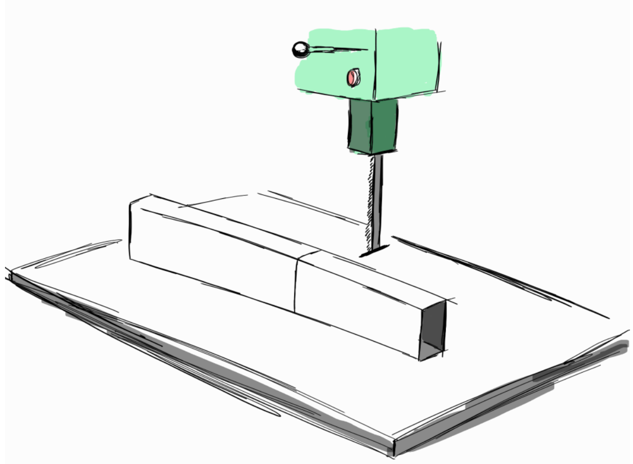
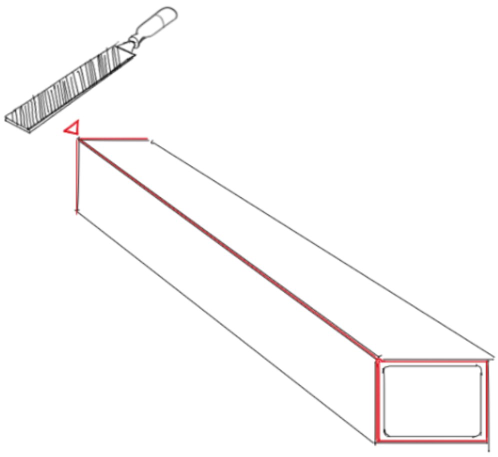
Funded by the European Union

Step	Instructions	Visual Assistance
Step 1.2.1-8	Components: • Trimmed rectangular profiles 60 mm x 30 mm; t = 3 mm Tools: • MIG welding machine Process: a) Tack weld the edges of the profile together. b) Use at least 4 tacks at each joint.	 

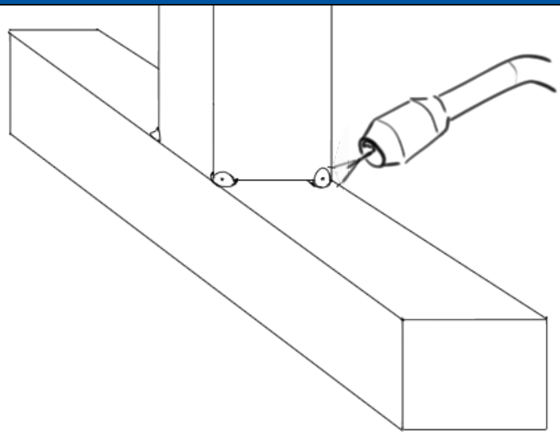
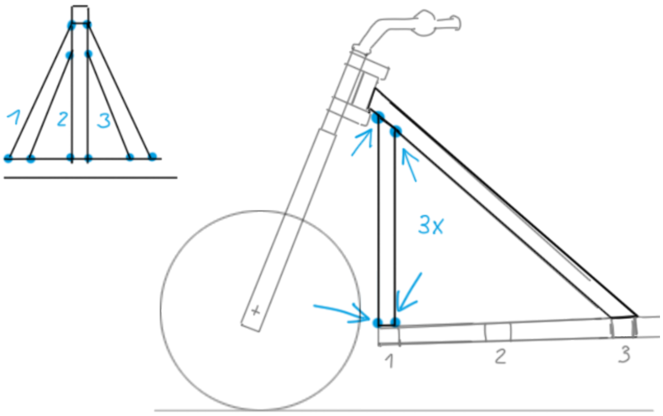
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.1-9	Components: • Cut rectangular (support-) profiles Tools: • Saw (preferably band saw) • File (used for deburring) • Tape Measure • Scriber Process: a) Mark profile length according to plan b) Saw profile to mitre c) Deburr cutting edges	    

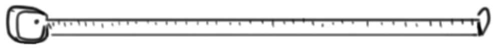
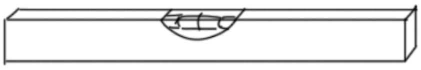
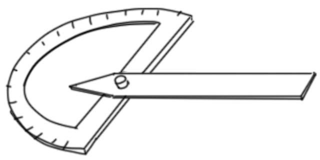
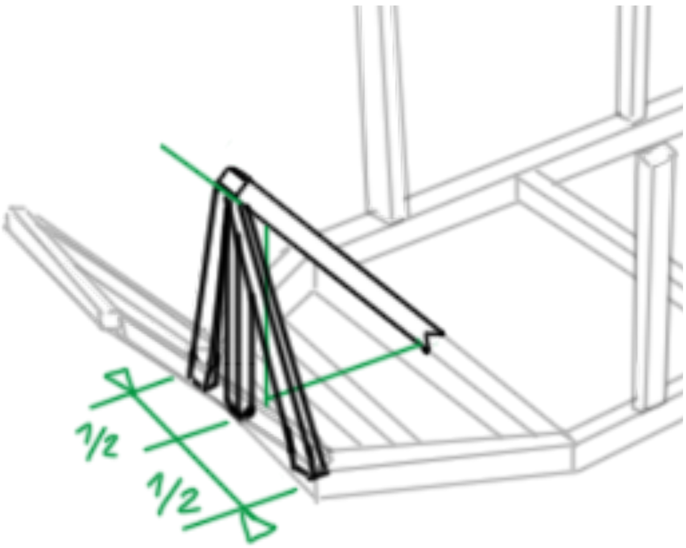
Funded by the European Union

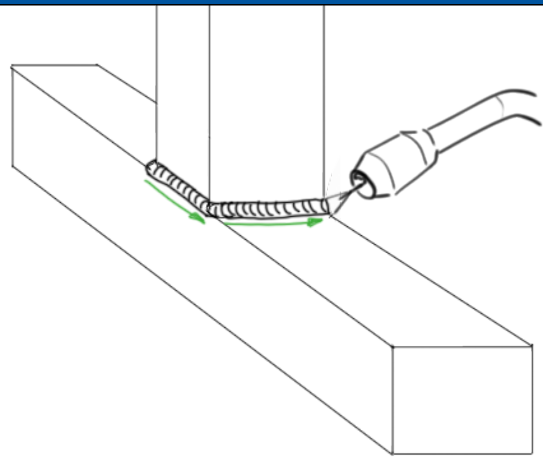
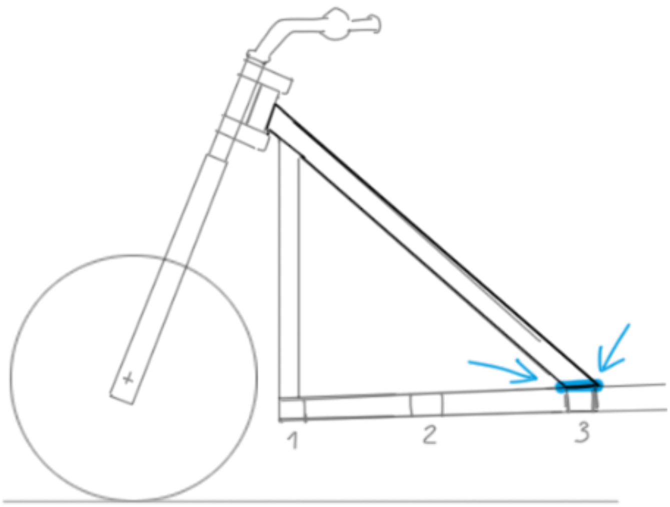
Funded by
the European Union

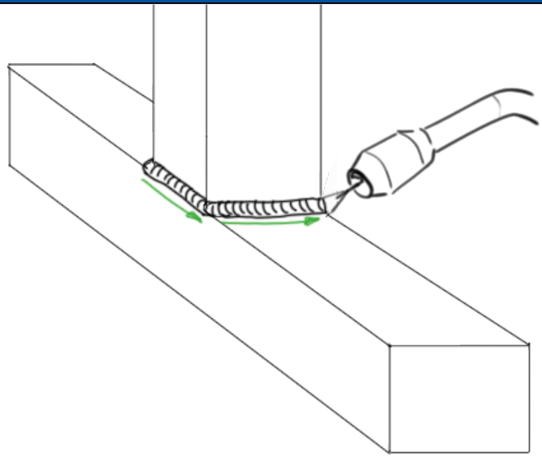
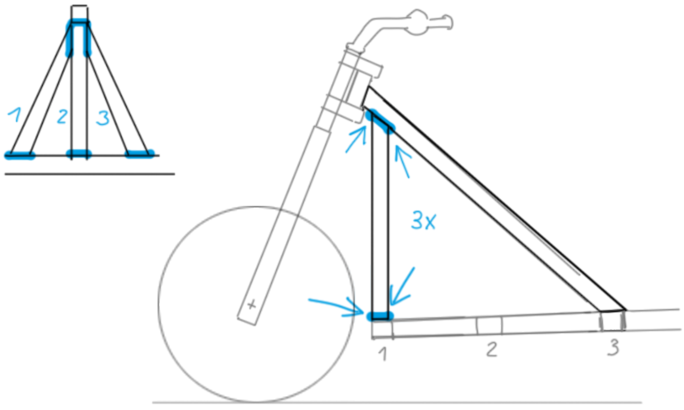
Step	Instructions	Visual Assistance
Step 1.2.1-10	Components: • Trimmed rectangular profiles 60 mm x 30 mm; t = 3 mm Tools: • MIG welding machine Process: a) Tack weld the edges of the profiles together b) Use at least 4 tacks at each joint	

Funded by
the European Union

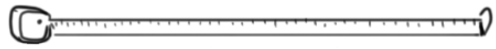
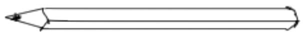
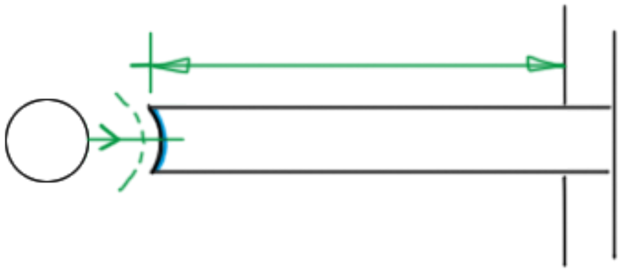
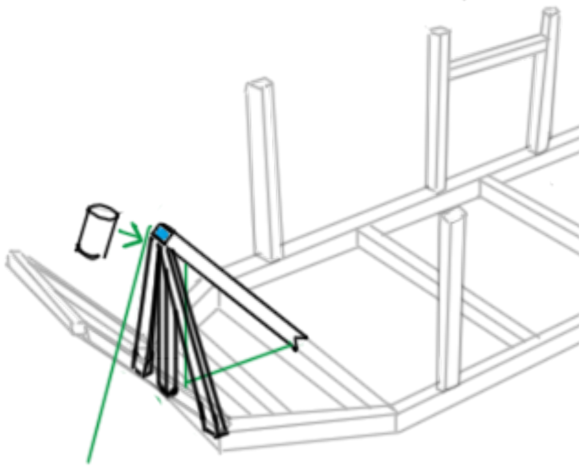
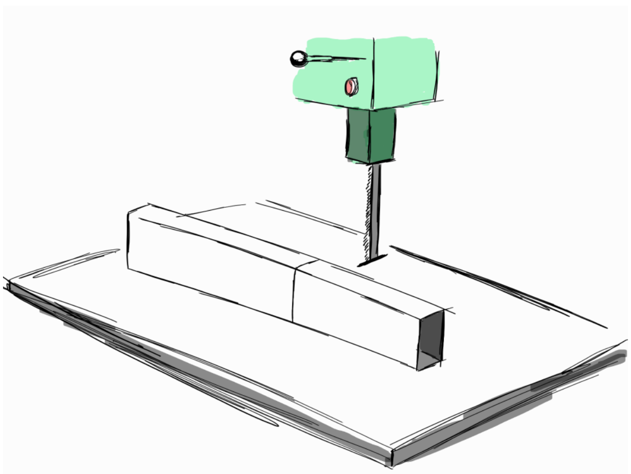
Step	Instructions	Visual Assistance
Step 1.2.1-11	Components: • Tack welded profiles on head tube support. Tools: • Tape measure • Protractor • Spirit level Process: a) Measure if the tack welded profiles are according to the measurement plans. b) If measurements are correct, proceed with step 1.2.2-12. c) If measurements are incorrect, separate the profiles and start again at step 1.2.2-10.	   

Funded by the European Union

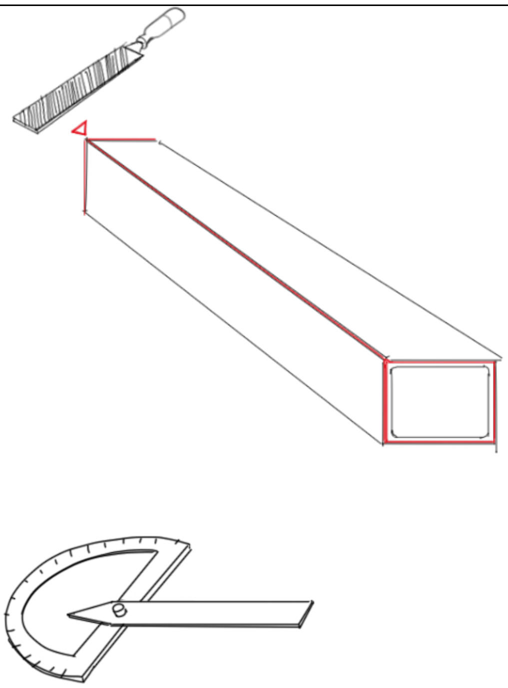
Step	Instructions	Visual Assistance
Step 1.2.1-12	Components: • Tack welded profile 1 Tools: • MIG welding machine Process: a) Fully weld all joints of the Base Frame.	 

Step	Instructions	Visual Assistance
Step 1.2.1-13	Components: • Tack welded profiles 2,3,4 Tools: • MIG welding machine Process: a) Fully weld all joints of the base frame and profiles.	 

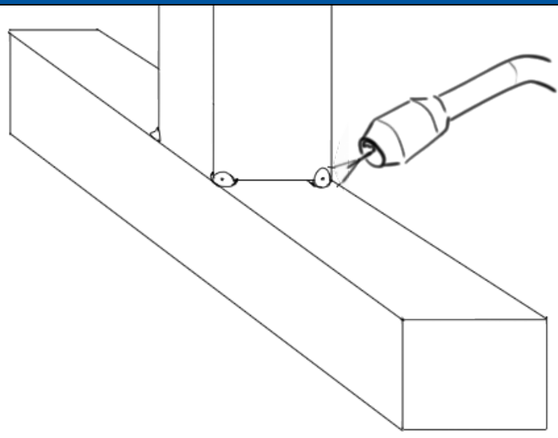
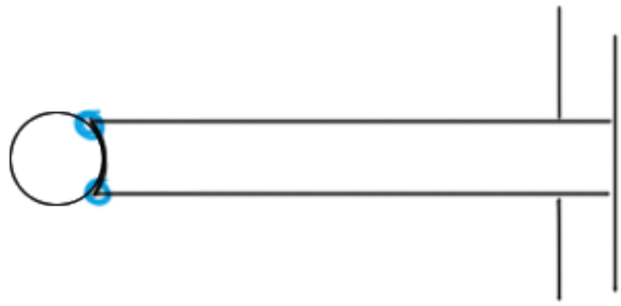
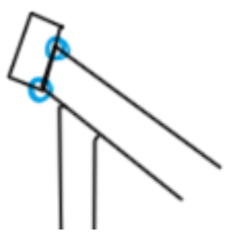
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.1-14	Components: • Head tube • Frame with support for head tube Tools: • Saw • File (used for deburring) • Scriber needle • Protractor • Tape Measure Process: a) Transfer the geometry of the head tube to profile 1 to create a cut-out to which the head tube can be welded. b) Cut out the marked geometry with a saw and rework the geometry with a file until the head tube fits into the cut-out.	     

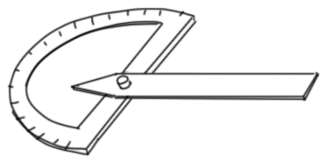
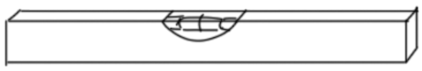
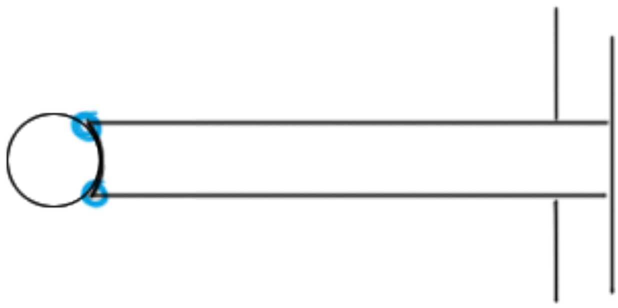
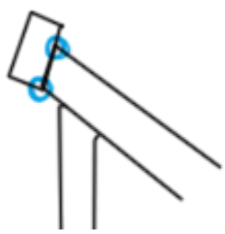
Funded by
the European Union

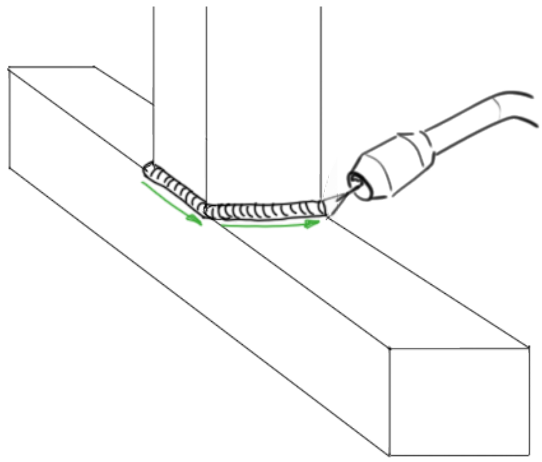
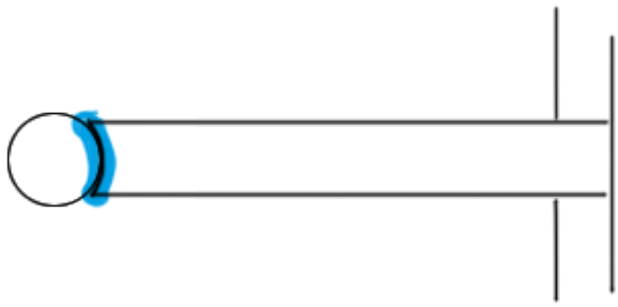
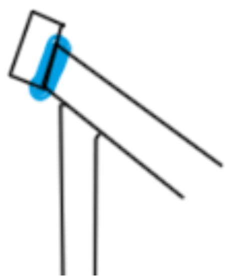
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.1-15	Components: - Support frame for head tube - Head tube Tools: - MIG welding machine Process: a) Weld on the head tube according to the specified position in the cut out of profile 1. Use at least 4 tacks at each joint.	  

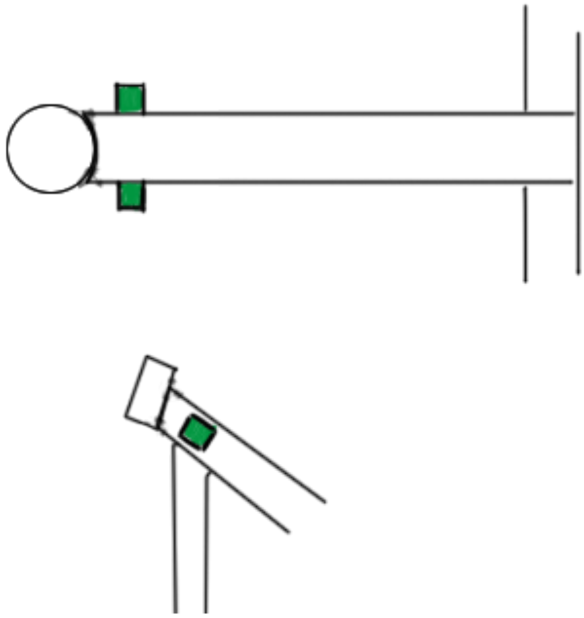
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.1-16	Components: • Tack welded head tube on profile 1 Tools: • Tape measure • Protractor • Spirit level Process: a) Measure if the tack welded profiles are according to the measurement plans. b) If measurements are correct, proceed with step 1.1.2-17. c) If measurements are incorrect, separate Profile 1 and start again at step 1.1.2-15.	    

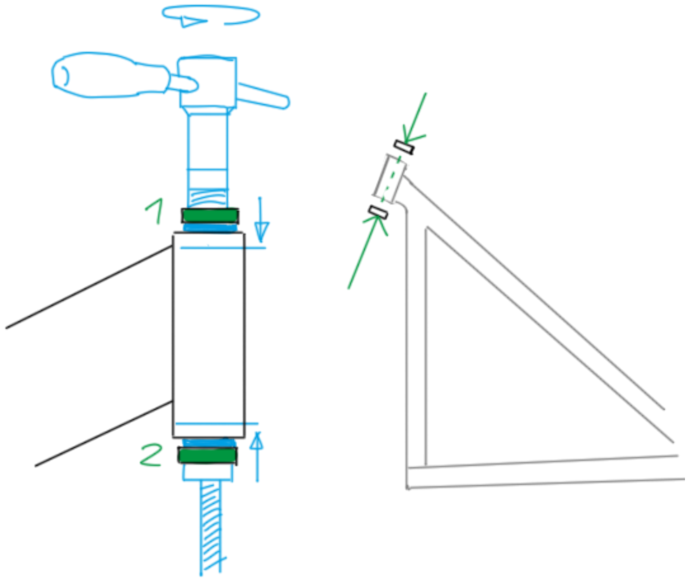
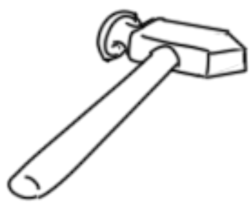
Funded by the European Union

Step	Instructions	Visual Assistance
Step 1.2.1-17	Components: • Tack welded profiles • Rubber bumpers Tools: • MIG welding machine Process: a) Fully weld all joints of the head tube. b) Use rubber bumpers on the top tube of the frame as a steering angle limiter to prevent damage to the fork, the frame or the brake and power cables. The rubber bumpers can be attached by drilling and screwing.	  

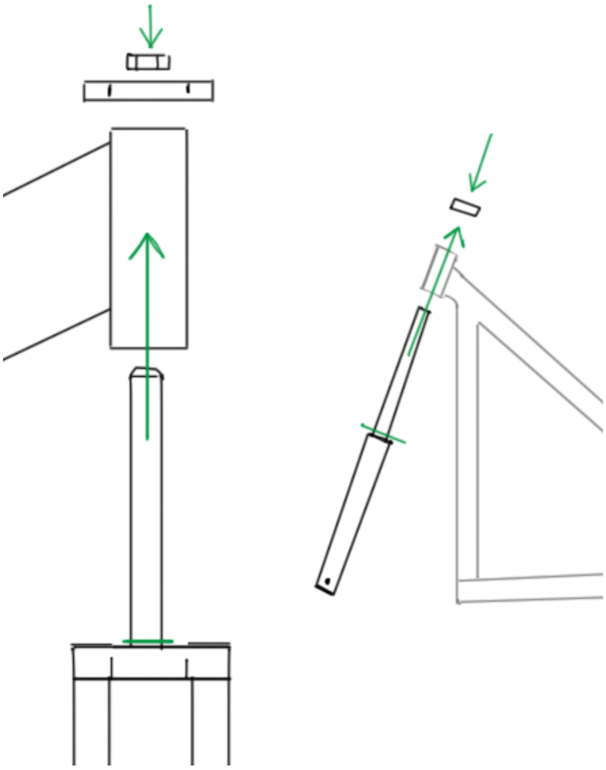
Funded by the European Union

Funded by
the European Union

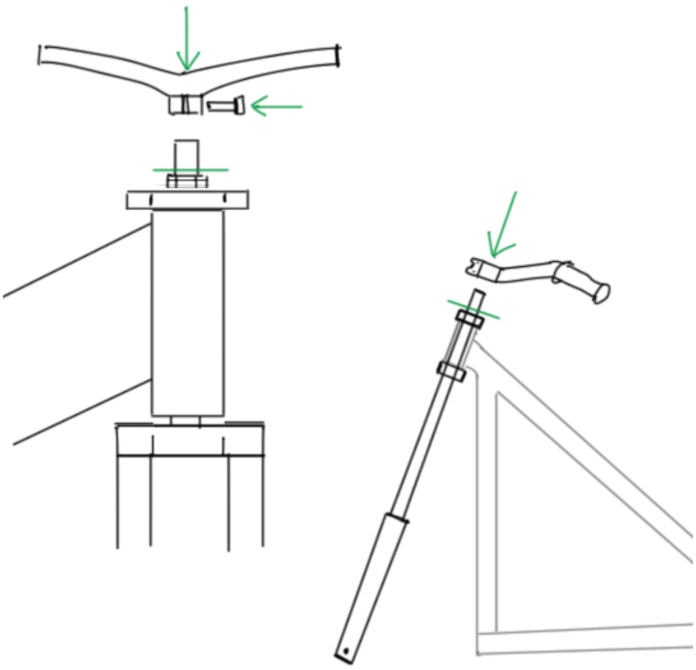
Step	Instructions	Visual Assistance
Step 1.2.1-18	Components: • Base Frame Tools: • Hammer or press in tool Process: a) The bearing has an outer and an inner bearing shell, which must be mounted separately. To integrate the bearing into the steering head, only the outer bearing shell needs to be pressed into the frame. One outer bearing shell is pressed into each side of the steering head. b) A press-in tool is particularly suitable for this. Alternatively, this can be done with a hammer. Care must be taken to ensure that the bearing shell is driven in without tilting. c) The inner bearing shells can then be inserted and the next step can be continued.	 

Funded by
the European Union

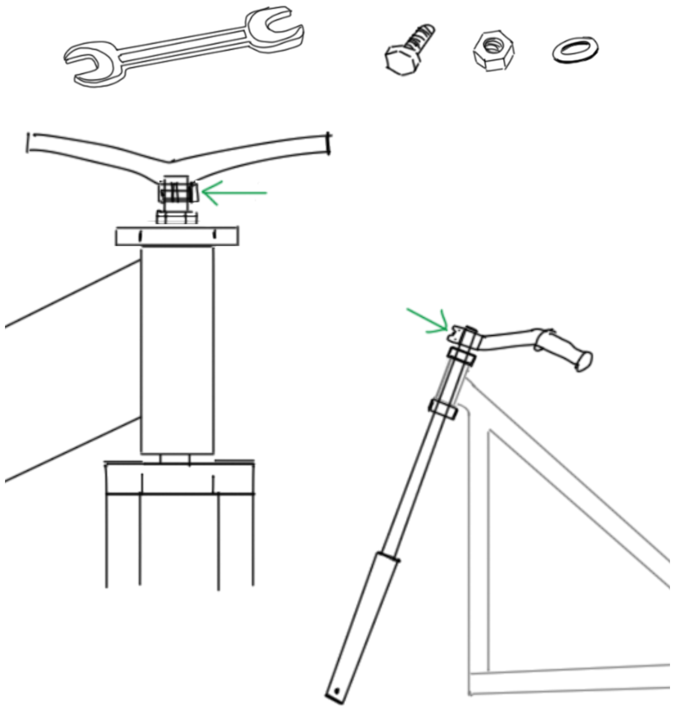
<table>
<tr><th>Step</th><th>Instructions</th><th>Visual Assistance</th></tr>
<tr><td>Step 1.2.1-19</td><td>Components:
Fork
Frame
(Tube)
Tools:
Hexagon socket screwdriver
Open-end spanner
Saw
Process:
a) Insert fork with lower fork crown into bearing of head tube.
b) If there is a gap between the upper bearing and the upper fork crown, which leads to play in the bearing, this must be filled with spacers. For this purpose, a suitable tube with a suitable inner diameter can be shortened to the appropriate length according to the steering tube and installed. In addition, depending on the design of the suspension fork and especially the bearing, a spacer may be required inside the steering head between the upper and lower bearings</td><td>
</td></tr>
</table>

Funded by
the European Union

	otherwise the bearings could be damaged during use. Refer to the manufacturer's instructions. c) Mount the upper fork crown on the head tube and tighten firmly.	

Step	Instructions	Visual Assistance
Step 1.2.1-20	Components: • None Tools: Process: a) Choose a handlebar that meets your personal ergonomic expectations.	

Funded by the European Union

Step	Instructions	Visual Assistance
Step 1.2.1-21	Components: • Fork • Handle bar clamp Tools: • Screwdriver • Open-end spanner Process: a) Fit the handlebar to the clamp on the upper triple clamp.	
Quality Gate	Check welds, distortions and mounted parts.	

Funded by the European Union

4.1.1.2.1.1 Fork Selection

The spring stiffness, among other things, is important when selecting the right fork. The spring stiffness depends on the total vehicle weight when loaded. The maximum deflection of the fork spring for this vehicle is set at 80 mm. This value is made up of the static preload of the spring, which acts as a force on the spring due to the weight of the vehicle when stationary, and the dynamic component, which is applied by driving over uneven surfaces. The dynamic component is referred to as dynamic wheel load fluctuation and can be ±50 % in uneven road conditions. To protect against suspension failure, a safety factor of 1.5 (corresponding to ±50 %) is therefore assumed for the applied forces. In the following, the spring stiffness is calculated according to this assumption.

Static mass onto the front wheel:

$$m_{wheel,front} = m_{vehcile,loaded} \cdot x_{distribution,weight,front} = 1100\,kg \cdot 0.21 = 231\,kg$$

Maximum deflection of the fork for this vehicle:
(Attention: Depending on the local road conditions, this value must be adjusted)

$$s = 80\,mm = 0.08\,m$$

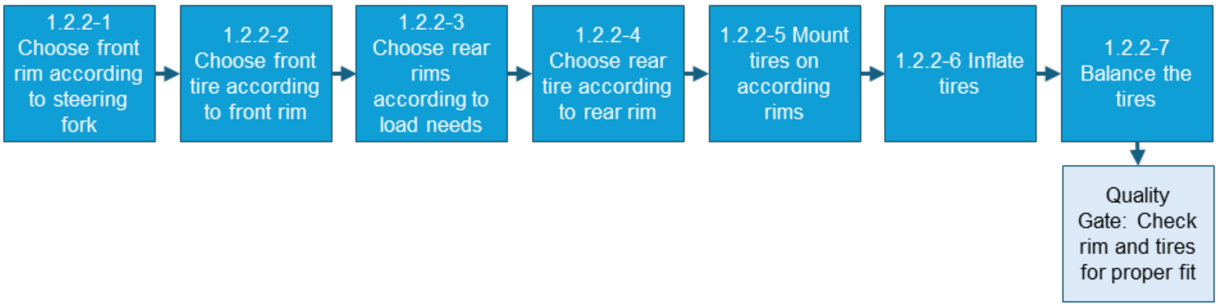
$$k = \frac{m_{wheel,front} \cdot g \cdot 1.5}{s} = \frac{231\,kg \cdot 9.81\frac{m}{s^2} \cdot 1.5}{0.08\,m} = 42489.5625\,\frac{N}{m}$$

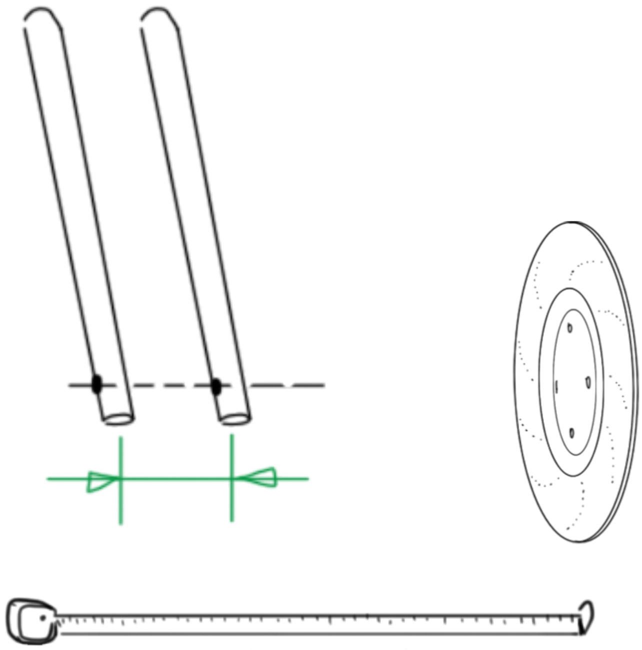
ATTENTION: The values specified above must be adapted to the individual concept for the design. The vehicle weight including payload may deviate from the concept presented here based on the materials selected, so that a calculation must be made at this point using the individual factors.

Funded by
the European Union

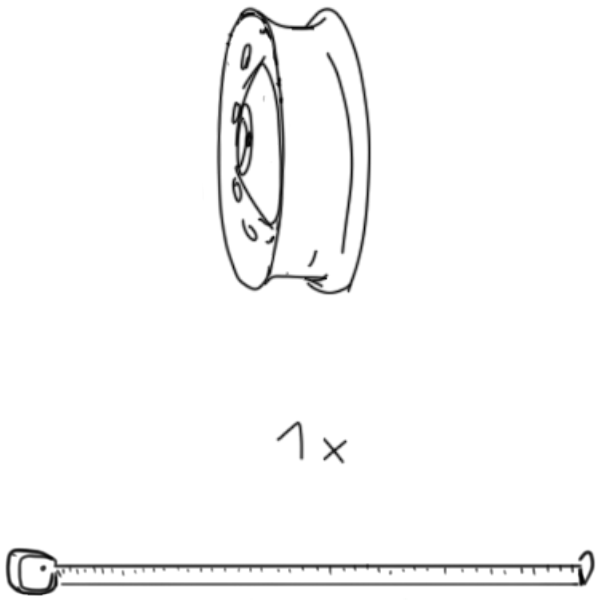
4.1.1.2.2 Wheels

The wheels are assembled and mounted below. Two are attached to the rear axle and one to the front axle at the fork of the eTukTuk and enable it to move, thereby influencing the driving dynamics and comfort.



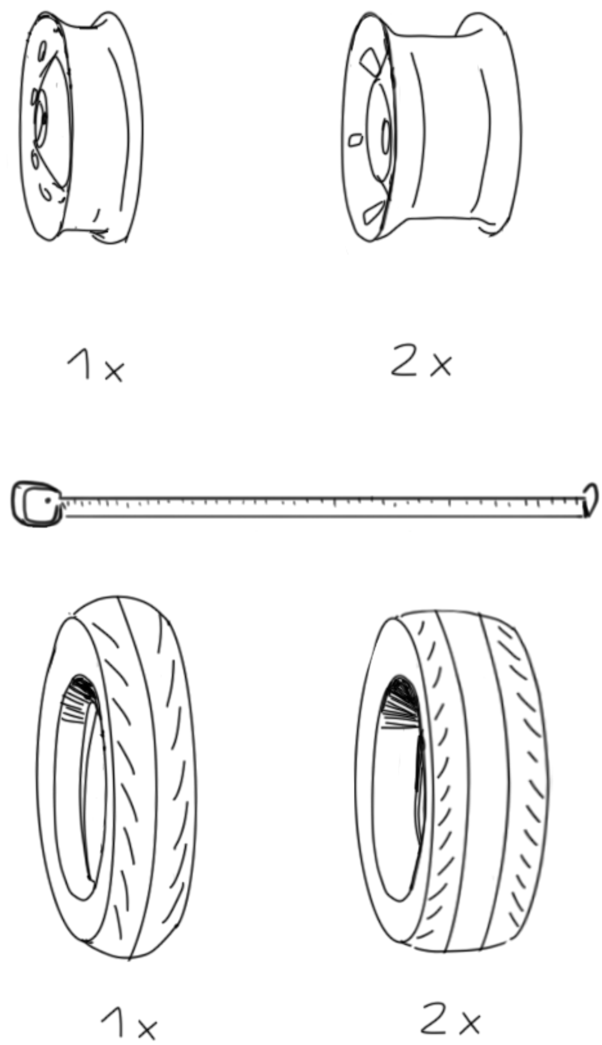
Step	Instructions	Visual Assistance
Step 1.2.2-1	Components: • Steering Fork Tools: • Tape Measure Process: a) Measure the space between the dampers of the Steering Fork. Also take into account the type of axle and, if used, a brake disk and brake caliper. They increase the space required between the rods of the fork. b) Choose according to the fitting rim.	

Funded by
the European Union

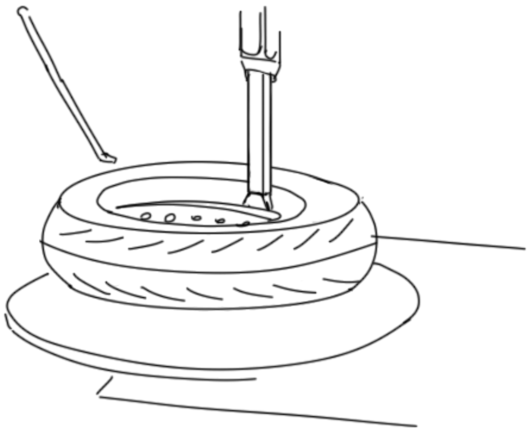
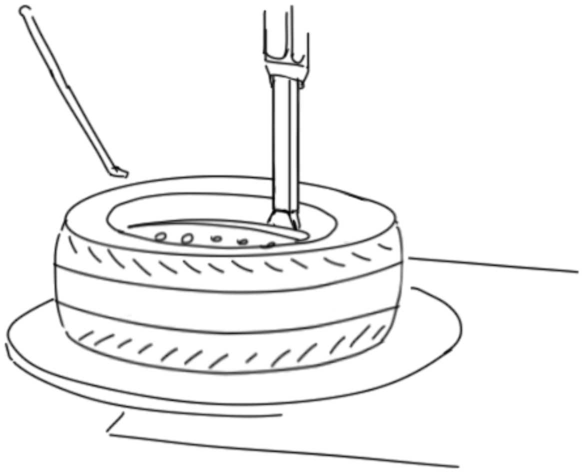
Step	Instructions	Visual Assistance
Step 1.2.2-2	Components: • Front Rim Tools: • Tape Measure Process: a) Measure rim b) Choose the according front tire	

Step	Instructions	Visual Assistance
Step 1.2.2-3	Components: • None Tools: • None Process: a) Estimate the load the eTukTuk has to take on the rear axle. b) Choose the according rear rim.	

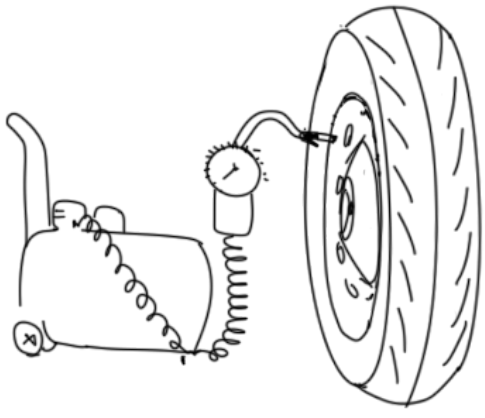
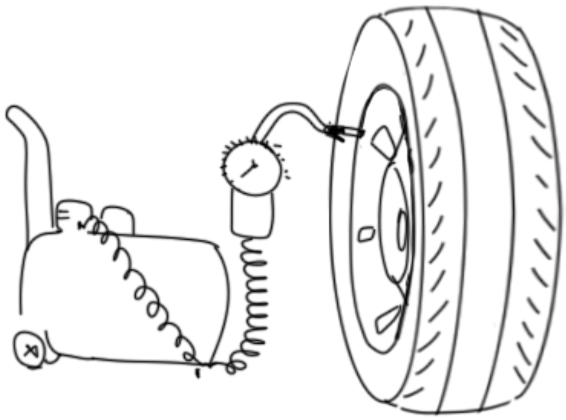
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.2-4	Components: • Rear rim Tools: • Tape measure Process: a) Measure rim. b) Choose the according rear tire.	

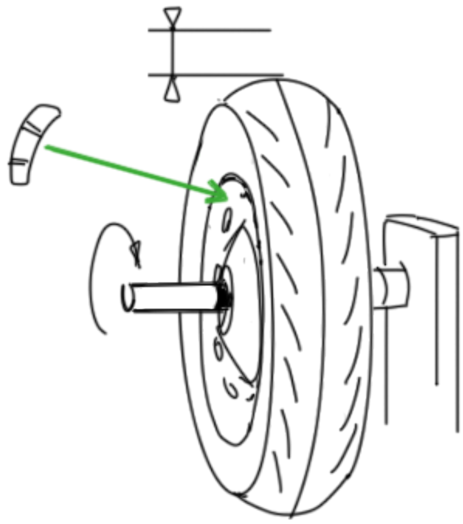
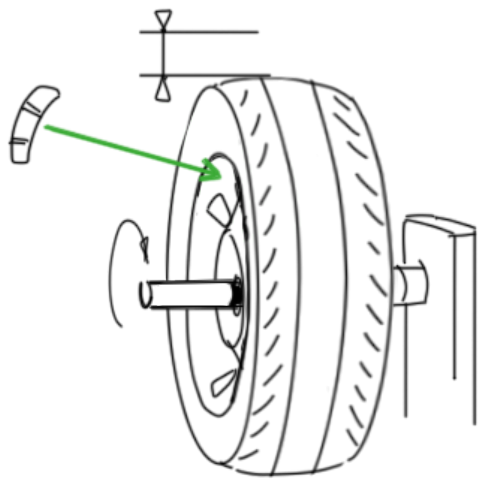
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.2-5	Components: • Front rim • Front tire • Rear rims • Rear tires Tools: • Tire fitting machine • Tire lever • Tire grease Process: a) Fit the tires to the rim according to the instructions on the tire fitting machine.	 

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.2-6	Components: • Front tire • Rear tires Tools: • Compressor Process: a) Inflate the tires to their according pressure setting. b) Check if the tires sit well on the rim and are inflated properly.	 

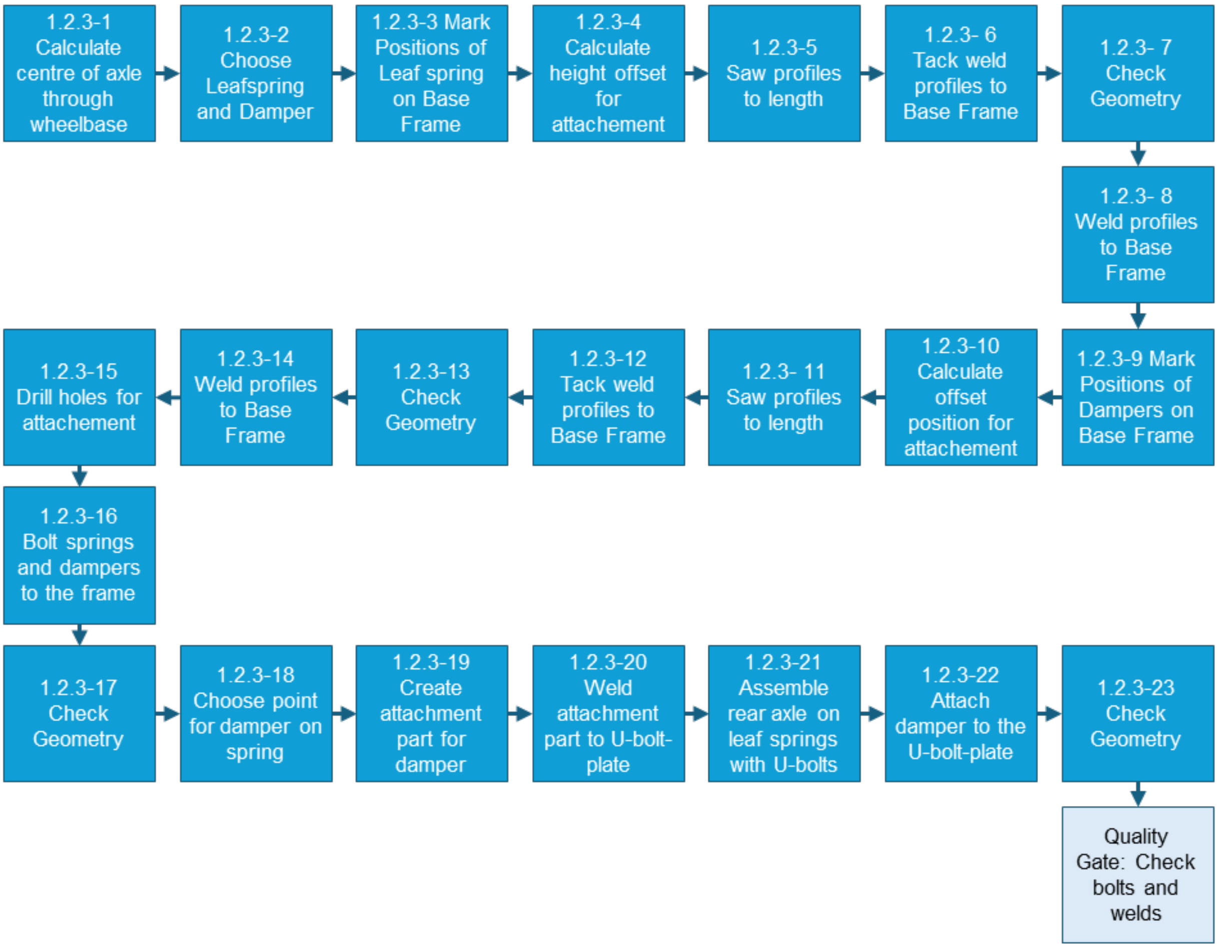
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.2-7	Components: • Front wheel • Rear wheels Tools: • Wheel balancing machine Process: a) Balance the wheels according to the instructions on the balancing machine.	 
Quality Gate	Check rim and tires for proper fit	

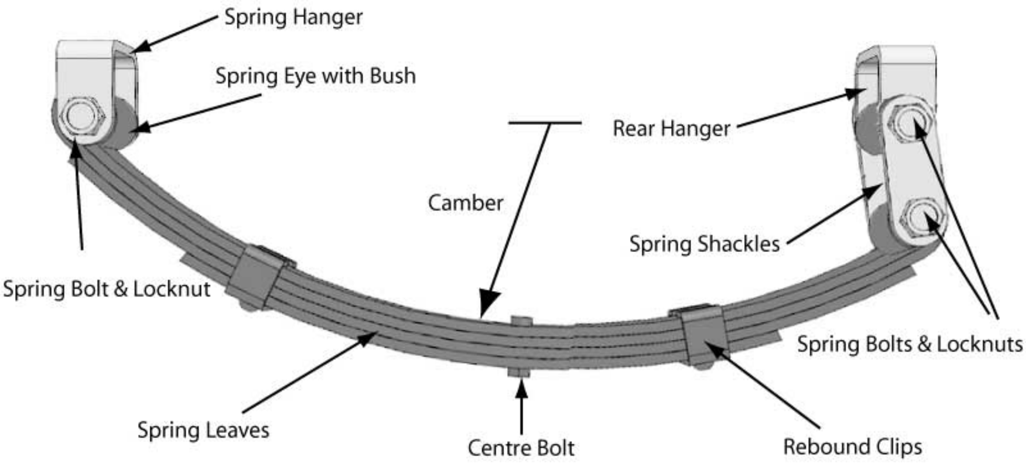
Funded by the European Union

4.1.1.2.3 Rear Springs & Dampers

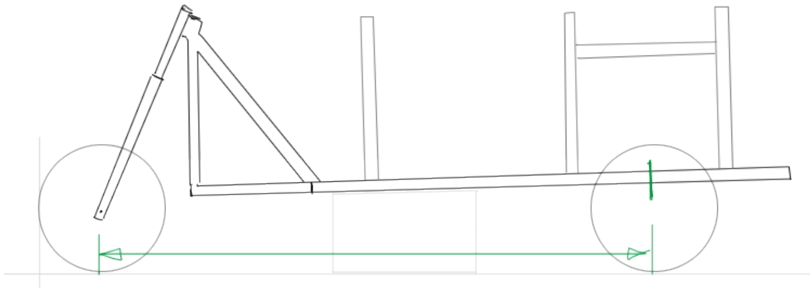
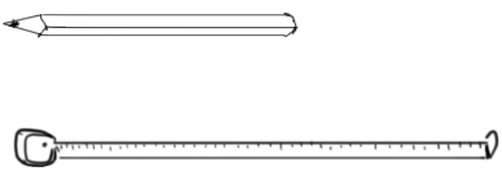
The rear springs and shock absorbers are designed, selected and fitted below. They are installed at the rear of the base frame and improve driving stability and comfort by absorbing shocks and vibrations and keeping the vehicle level. In the overall vehicle manufacturing process, the rear springs and shock absorbers are installed after the steering system and suspension fork have been fitted.



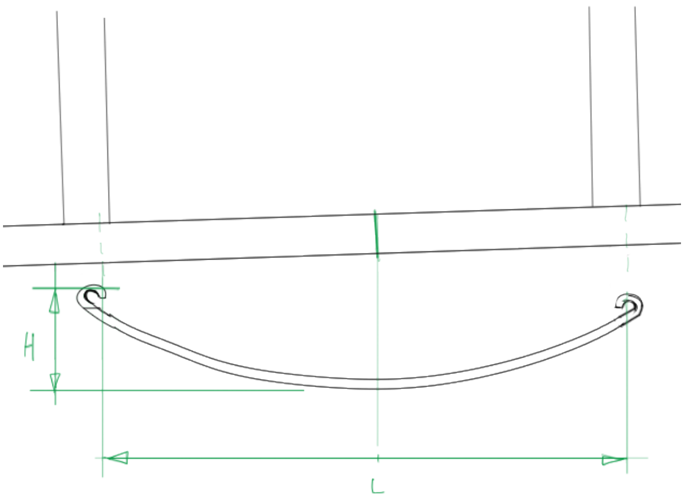
Funded by the European Union



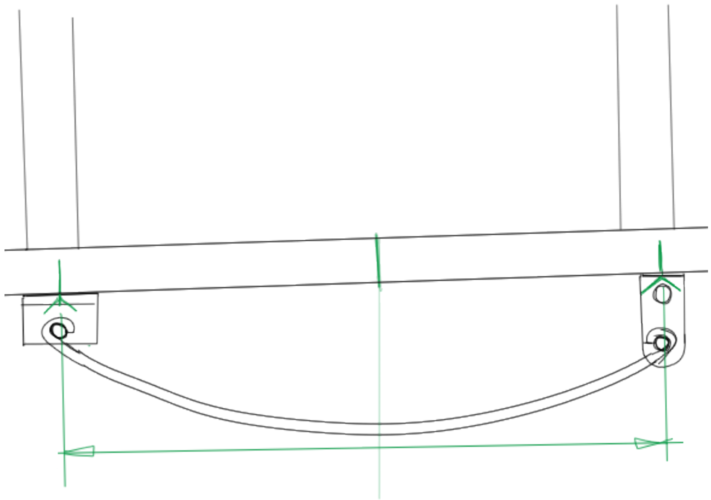
EYE/EYE SPRING COMPONENTS

Step	Instructions	Visual Assistance
Step 1.2.3-1	Components: • Base Frame Tools: • Tape Measure • Scriber Process: a) Measure the wheelbase from the center of the front axle and mark the center of the rear axle on the base frame.	 

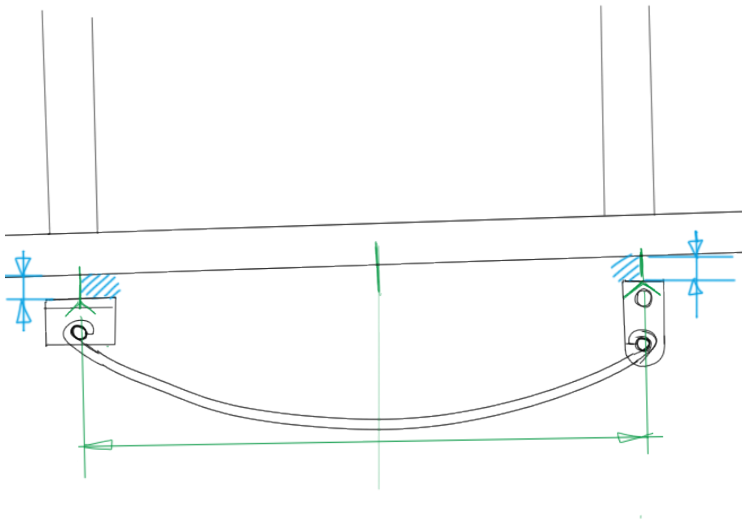
Funded by the European Union

Step	Instructions	Visual Assistance
Step 1.2.3-2	Components: • None Tools: • Calculator Process: a) Calculate the Spring according to Chapter 4.1.1.2.4.1. b) Calculate the corresponding damper according to chapter 4.1.1.2.4.2.	

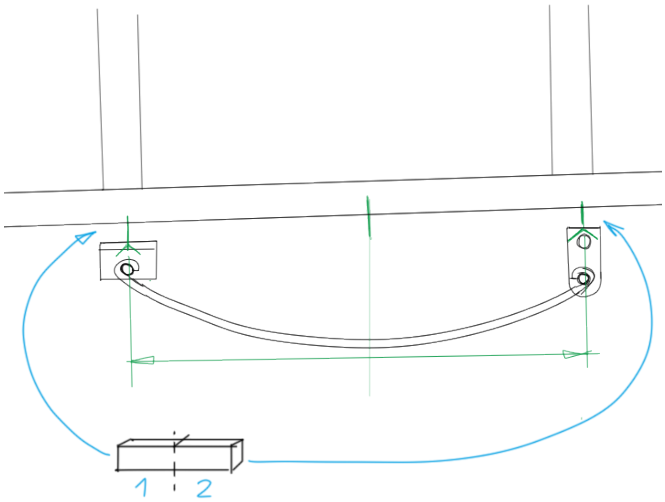
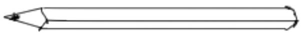
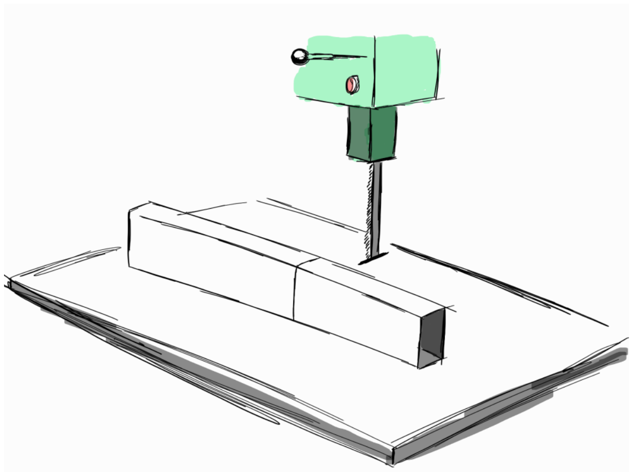
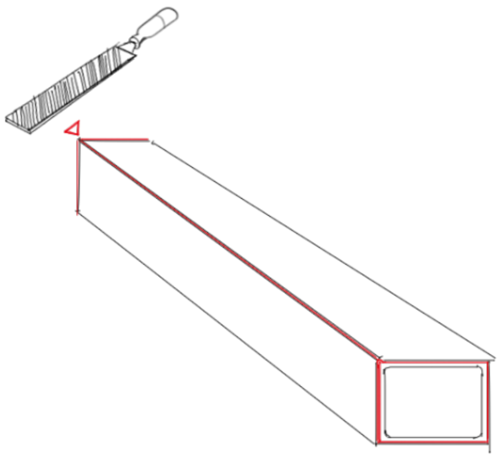
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.3-3	Components: • Base Frame • Leaf Springs incl. mounting shackles Tools: • Scriber • Square Process: a) Hold shackles with leaf spring on to the frame and locate its apex right under the rear axle center mark from Step 1.2.3-1. b) Mark the position of the shackles on the Base Frame.	  

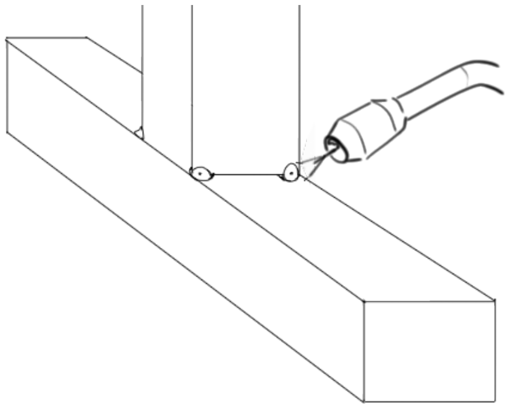
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.3-4	Components: • None Tools: • None Process: a) If the leaf spring needs to be placed further away from the frame calculate the offset.	

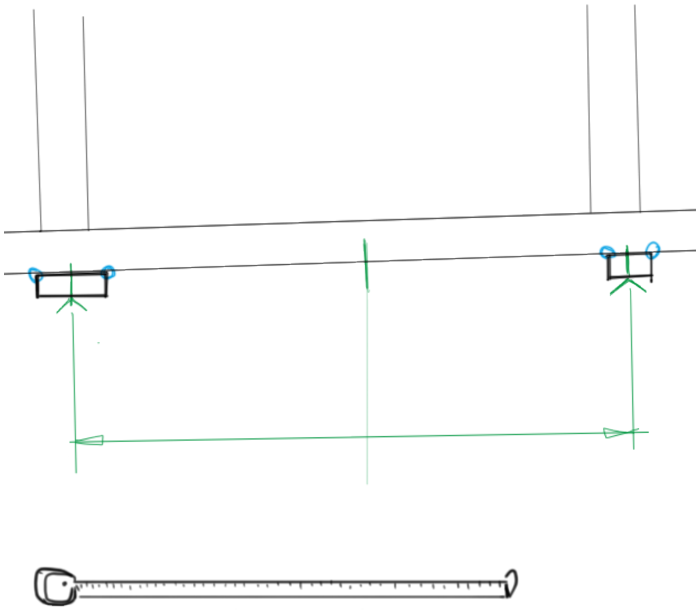
Funded by the European Union

Step	Instructions	Visual Assistance
Step 1.2.3-5	Components: • Rectangular profiles 60 mm x 30 mm; t = 3 mm Tools: • Tape Measure • Scriber • Saw (preferably band saw) • File (used for deburring) Process: a) Only to do if 1.2.3-4 applies b) Mark Profile length c) Saw profiles to length d) Deburr cutting edges	    

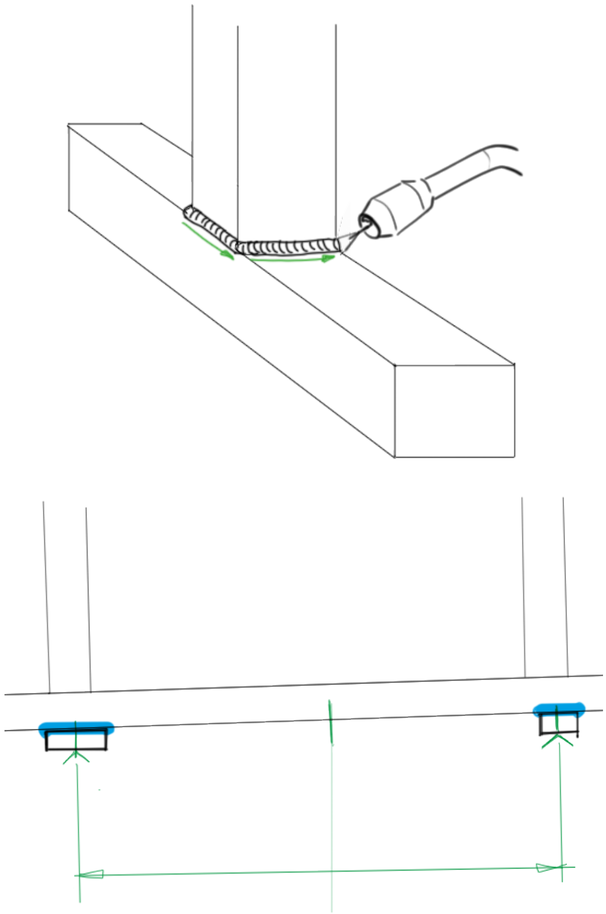
Funded by the European Union

Step	Instructions	Visual Assistance
Step 1.2.3-6	Components: • Cut profiles • Base Frame Tools: • MIG welding machine Process: a) Tack weld the edges of the profiles to the Base Frame. b) Use at least 4 tacks at each joint.	

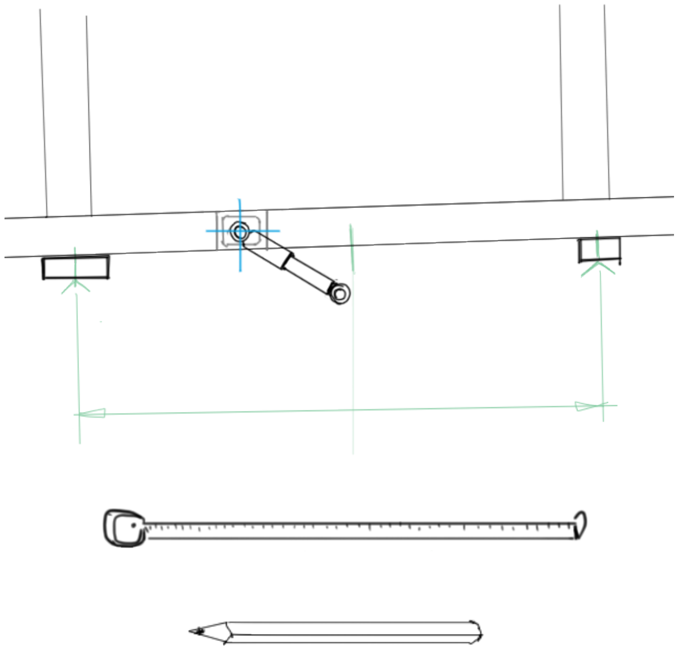
Funded by
the European Union

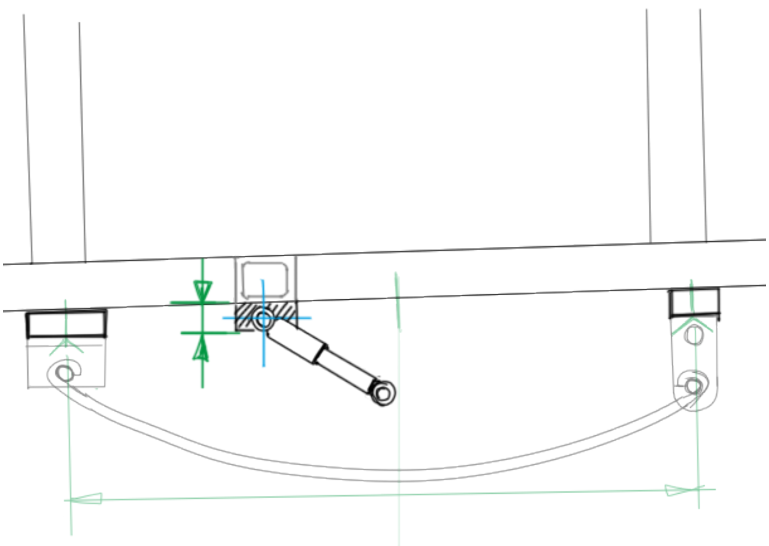
Step	Instructions	Visual Assistance
Step 1.2.3-7	Components: • Tack welded profiles on Base Frame Tools: • Tape Measure Process: a) Check if the tack welded parts on welding distortion. b) If distortion is high, try to correct it.	

Funded by
the European Union

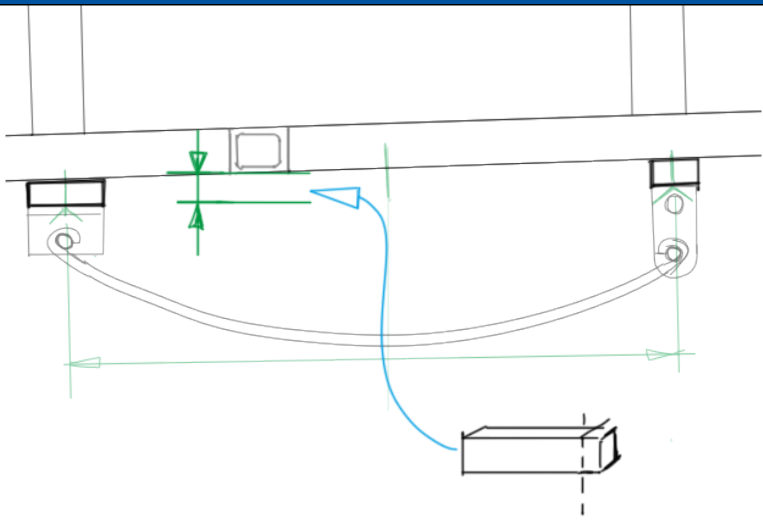
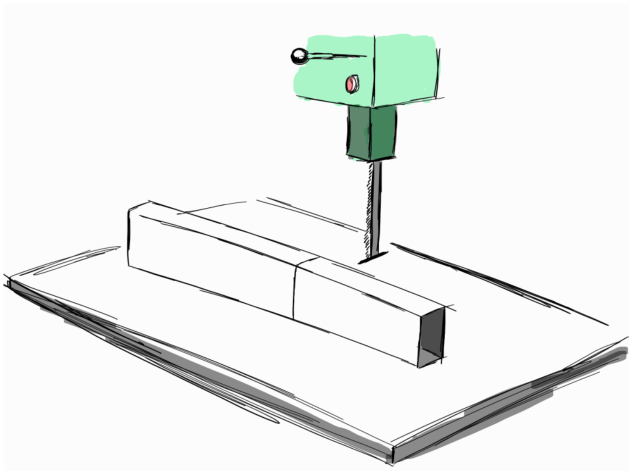
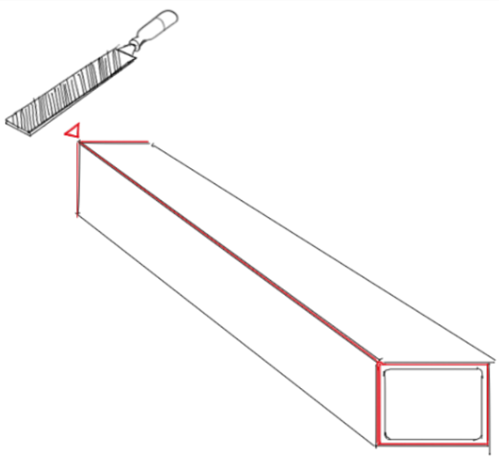
Step	Instructions	Visual Assistance
Step 1.2.3-8	Components: • Tack welded profiles on Base Frame Tools: • MIG welding machine Process: a) Fully weld all joints. b) Follow Quality Gate to check the quality of the welding seams and the Base Frame regarding welding distortions.	

Funded by
the European Union

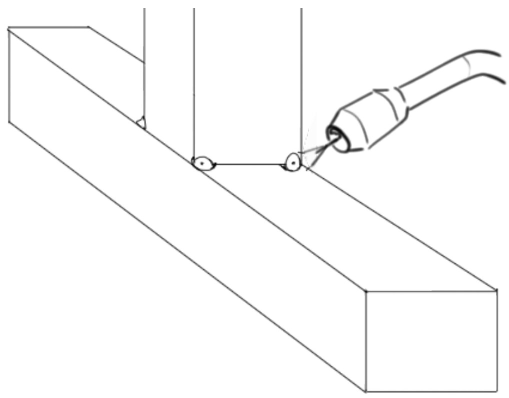
Step	Instructions	Visual Assistance
Step 1.2.3-9	Components: • Base Frame • Dampers Tools: • Scriber • Square • Scriber Process: a) Position the upper part of the damper on a cross brace of the Base Frame. b) Mark the Position.	

Step	Instructions	Visual Assistance
Step 1.2.3-10	Components: • None Tools: • None Process: a) If dampers need to be place further away from the frame calculate the offset.	

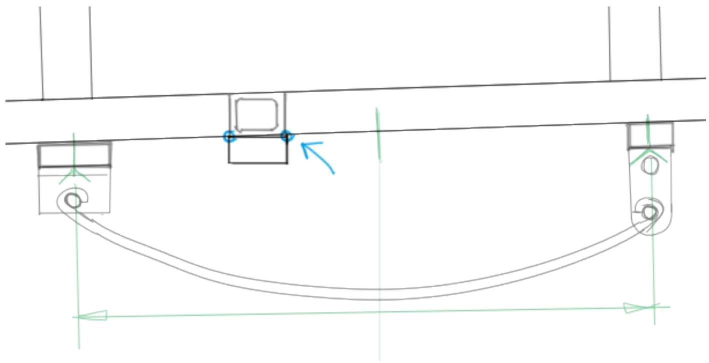
Funded by the European Union

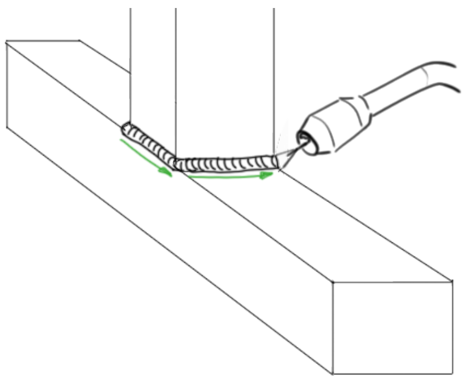
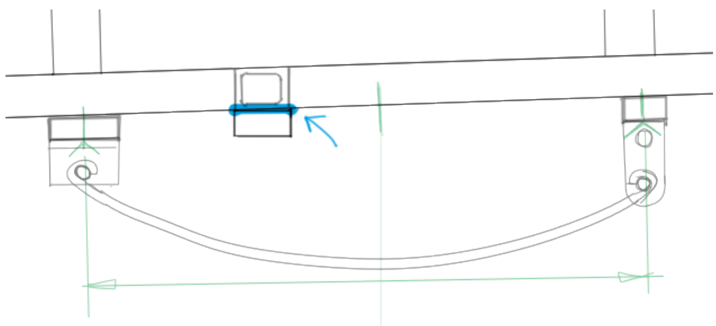
Step	Instructions	Visual Assistance
Step 1.2.3-11	Components: • Rectangular profiles 60 mm x 30 mm; t = 3 mm Tools: • Tape Measure • Scriber • Saw (preferably band saw) • File (used for deburring) Process: a) Only to do if 1.2.3-10 applies b) Mark Profile length c) Saw profiles to length d) Deburr cutting edges	    

Funded by the European Union

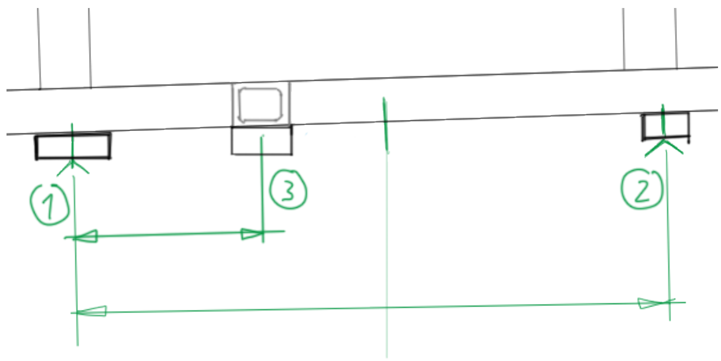
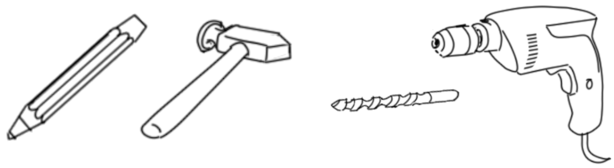
Step	Instructions	Visual Assistance
Step 1.2.3-12	Components: • Cut profiles • Base Frame Tools: • MIG welding machine Process: a) Tack weld the edges of the profiles to the Base Frame. b) Use at least 4 tacks at each joint.	

Funded by the European Union

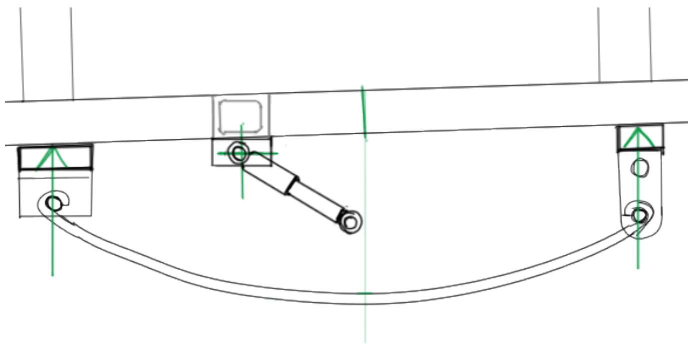
Step	Instructions	Visual Assistance
Step 1.2.3-13	Components: • Tack welded profiles on Base Frame Tools: • Tape Measure Process: a) Check whether the tack-welded parts are distorted during welding. b) If distortion is high, try to correct it.	 

Step	Instructions	Visual Assistance
Step 1.2.3-14	Components: • Tack welded profiles on Base Frame Tools: • MIG welding machine Process: a) Fully weld all joints. b) Follow Quality Gate to check the quality of the welding seams and the Base Frame regarding welding distortions.	 

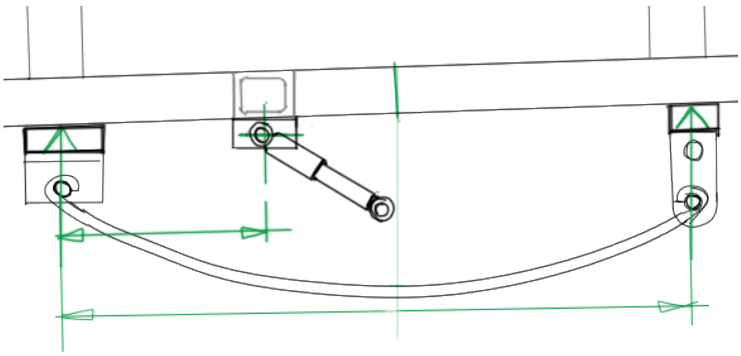
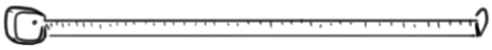
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.3-15	Components: • Base Frame Tools: • Punch • Drill • Tape Measure Process: a) Measure the attachment points for the leaf spring shackles and the dampers on the frame. b) Mark all drill spots with a punch. c) Choose the right drill diameter and drill all holes. d) Deburr all drilled holes.	  

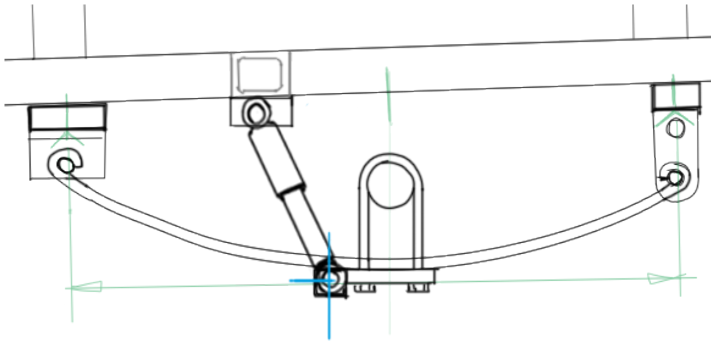
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.3-16	Components: • Base Frame • Dampers • Leaf Springs • Screws • Washers • Nuts • Screw lock Tools: • Socket wrench • Torque wrench • spanner Process: a) Fit the bolts with the washers in the holes and screw them securely into the nuts – use screw lock. b) Turn the screws with the torque wrench set to the correct torque.	  

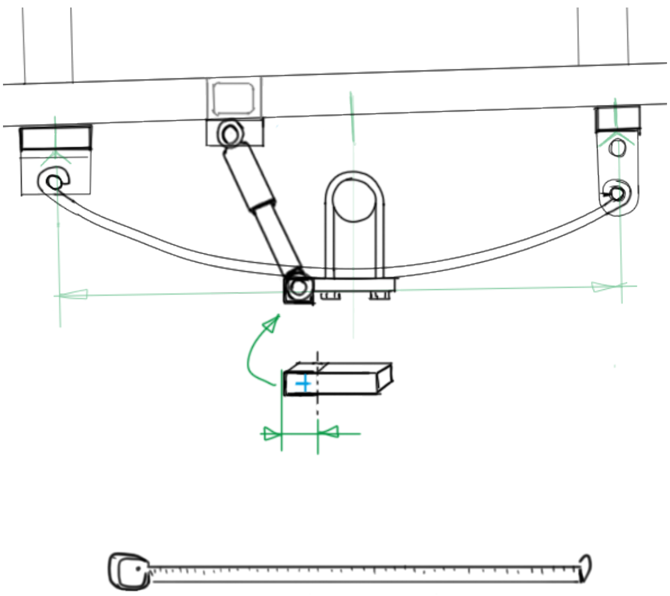
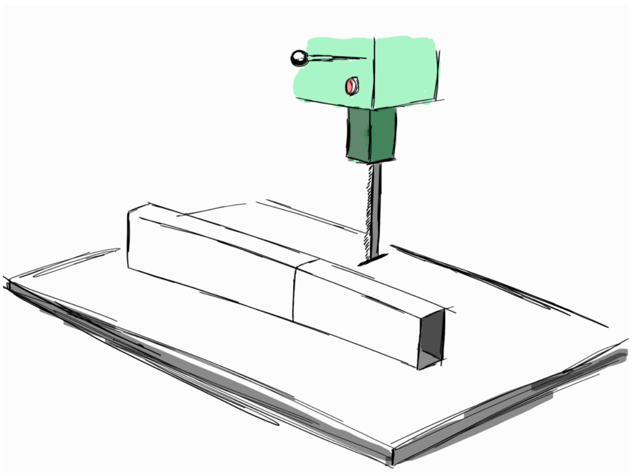
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.3-17	Components: • Base Frame with all attachments from before Tools: • Tape Measure Process: a) Measure if the geometry is as planned. b) If measurements are right, proceed with step 1.2.3-18. c) If measurements are incorrect, separate the tack welds and start again at step 1.2.3-16.	 

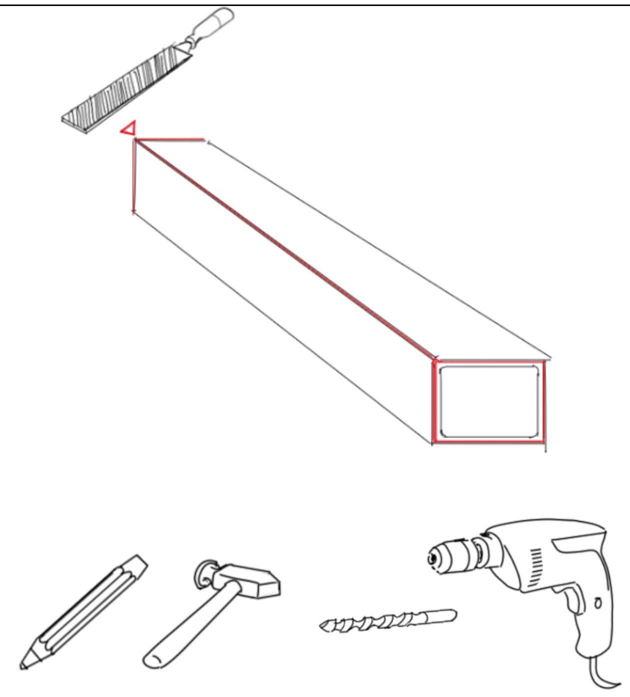
Funded by the European Union

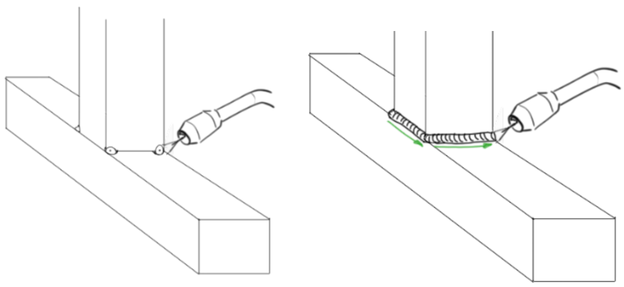
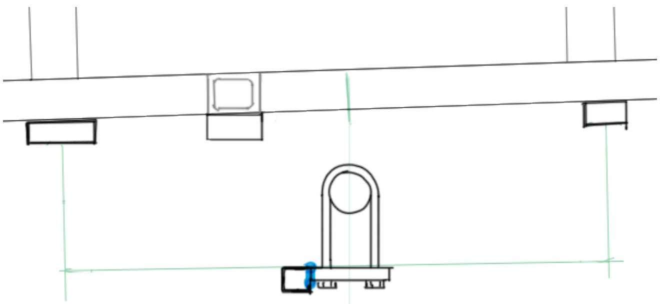
Step	Instructions	Visual Assistance
Step 1.2.3-18	Components: • Base Frame with all attachments from before Tools: • None Process: a) Choose the mounting point to attach the damper to the leaf spring at the U-Bolt-Plate.	

Funded by the European Union

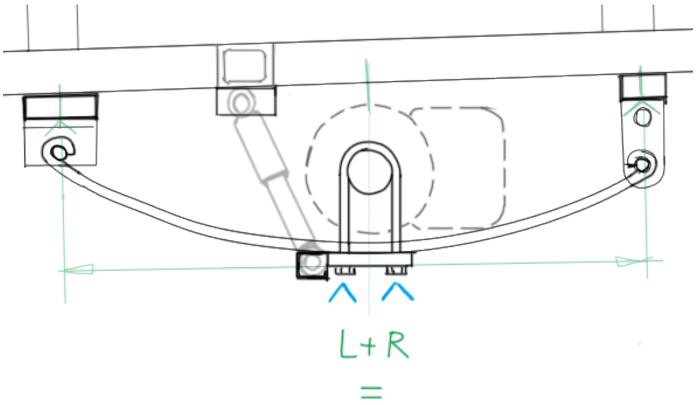
Step	Instructions	Visual Assistance
Step 1.2.3-19	Components: • Rectangular profiles 60 mm x 30 mm; t = 3 mm Tools: • Tape Measure • Scriber • Saw (preferably band saw) • File (used for deburring) Process: a) Based on 1.2.3-18 make an attachment part for mounting the damper. b) Measure the profile, mark it and cut it to length. c) Punch the position of the mounting hole. d) Choose the right drill diameter, drill the hole and deburr it.	 

Funded by
the European Union

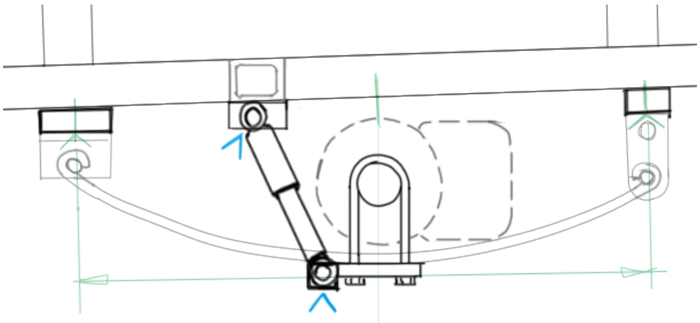
		

Step	Instructions	Visual Assistance
Step 1.2.3-20	Components: • Attachment Part Tools: • MIG welding machine Process: a) Fix the Attachment Part at the right position of the U-Bolt-Plate. b) Weld the attachment to the U-Bolt-Plate.	 

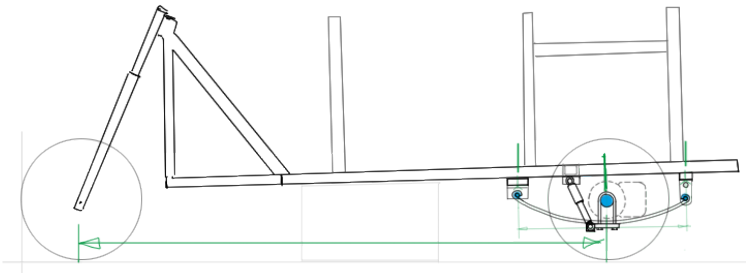
Funded by the European Union

Step	Instructions	Visual Assistance
Step 1.2.3-21	Components: • Base Frame with all the attachments • Rear axle with differential Tools: • Socket wrench • Torque wrench • Spanner Process: a) Place the U-Bolt-Plate on the leaf spring. b) Position the rear axle on the marked center of the axle of the base frame. c) Secure the axle with the U-Bolts and tighten them. d) Adjust the position of the rear axle so that the wheelbase on the left and right side is correct. e) Finally, fasten the axle with the U-Bolts with the Torque wrench.	

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.3-22	Components: • Assembled Base Frame Tools: • Socket wrench • Torque wrench • Spanner Process: a) Screw the damper to the attachment part. b) Finally fasten the damper with the Torque wrench.	  

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.3-23	Components: • Base Frame with all attachments from before Tools: • Tape Measure Process: a) Measure if the geometry is as planned. b) If measurements are correct proceed with step 1.2.3-24. c) If measurements are incorrect, separate the tack welds and start again at step 1.2.3-20.	 
Quality Gate	• Check welds for distortion • Check bolts for proper fit and firmness	

Funded by
the European Union

4.1.1.2.3.1 Spring calculation

As is usual for this type of vehicle, leaf springs are used on the rear axle. The calculation basis for the design of the leaf springs is shown below. The leaf spring must be designed and selected according to the calculation.

Leaf spring parameters:

E: Modulus of elasticity of the spring steel (in Pa)

b: Leaf spring width (in mm)

t: Leaf spring thickness (in mm)

L: Length of the leaf spring (in mm)

Force onto the spring: $F = m \cdot g$

Spring stiffness: $k = \frac{F}{s} = \frac{m \cdot g}{s}$

Maximum deflection of a leaf spring under a force F: $\delta = \frac{4 \cdot F \cdot L^3}{E \cdot b \cdot t^3}$

For a given maximum spring deflection s: $s = \frac{4 \cdot F \cdot L^3}{E \cdot b \cdot t^3}$

Resolve according to the thickness of the leaf spring t: $t = \left(\frac{4 \cdot F \cdot L^3}{E \cdot b \cdot s}\right)^{\frac{1}{3}}$

The maximum deflection of a leaf spring for this vehicle is set to $80\ mm$. This value is made up of the static preload of the spring, which acts as a force on the spring due to the weight of the vehicle when stationary, and the dynamic component, which is applied by driving over uneven surfaces. The dynamic component is referred to as dynamic wheel load fluctuation and can be ±50% for uneven road conditions. To protect against suspension failure, a safety factor of 1.5 (corresponding to ±50 %) is therefore assumed for the forces applied.

Parameters for the static preload of the leaf spring:

Static mass onto each wheel of the rear axis:

$$m_{wheel,rear} = \frac{m_{vehcile,loaded} \cdot i_{axleload,rear}}{2} = \frac{1100\ kg \cdot 0.79}{2} = 434.5\ kg$$

Maximum deflection of a leaf spring for this vehicle:

$$s = 80\ mm = 0.08\ m$$

Funded by
the European Union

Modulus of elasticity for spring steel:

$E = 210 \cdot 10^9 \; Pa$

Leaf spring width:

$b = 50 \; mm = 0.05 \; m$

Length of the leaf spring:

$L = 1 \; m$

Safety factor for dynamic wheel load fluctuation:

$S = 1.5$

ATTENTION: The values specified above must be adapted to the individual concept for the design. The vehicle weight including payload may deviate from the concept presented here based on the materials selected. The modulus of elasticity of the steel as well as the width and length of the spring can also vary depending on the concept used, so that a calculation must be made at this point using the individual factors.

Calculation:

$$F = m_{wheel,rear} \cdot g \cdot S = 434.5 \; kg \cdot 9.81 \frac{m}{s^2} \cdot 1.5 = 6393.6675 \; N$$

$$k = \frac{m_{wheel,rear} \cdot g \cdot S}{s} = \frac{434.5 \; kg \cdot 9.81 \frac{m}{s^2} \cdot 1.5}{0.08 \; m} = 79920.84375 \frac{N}{m}$$

$$t = \left(\frac{4 \cdot 6393.6675 \; N \cdot 1^3}{210 \cdot 10^9 \; Pa \cdot 0.05 \; m \cdot 0.08 \; m} \right)^{\frac{1}{3}} = 0.03123 \; m = 31.23 \; mm$$

The leaf spring must be selected according to the designed and calculated spring value $\boldsymbol{E, k, b, L, t}$.

4.1.1.2.3.2 Damper calculation

The damper constant c is calculated below for the design of the shock absorber. The damper constant c is designed primarily on the basis of the spring stiffness k and the relevant mass.

Relevant parameters:

Spring stiffness: $k = 79920.84375 \frac{N}{m}$

Static mass onto each wheel of the rear axis: $m_{wheel,rear} = 434.5 \; kg$

Funded by the European Union

Critical damping:

$$c_{crit} = 2\sqrt{m_{wheel,rear} \cdot k} = 2\sqrt{434.5\ kg \cdot 79920.84375 \frac{N}{m}} = 11785.68736 \frac{kg}{s}$$

Actual damper constant:

In practice, a certain percentage of the critical damping is often used, depending on how "soft" or "hard" the ride feel should be. A common value is between 60 % and 80 % of the critical damping. A value of 70 % of the critical damping is used here.

$$c = 0.7 \cdot c_{crit} = 0.7 \cdot 11785.68736 \frac{kg}{s} = 8249.981149 \frac{kg}{s} \approx 8250 \frac{kg}{s}$$

ATTENTION: The calculated damper constant is based on the previously calculated leaf spring and the vehicle weight. Accordingly, the individual calculation must be adapted to the specific parameters of the individual concept.

4.1.2 Drivetrain

In the following chapter, the drive train of the vehicle is dimensioned. This includes information and calculations for the transmission as well as power requirement calculations for the motor.

ATTENTION: The following is the layout of the drive unit and the battery. Various calculations are given for this purpose, which must be recalculated and adapted with the parameters and framework factors of your own concept.

4.1.2.1 E-Motor

The vehicle described here is an electrically powered vehicle. In order to select an electric motor, calculations must be made with regard to the power requirements of the drivetrain. The following chapter presents the calculation principles for determining the necessary dimensions of the drivetrain.

ATTENTION: It is important to note that an AC/DC or DC/DC converter can be avoided under certain conditions.

Motor: DC

If the drive unit operates at the voltage level of the battery (e.g. 60 V or 72 V), an additional DC/DC converter can also be dispensed with.

If the drive unit operates at a different voltage level than the battery (e.g. 60 V or 72 V), an additional DC/DC converter must be installed, which provides the operating voltage of the drive unit as the input voltage.

Funded by
the European Union

Motor: AC

An AC/DC converter must be provided regardless of the operating voltage of the drive unit, which provides the operating voltage of the drive unit as the input voltage.

4.1.2.1.1 E-Motor selection

Several factors play a decisive role in selecting the right electric motor. The aim of the motor selection is to provide the motor power required for the designed vehicle concept. The factors influencing the determination of the motor power include the maximum vehicle weight, consisting of the vehicle's own weight and the maximum payload, the vehicle's intended climbing ability and the air resistance of the vehicle concept. The factors mentioned influence the driving resistance that occurs, which must be overcome by the engine power. Another important factor in the engine's design is the intended maximum speed of the vehicle. As it is an electric drive in any case, there is no need for a multi-stage gearbox. Shifting between forward and reverse gear is realized by reversing the polarity of the electric motor and is already provided for in most electric motors available on the market, so that a dedicated consideration is not necessary. However, by eliminating a multi-stage gearbox, the design of the motor and the reduction gearbox directly defines the maximum achievable top speed. For this reason, the reduction gearbox and electric motor must be selected accordingly and matched to each other. The power requirement calculation is generally based on the greatest demand from a number of different requirements. A first requirement may be to be able to achieve a certain speed in a certain time. This case is not relevant for the present case of the simplest possible vehicle concept. A second requirement may be to be able to reproduce certain dynamic driving characteristics (max. speed, max. gradient, etc.) with the vehicle performance. A third criterion may be to be able to overcome a certain curb height with the vehicle from a standstill, i.e. to have sufficient vehicle power to overcome a certain height of a step. The formulas for the last two design requirements are given below. The layout for the realization of certain driving characteristics is carried out as an example. The calculation of the necessary power to overcome steps and curbs must be carried out individually in relation to the local conditions. The required motor power is subsequently defined by the greater of the two power requirements.

Power Requirement Calculation

Required parameters:

Weight of the vehicle (incl. payload):	m (in kg)
Maximum speed:	v_{max} (in m/s)
Rolling resistance coefficient:	c_r
Coefficient of drag:	c_w

Funded by
the European Union

Frontal area of the vehicle: A (in m²)

Air density: $\rho \approx 1.225 \frac{kg}{m^3}$ (at sea level and 15°C)

Gradient of the road: θ (in degrees)

Efficiency of the electric motor: η

Calculation formulas:

The power P is made up of various components:

Rolling resistance force: $F_{roll} = c_r \cdot m \cdot g$

Air resistance force: $F_{air} = \frac{1}{2} \cdot c_d \cdot A \cdot \rho \cdot v^2$

Inclination resistance force: $F_{inclination} = m \cdot g \cdot sin(\theta)$

The total drag force: $F_{tot} = F_{roll} + F_{air} + F_{inclination}$

The required drive power: $P = F_{tot} \cdot v_{max}$

Since the e-machine has an efficiency, the electrical power actually required P_{electr} must be taken into account:

Electrical power (taking into account the efficiency): $P_{electr} = \frac{P}{\eta}$

Relevant vehicle parameters:

Total vehicle weight (including payload): $m = 1100\ kg$

Maximum speed: $v_{max} = 14 \frac{m}{s} \approx 50 \frac{km}{h}$

Rolling resistance coefficient: $c_r = 0.01$

Drag coefficient: $c_d = 0.4$

Frontal area: $A = b \cdot h = 0.7\ m \cdot 1.5\ \mathrm{m} = 1.05\ m^2$

Gradient: $\theta = 7° \approx 12\%$

Efficiency of the electric motor: $\eta = 0.85$

Funded by
the European Union

Calculation:

Rolling resistance force:

$$F_{roll} = 0.01 \cdot 1100\, kg \cdot 9.81 \frac{m}{s^2} = 107.91\, N$$

Air resistance force:

$$F_{air} = \frac{1}{2} \cdot 0.4 \cdot 1.05\, m^2 \cdot 1.225 \frac{kg}{m^3} \cdot \left(14 \frac{m}{s}\right)^2 = 50.421\, N$$

Inclination resistance force:

$$F_{inclination} = 1100\, kg \cdot 9.81 \frac{m}{s^2} \cdot sin(7°) = 1315.09\, N$$

The total resistance force:

$$F_{tot} = 107.91\, N + 50.421\, N + 1315.09\, N = 1473.421\, N$$

As described above, the required motor power depends on the driving speed and the total resistance forces. It should be noted that the vehicle should not be designed in such a way that the intended maximum speed can be reached at maximum inclination, as this would lead to a significant oversizing of the drive unit and thus to higher costs, weight and therefore also to a larger dimensioning of the battery, which in turn has an influence on costs and weight. Instead, the vehicle is designed in such a way that it can achieve the targeted maximum driving speed on level ground and still reach around 25% of the targeted maximum speed with maximum load and maximum inclination (edge case). The following two load cases must therefore be checked (ground level, inclination) and the dimensions of the drive unit determined accordingly.

The required drive power on ground level:

$$P_{ground} = F_{tot} \cdot v_{max} = (F_{roll} + F_{air}) \cdot v_{max}$$

$$P_{ground} = (107.91\, N + 50.421\, N) \cdot 14 \frac{m}{s} = 2216{,}63\, W \approx 2.2\, kW$$

The required drive power for maximal inclination ($v_{inclination} = 0.25 \cdot v_{max} = 3.5 \frac{m}{s}$):

$$P_{inclination} = F'_{tot} \cdot v_{inclination} = (F_{roll} + F'_{air} + F_{inclination}) \cdot v_{inclination}$$

$$F'_{air} = \frac{1}{2} \cdot c_d \cdot A \cdot \rho \cdot {v_{inclination}}^2 = \frac{1}{2} \cdot 0.4 \cdot 1.05\, m^2 \cdot 1.225 \frac{kg}{m^3} \cdot \left(3.5 \frac{m}{s}\right)^2 = 3.15\, N$$

$$P_{inclination} = (107.91\, N + 3.15\, N + 1315.09\, N) \cdot 3.5 \frac{\mathrm{m}}{\mathrm{s}} = 4991.525\, W \approx 5\, kW$$

Funded by
the European Union

The required motor power P_{req} is now determined using the larger of the required powers (P_{ground},$P_{inclination}$).

$$P_{req} = \max(P_{ground}, P_{inclination}) = P_{inclination} = 5\ kW$$

The electrical motor output P_{electr} now depends on the efficiency of the motor, which is assumed here to be $\eta = 0.85$.

$$P_{electr} = \frac{P_{inclination}}{\eta} = \frac{5\ kW}{0.85} = 5.88\ kW\ \approx 6kW$$

Power requirement for wheel curb climbing torque:

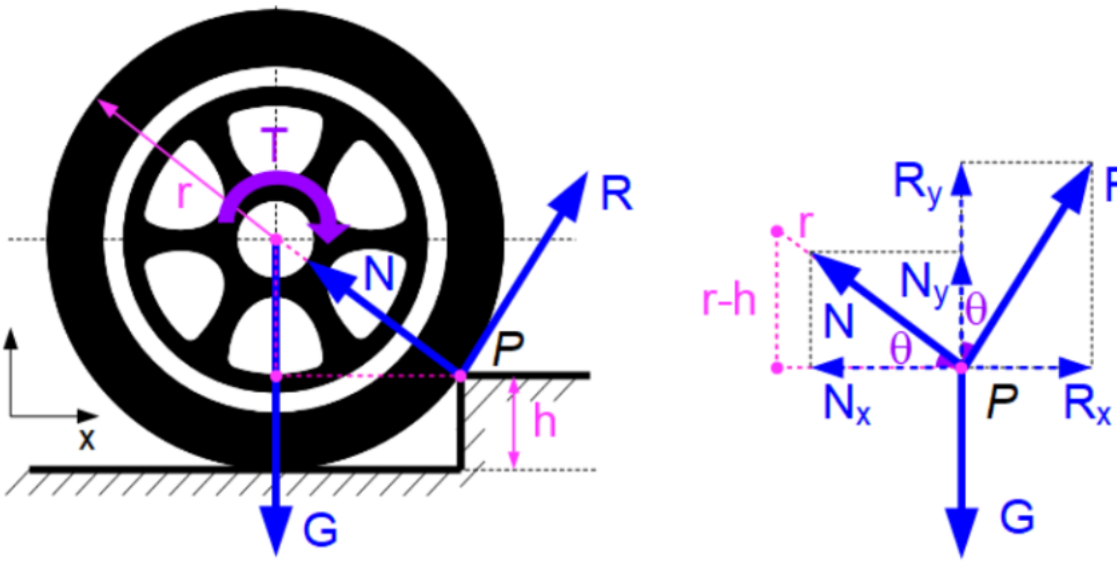


Figure 10: Wheel curb climbing torque

$$R = G \cdot \cos(\theta)$$

$$\theta = sin^{-1}\frac{r-h}{r}$$

$$T = R \cdot r$$

$$T_{mot} = \frac{T}{i_{tot}}$$

ATTENTION: The motor selection carried out should be adapted individually, taking into account the individual vehicle concept. The weight and climbing ability in particular have a major influence on the power requirement. In the event of deviations, an individual assessment should therefore be carried out.

Funded by
the European Union

4.1.2.1.2 Reduction gearbox selection

Since a multi-stage gearbox is not used in this vehicle concept, a reduction gearbox must be designed which reduces the engine speed of the drive unit to the rotational speed of the wheels. The layout of the reduction gear is based on the maximum speed of the electric motor, which is reached at full power, as well as on the radius of the tires and the targeted maximum speed of the vehicle, which is to be achieved taking into account the power limits.

<u>Relevant parameters</u>

Maximum motor speed: $N_{motor} = 6000\, min^{-1}$

Wheel radius (14-inch rim, standard tires): $r_{wheel} = 0.3\, m$

Maximum vehicle speed: $v_{max} = 14\, \frac{m}{s} \approx 50\, \frac{km}{h}$

Rotational speed of the wheels:

$$N_{wheel} = \frac{v_{max}}{2\pi r_{wheel}} = \frac{14\, \frac{m}{s}}{2\pi \cdot 0.3\, m} = 7.43\, s^{-1} \approx 445.63\, min^{-1}$$

Calculation of the reduction ratio (i):

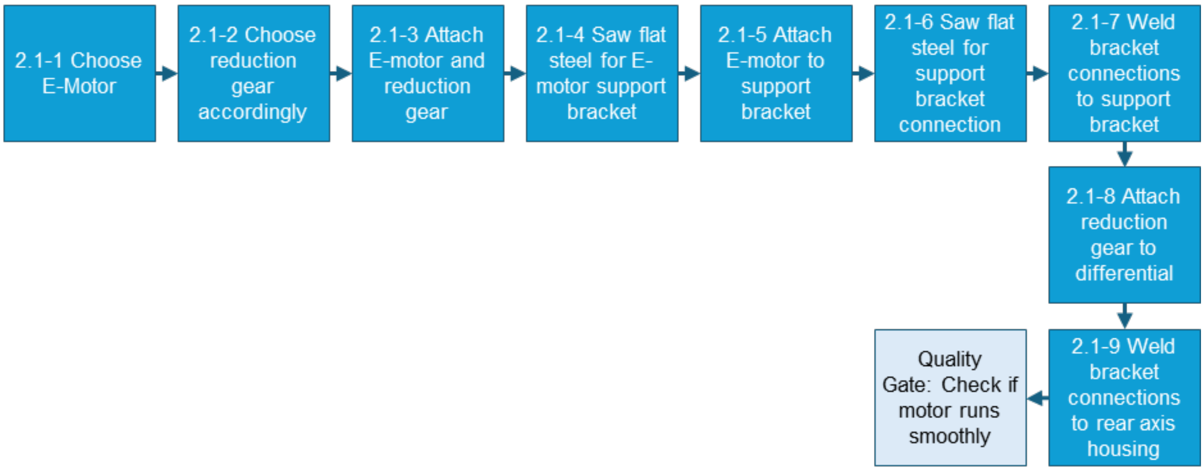
$$i = \frac{N_{motor}}{N_{wheel}} = \frac{6000\, min^{-1}}{445.63\, min^{-1}} = 13.464 \approx 13.5$$

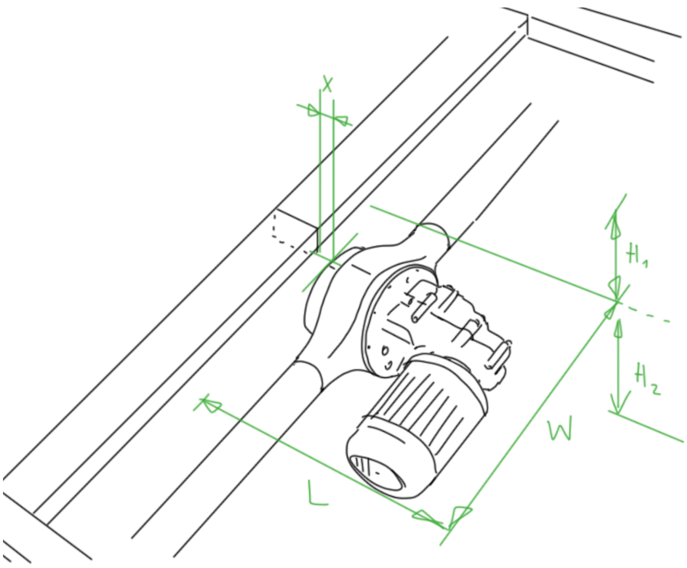
ATTENTION: The reduction gear selection carried out should be adapted individually, taking into account the individual vehicle concept. The maximum speed of the motor and the tire size must be adapted to your own selection in the calculation.

Funded by the European Union

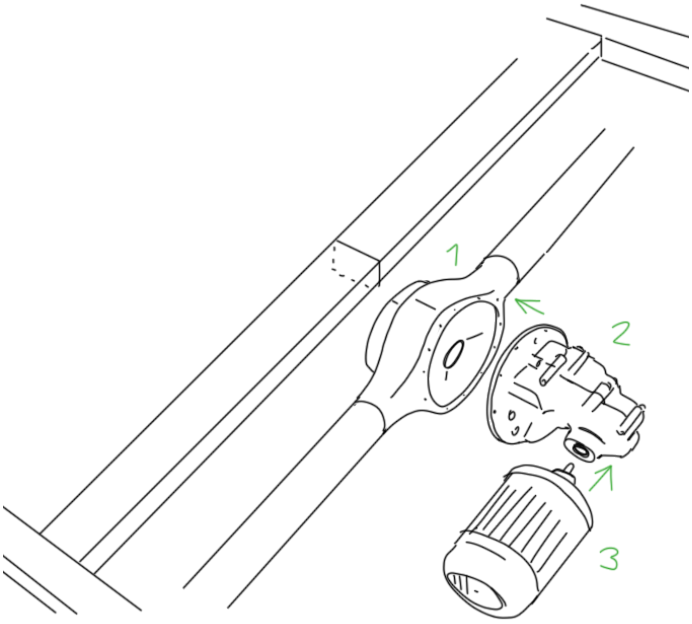
4.1.2.1.3 E-Motor installation

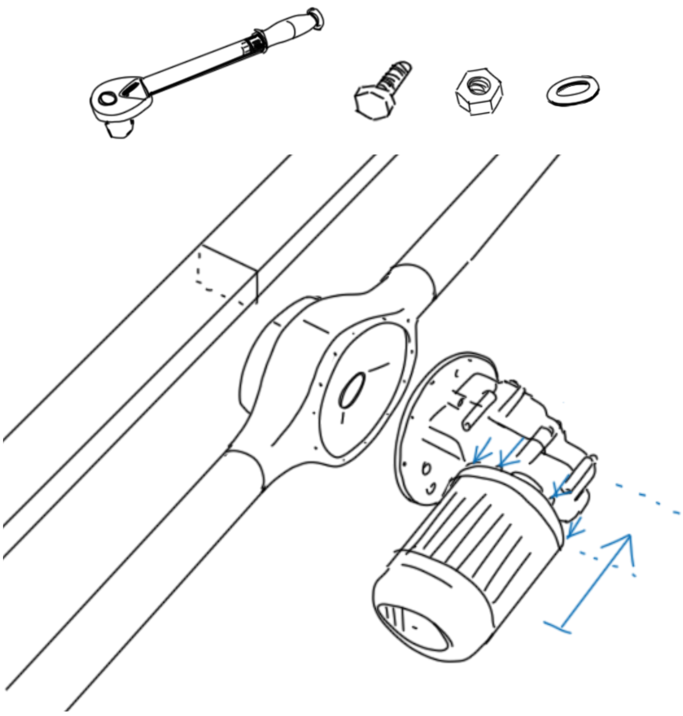
ATTENTION: Pay attention to the ground clearance of the vehicle during the following steps. When attaching the motor, make sure that the motor does not touch the frame or the road if the vehicle deflects.



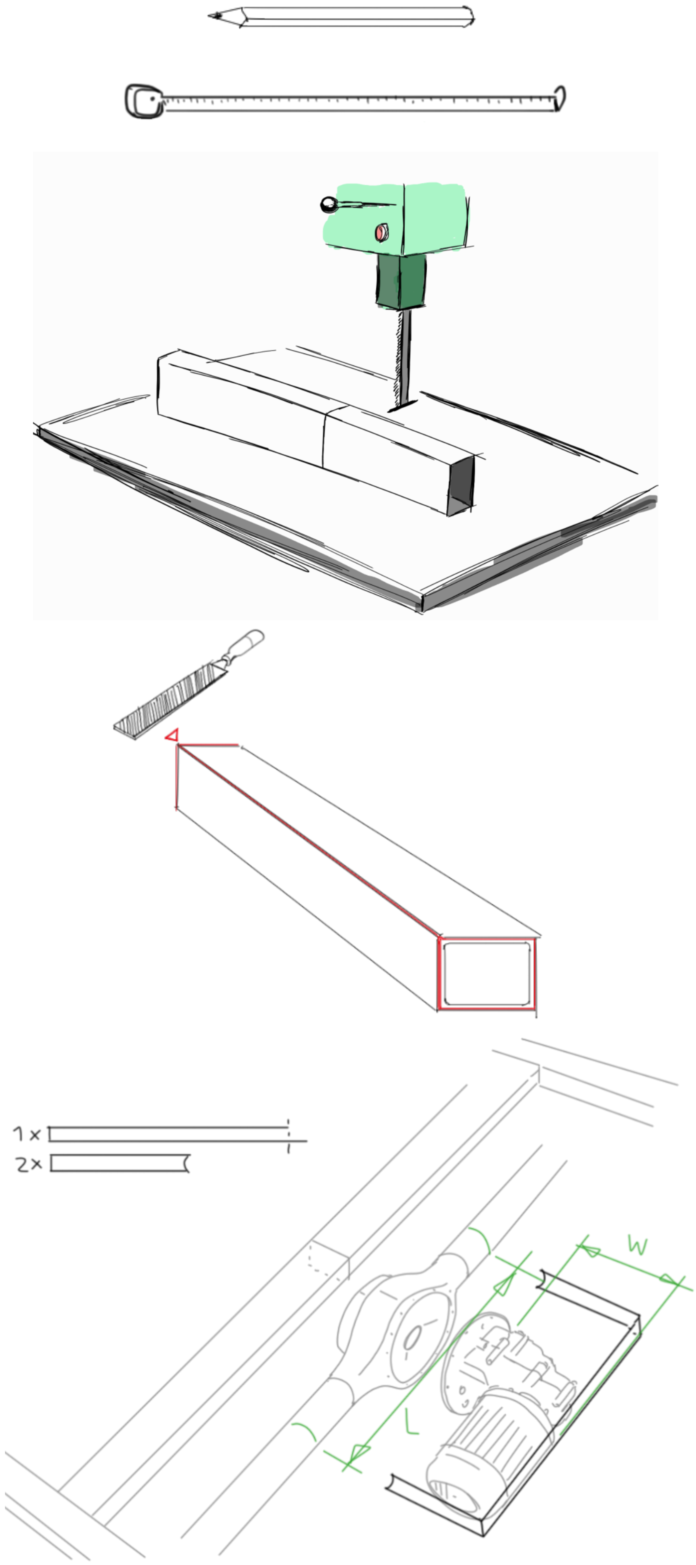
Step	Instructions	Visual Assistance
Step 2.1-1	Components: • None Tools: • Calculator Process: a) Calculate the required electric motor power output according to Chapter 4.1.2.1.1. b) Select a market available electric motor according to calculation results of a).	

Funded by
the European Union

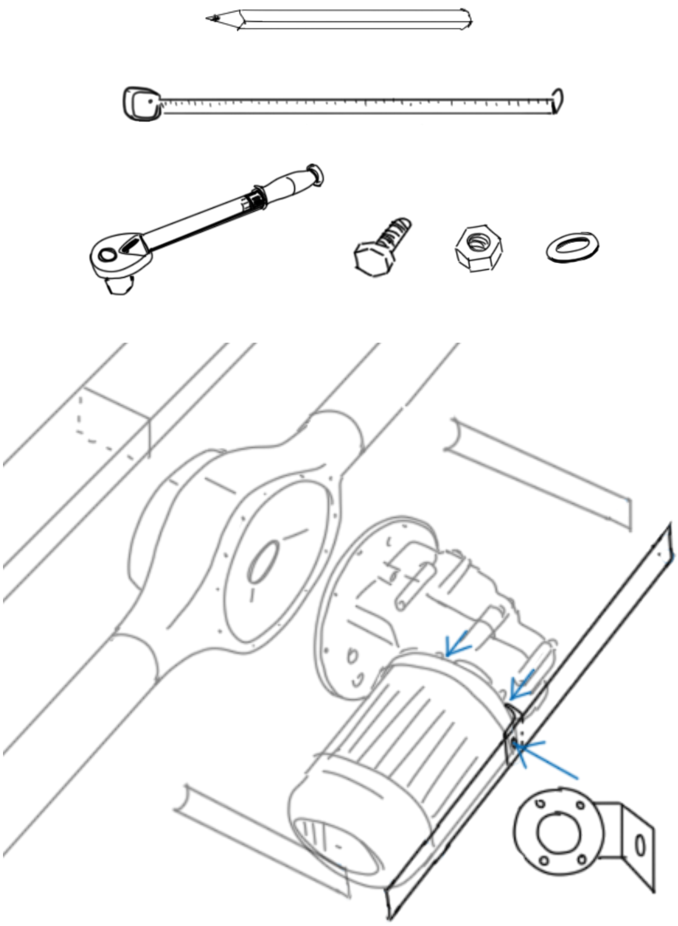
Step	Instructions	Visual Assistance
Step 2.1-2	Components: • None Tools: • Calculator Process: a) Calculate the required reduction gear ratio according to Chapter 4.1.2.1.2. b) Select a market available reduction gear to calculation results of a).	

Step	Instructions	Visual Assistance
Step 2.1-3	Components: • E-Motor • Reduction gear Tools: • Screws • Screwdriver Process: a) Attach the reduction gear to the electric motor.	

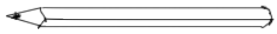
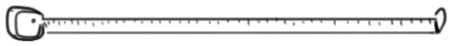
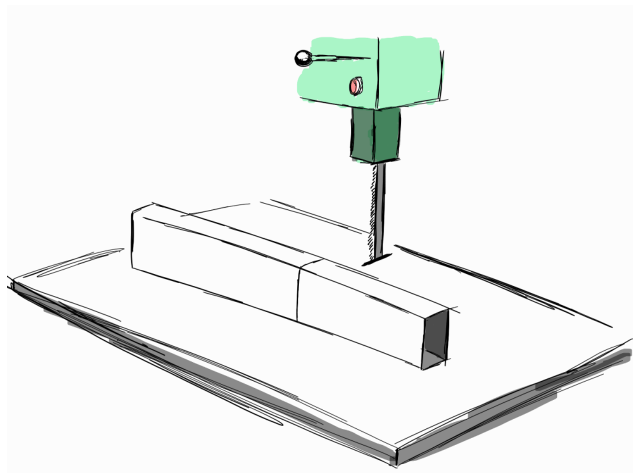
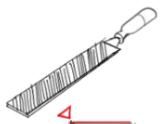
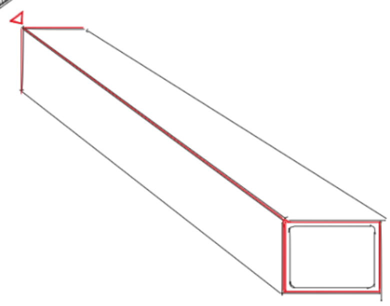
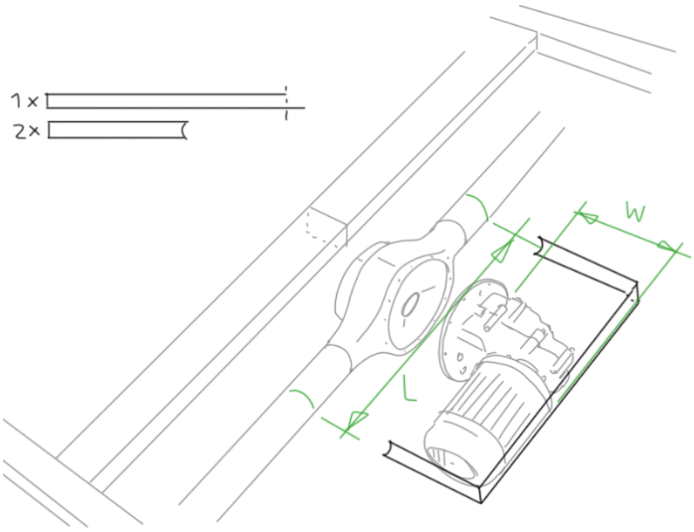
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 2.1-4	Components: • Flat steel t_{min} >= 3 mm Tools: • Tape Measure • Scriber • Saw (preferably band saw) • File (used for deburring) Process: a) Measuring flat steel b) Mark flat steel length according to plan c) Saw flat steel d) Deburr cutting edges	

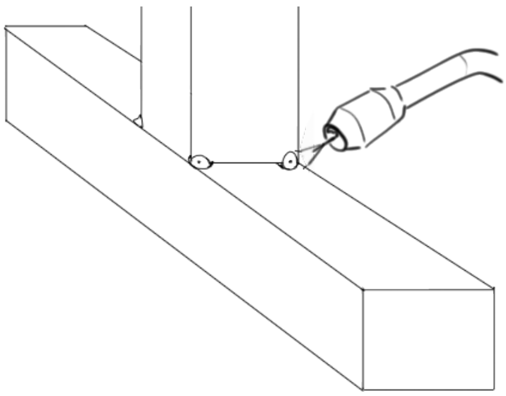
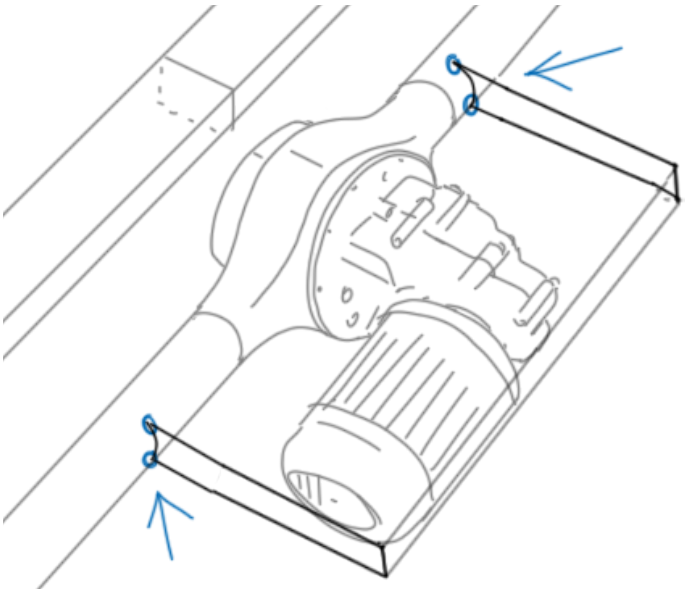
Funded by
the European Union

<table>
<tr><th>Step</th><th>Instructions</th><th>Visual Assistance</th></tr>
<tr><td>Step 2.1-5</td><td>Components:
E-Motor
Reduction gear
Trimmed flat steel
Sheet metal t_{min} > 1.5 mm
Tools:
Screws
Screwdriver
Tape Measure
Scriber
Saw (preferably band saw)
File (used for deburring)
Process:
a) If necessary, make an adapter for attaching the motor to the trimmed flat steel.
b) Attach the electric motor (including the reduction gear) to the trimmed flat steel.</td><td></td></tr>
</table>

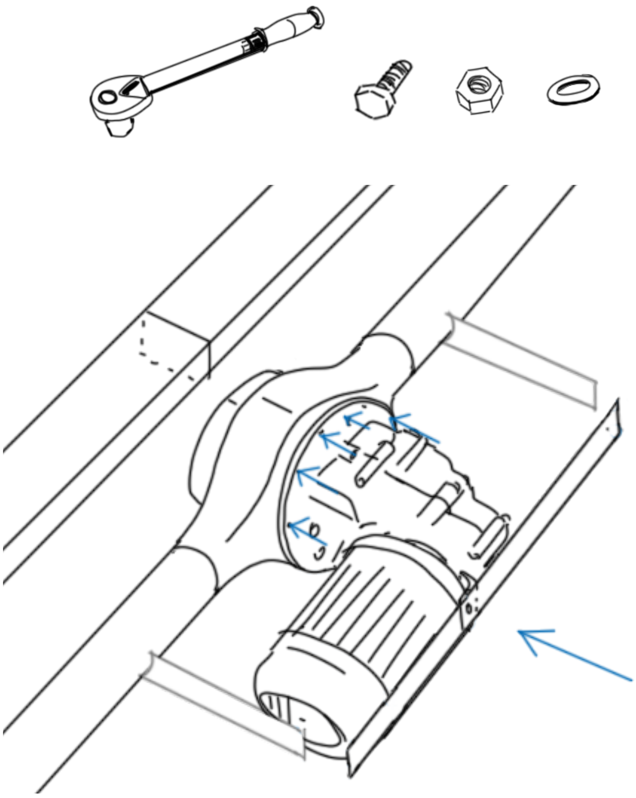
Funded by
the European Union

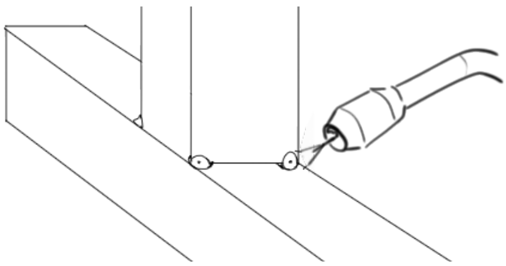
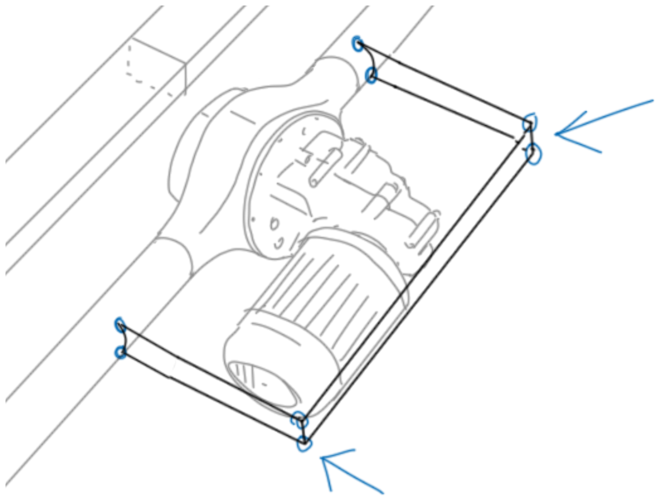
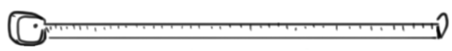
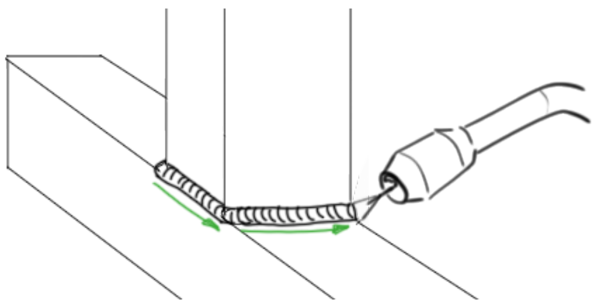
Step	Instructions	Visual Assistance
Step 2.1-6	Components: • E-Motor assembly • Flat steel t_{min} >= 3 mm Tools: • Tape Measure • Scriber • Saw (preferably band saw) • File (used for deburring) Process: a) Measure the distance between the trimmed flat bar and the differential of the rear axle to attach the electric motor assembly to the differential. b) Mark flat steel length according to measurement. c) Saw flat steel. d) Deburr cutting edges.	     

Funded by
the European Union

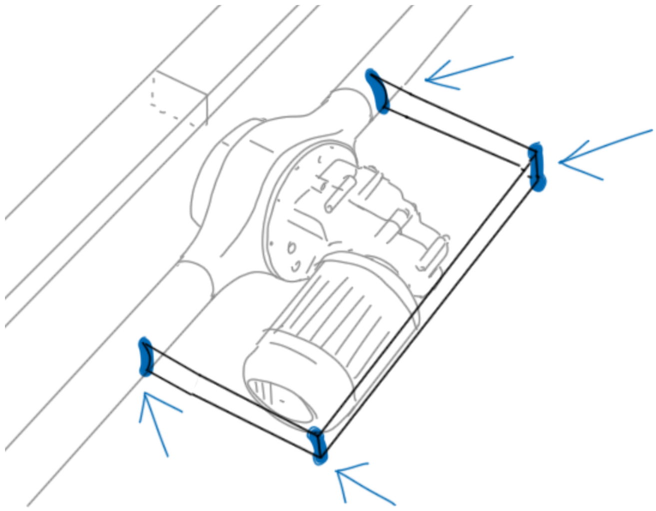
Step	Instructions	Visual Assistance
Step 2.1-7	Components: - E-Motor assembly - Trimmed flat steel Tools: - MIG welding machine Process: a) Place the trimmed flat steel parts on the endings of the E-Motor assembly. b) Fully weld all joints of the flat steel parts.	 

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 2.1-8	Components: • E-Motor assembly Tools: • Screws • Screwdriver Process: a) Attach electric motor assembly to rear axle differential.	

Step	Instructions	Visual Assistance
Step 2.1-9	Components: • None Tools: • MIG welding machine Process: a) Fully weld all joints of the flat steel parts to the housing of the rear axle. b) Follow Quality Gate to check the quality of the welding seams and the Base Frame regarding welding distortions.	   

Funded by
the European Union

		
Quality Gate	Check if motor runs smoothly by applying a power supply	

4.1.3 Energy Storage

In the following section, the battery is designed for the developed vehicle. It is recommended that a battery including battery housing and BMS be purchased and provided for the vehicle concept. If a battery without a housing is planned for the concept, it is essential to manufacture a separate battery housing to protect the battery from external influences such as moisture.

4.1.3.1 Battery selection

For the design of the necessary battery size for the vehicle concept, some boundary conditions and assumptions must be made. The required battery capacity essentially depends on the intended range and the energy requirements of the vehicle. The target range is set at $100\ km$ based on the experience gained from the SOLUTIONSplus project. For the energy requirement, the formulas for the power requirement, which were already used in Chapter 4.1.2.1.1 for the calculation of the engine power, are applied below. An additional assumption must be made regarding the average speed and the altitude profile. At this point, the average speed is assumed to be $30\frac{km}{h}\left(\approx 8.3\frac{m}{s}\right)$ and the average gradient to be $2\% \ (\approx 1.1°)$. In the following, the power requirement is calculated and then converted into the energy requirement.

$$F_{tot} = F_{roll} + F_{air} + F_{inclination}$$

$$F_{roll} = 107.91\ N$$

Funded by
the European Union

$$F''_{air} = \frac{1}{2} \cdot 0.4 \cdot 1.05\, m^2 \cdot 1.225 \frac{kg}{m^3} \cdot \left(8.3 \frac{m}{s}\right)^2 = 17.722\, N$$

$$F''_{inclination} = 1100\, kg \cdot 9.81 \frac{m}{s^2} \cdot sin(1.1°) = 207.16\, N$$

$$F''_{tot} = 107.91\, N + 17.772\, N + 207.16\, N = 332.842\, N$$

$$P_{req} = F''_{tot} \cdot\ 8.3 \frac{\mathrm{m}}{\mathrm{s}} = 2762.6W\ \approx 2.76\, kW$$

$$P_{electr} = \frac{P_{req}}{\eta} = \frac{2.76\, kW}{0.85} = 3.25\, kW$$

On average, an output of $3.25\ kW$ of the drive is therefore called up for the assumptions made. The energy requirement is now derived from the time required.

$$\Delta E = P_{electr} \cdot \Delta t = P_{electr} \cdot \frac{s}{v} = 3.25\, kw\ \cdot \frac{100\, km}{30 \frac{km}{h}} = 10.8\, kWh$$

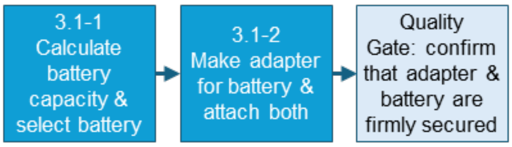
ATTENTION: The battery design carried out should be adapted individually, taking into account the individual vehicle concept as well as your own requirements for the vehicle and the driving cycle (made here by assuming). The weight and climbing ability in particular have a major influence on the power requirement. In the event of deviations, an individual assessment should therefore be carried out.

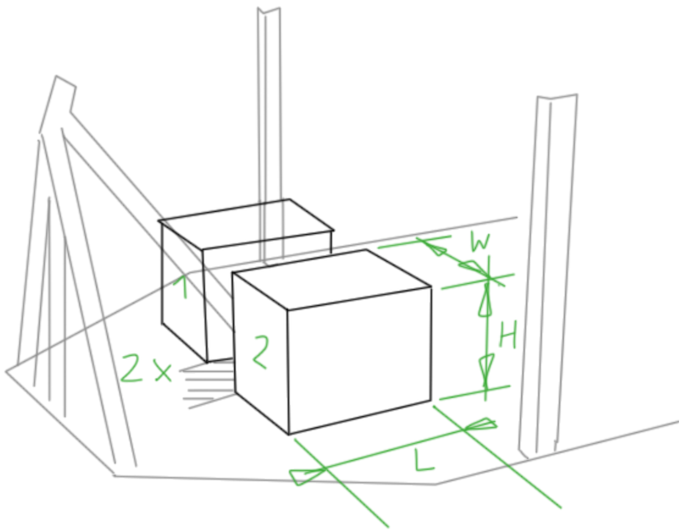
BMS:

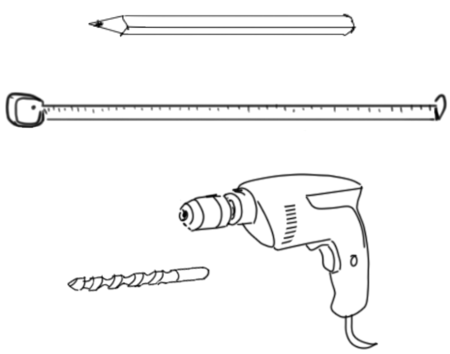
The battery management system is a central component of an electric drive. It is the control unit of the battery. It is recommended to select a battery that already contains a BMS in order to avoid time-consuming adaptations of a separate BMS to the battery.

Funded by
the European Union

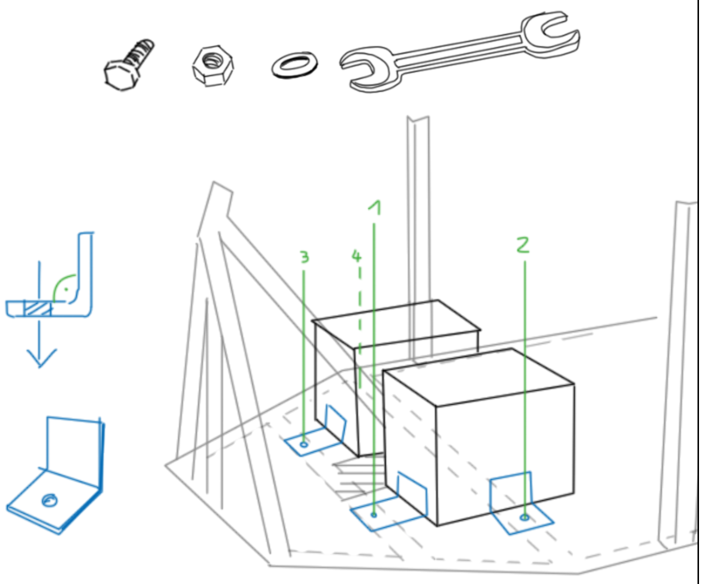
4.1.3.2 Battery installation



Step	Instructions	Visual Assistance
Step 3.1-1	Components: • None Tools: • Calculator Process: a) Calculate the required capacity of the battery according to Chapter 4.1.3.1. b) Select an available battery (incl. BMS and housing) according to calculation results of a).	

Step	Instructions	Visual Assistance
Step 3.1-2	Components: • Battery • Base frame • Sheet metal t_{min} > 1.5 mm Tools: • Screws • Screwdriver • Tape Measure • Scriber • Saw (preferably band saw)	

Funded by the European Union

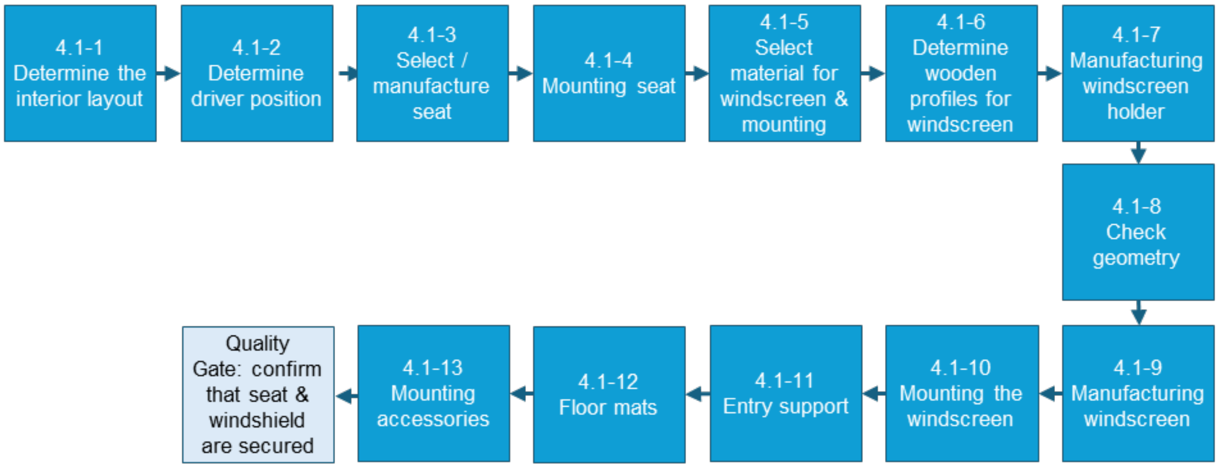
	• File (used for deburring) Process: a) If necessary, make an adapter for attaching the battery to the base frame. b) Attach the battery to the base frame (attachment points not only in the base plate, but in the underlying structure).	
Quality Gate	Check whether adapter and battery are firmly attached	

4.1.4 Modular Body Structure

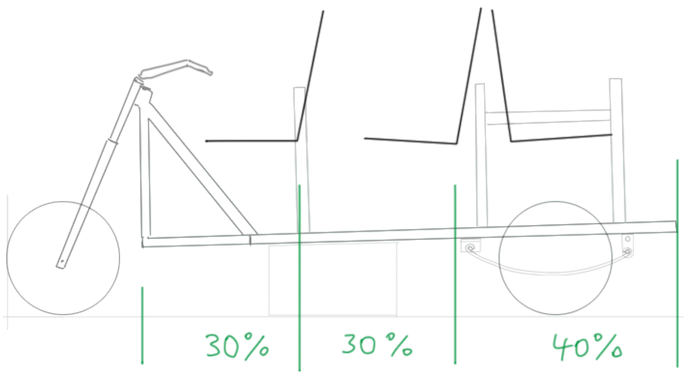
In order to design the eTukTuk as efficiently as possible to suit the different locations and associated requirements, the design of the eTukTuk is modular. The body can be designed as a cargo or passenger version.

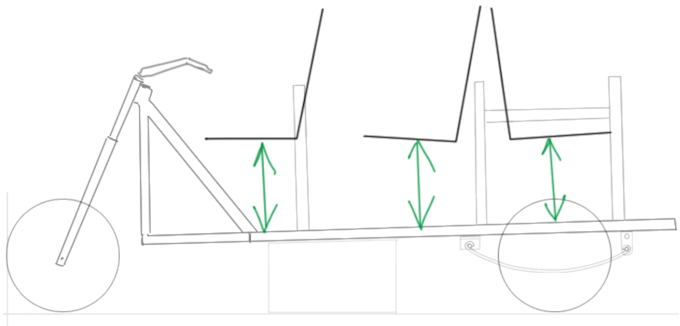
4.1.4.1 Driver Compartment

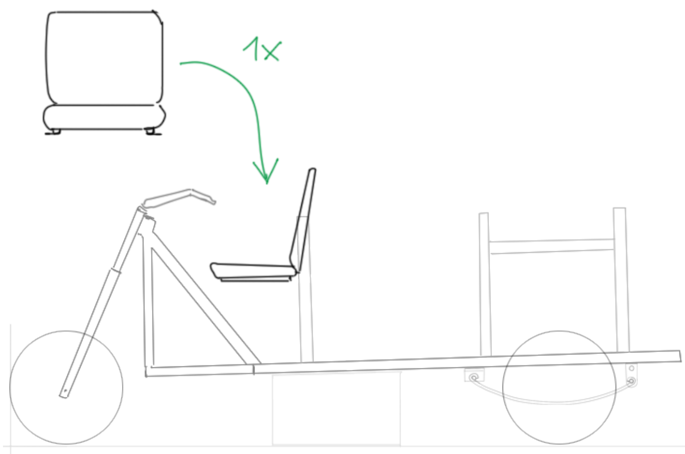
The driver's compartment is manufactured and installed below. It is installed in the front part of the vehicle, where the driver sits and controls the vehicle. The driver's compartment offers the driver protection and comfort and enables safe control of the vehicle. In the overall vehicle manufacturing process, the driver's compartment is installed after the assembly of the base frame and the main mechanical and electrical components and is crucial for the ergonomics and operability of the vehicle.



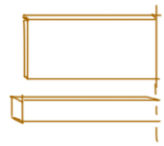
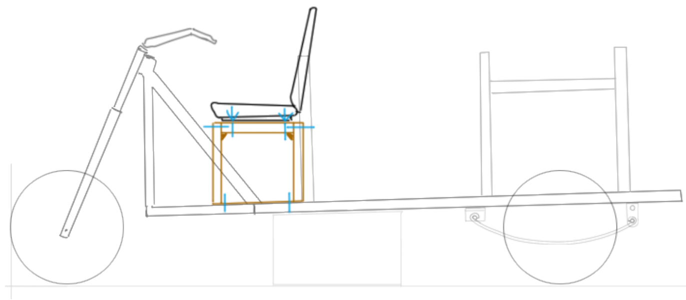
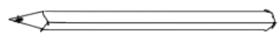
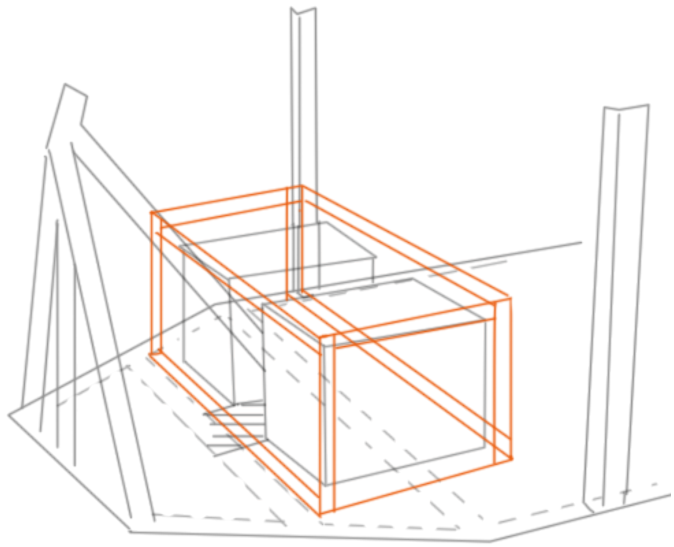
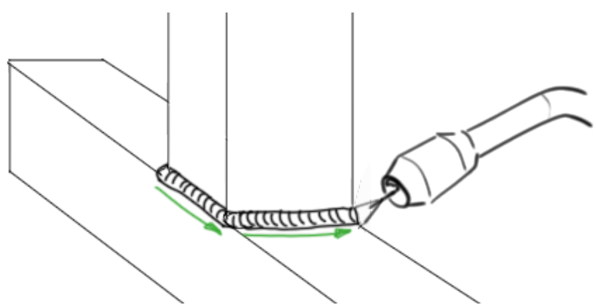
Funded by the European Union

Step	Instructions	Visual Assistance
Step 4.1-1	Components: • None Tools: • None Process: a) Divide the areas for the driver and passengers approximately lengthways in relation to the base frame according to the following key. Personal preferences can be taken into account. Driver: 30% Passenger row 1: 30% Passenger row 2: 40%. b) The Battery is located below the driver seat.	

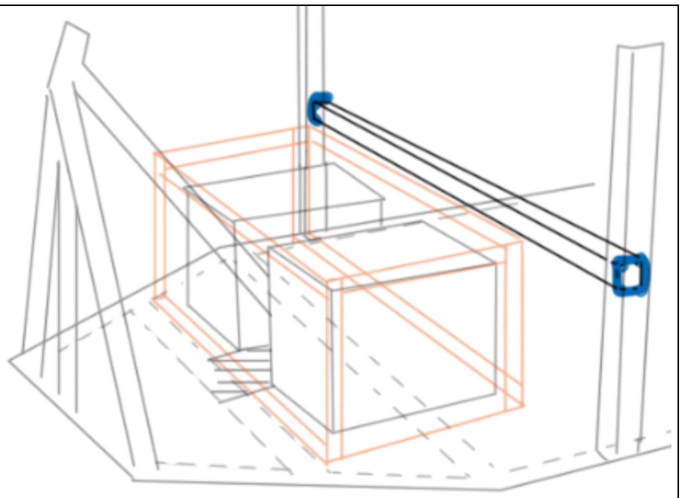
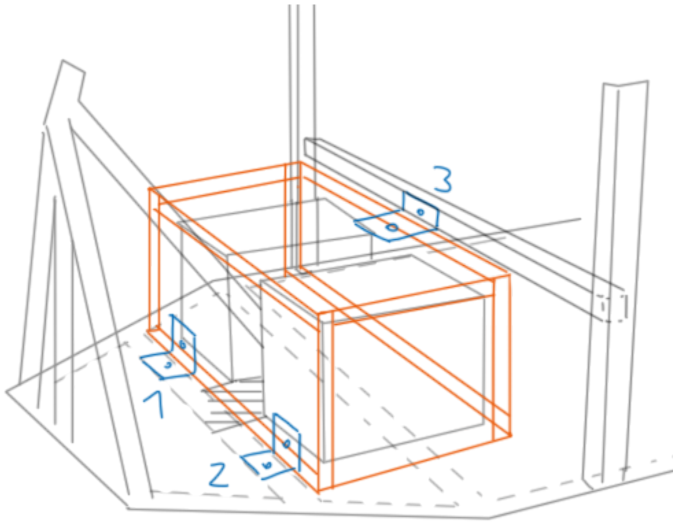
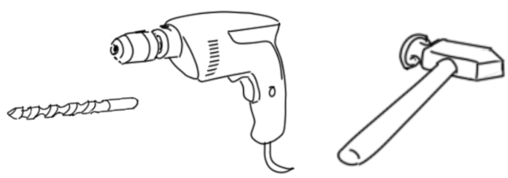
Step	Instructions	Visual Assistance
Step 4.1-2	Components: • None Tools: • Tape Measure • Calculator Process: a) Set the driver's position in the center plane of the vehicle at the desired and ergonomic height. Standard seat height: 430 mm.	

Step	Instructions	Visual Assistance
Step 4.1-3	Components: • None Tools: • None Process: a) Choose a seat that meets your personal ergonomic requirements.	

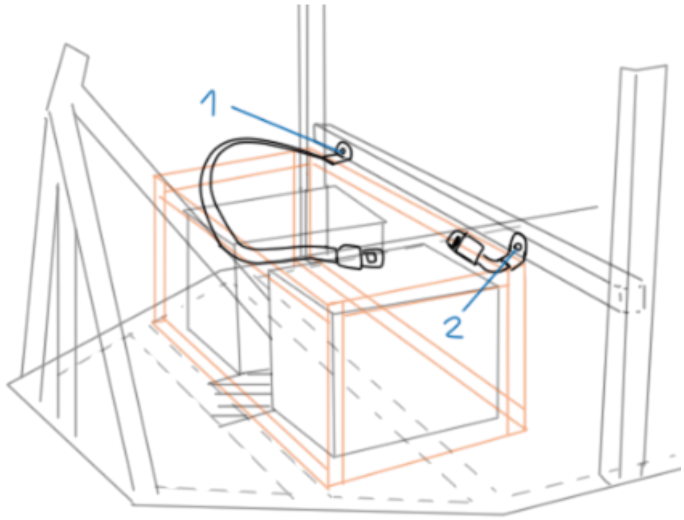
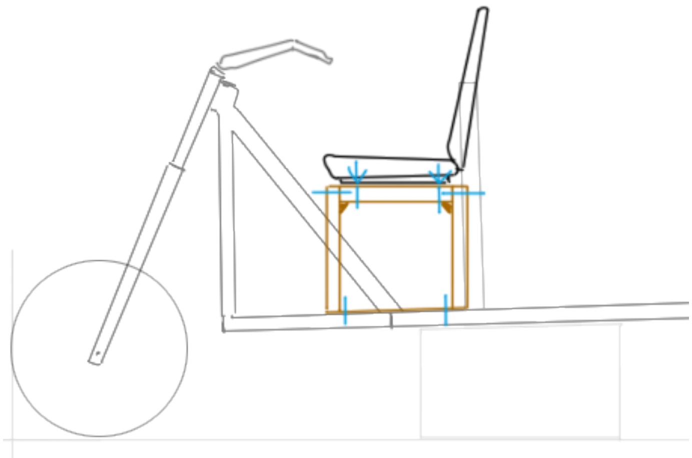
Funded by the European Union

Step	Instructions	Visual Assistance
Step 4.1-4	Components: • Frame • Wood profiles (to accommodate battery 300 mm x 300 mm x 300 mm) Tools: • Drilling Machine • Tap • Screws • Screwdriver • Hammer Process: a) Determine the dimensions for the wooden crate so that the batteries can be placed inside and easily removed. Furthermore, there must be sufficient surface area or connection points for mounting the driver seat. b) Cut wooden profiles, assemble them and mount them to the metal profiles of the base frame using angles by drilling and screwing. c) Weld a metal profile between the horizontal metal profiles of the support frame.	     

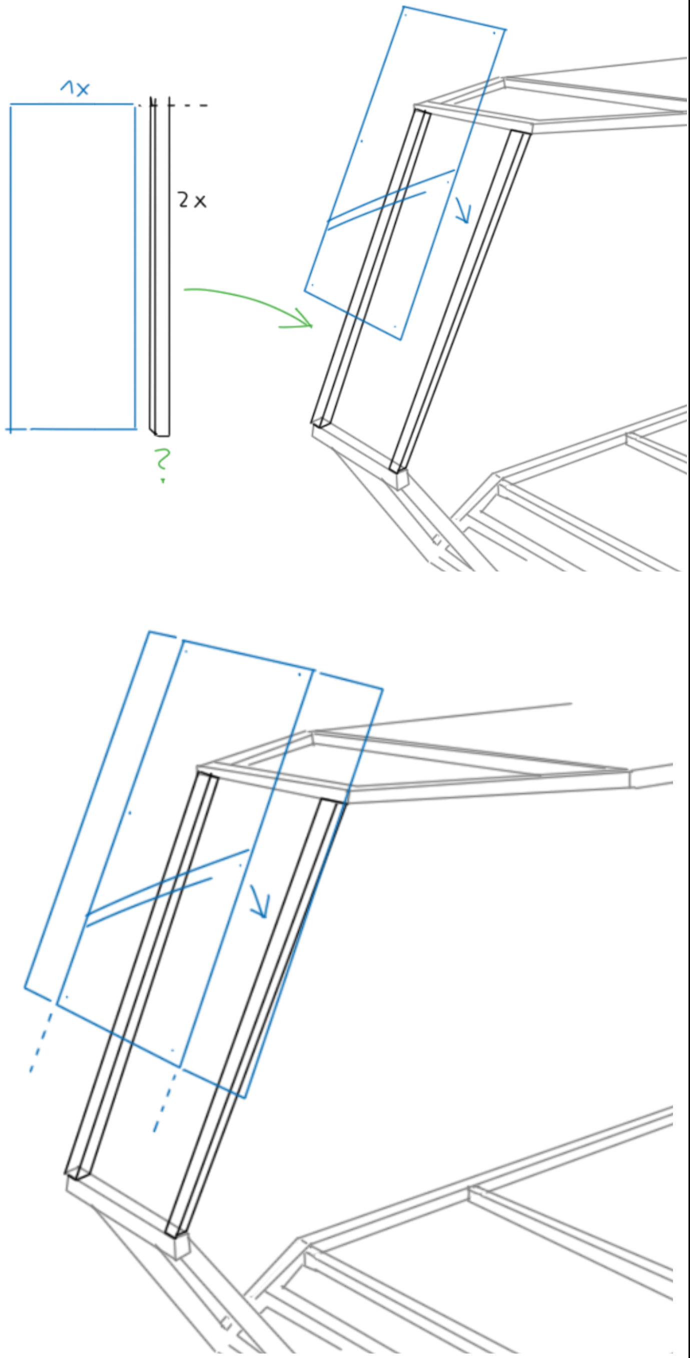
Funded by
the European Union

	d) Mount the seat box and belts to the previously attached metal profile by drilling and screwing. e) Screw the seat from above onto the wooden structure.	  

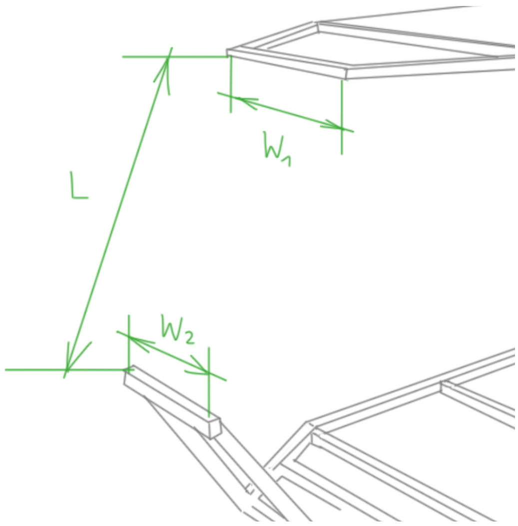
Funded by
the European Union

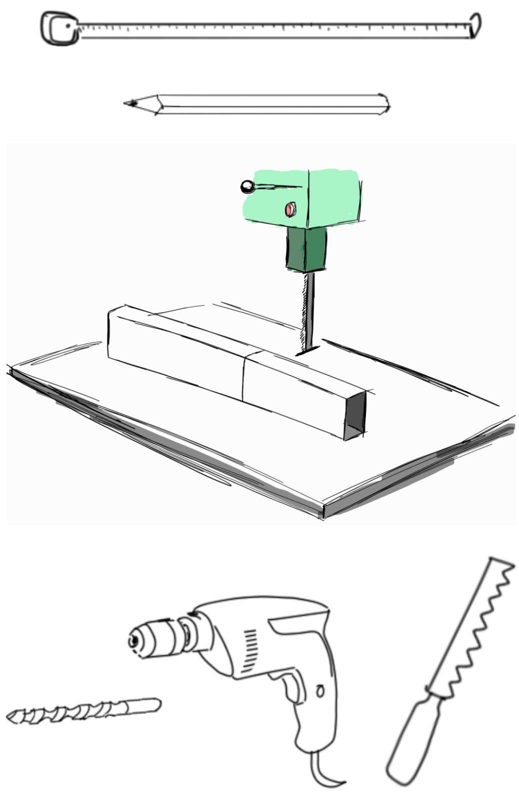
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.1-5	Components: • None Tools: • None Process: a) Choose the material for windscreen and the support structure of the windscreen depending on availability. b) Recommended: Rectangular wood profile that was used for the roof structure. (e.g. 50 mm x 30 mm wood profiles) The manufacture of a wooden windscreen support structure is described below. For production with metal profiles, proceed as for base frame. The recommended material for the windscreen is plexiglass, which is described in the following process.	

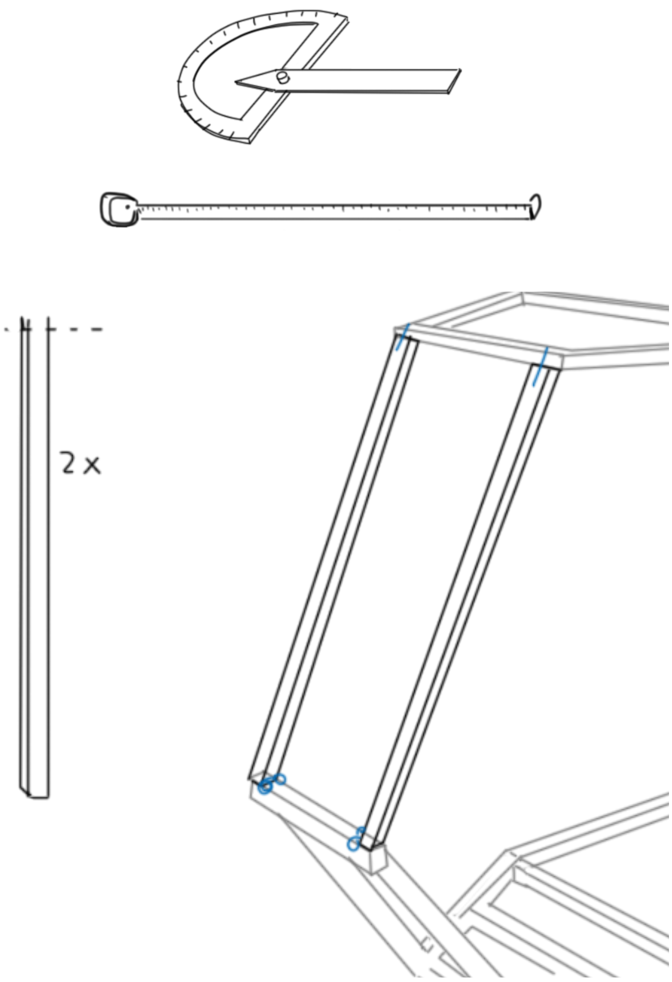
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.1-6	Components: • Frame Tools: • Tape measure Process: a) Take the dimensions to close the gap between the front paneling and the roof structure with wooden profiles. Make sure there is sufficient wind protection for the driver.	 

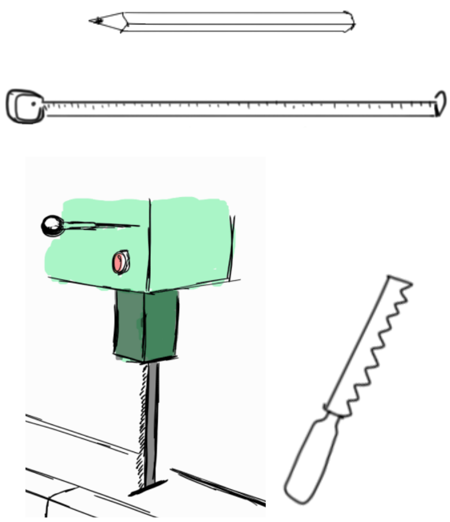
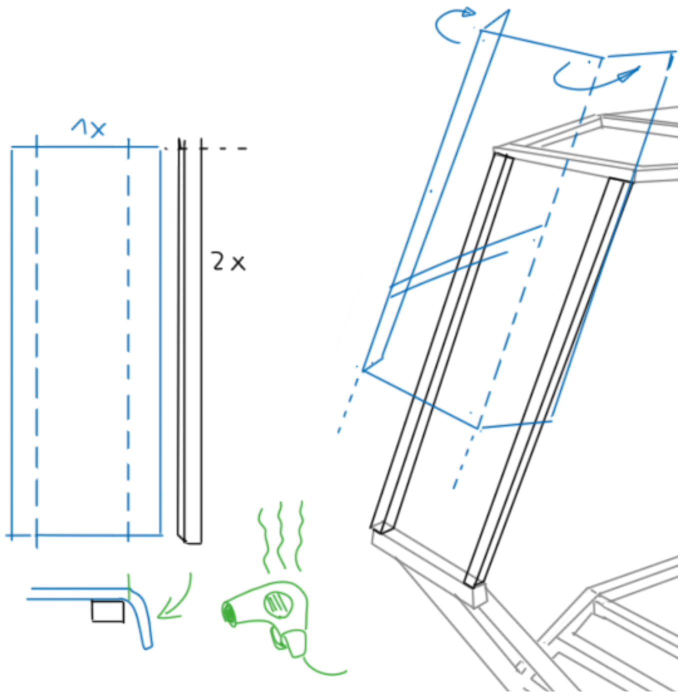
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.1-7	Components: • None Tools: • Tape measure • Saw (preferably band saw) • Pencil • Wood screws • Screwdriver • Drilling machine • Tap Process: a) Cut the wooden profiles according to the dimensions specified in step 4.1-6. b) Screw the wooden profiles together to form the windscreen holder. Use 3 screws per connection point at different levels if possible.	

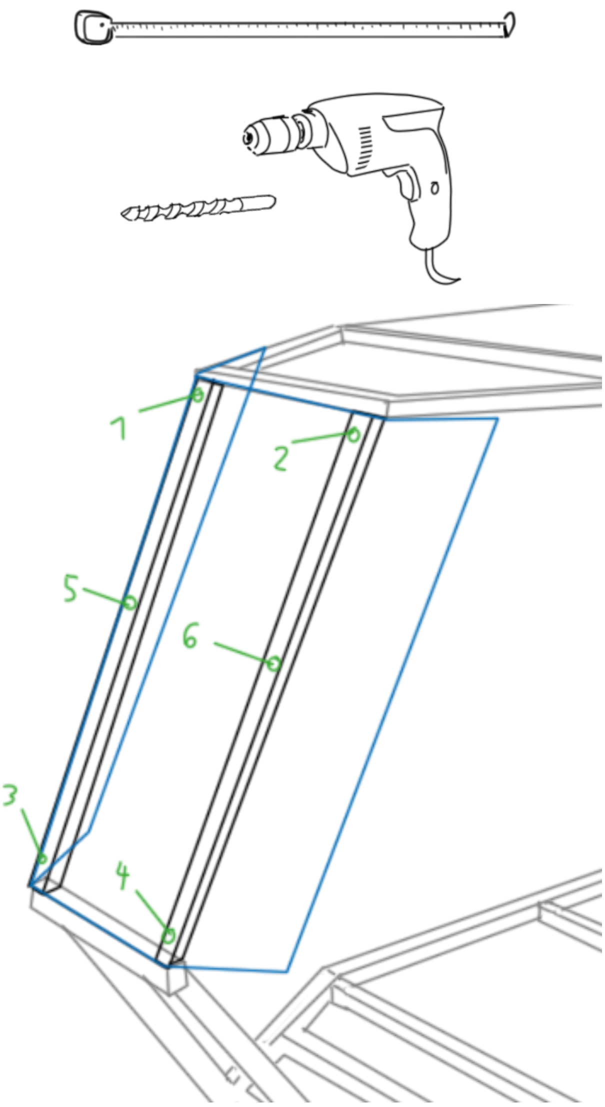
Funded by
the European Union

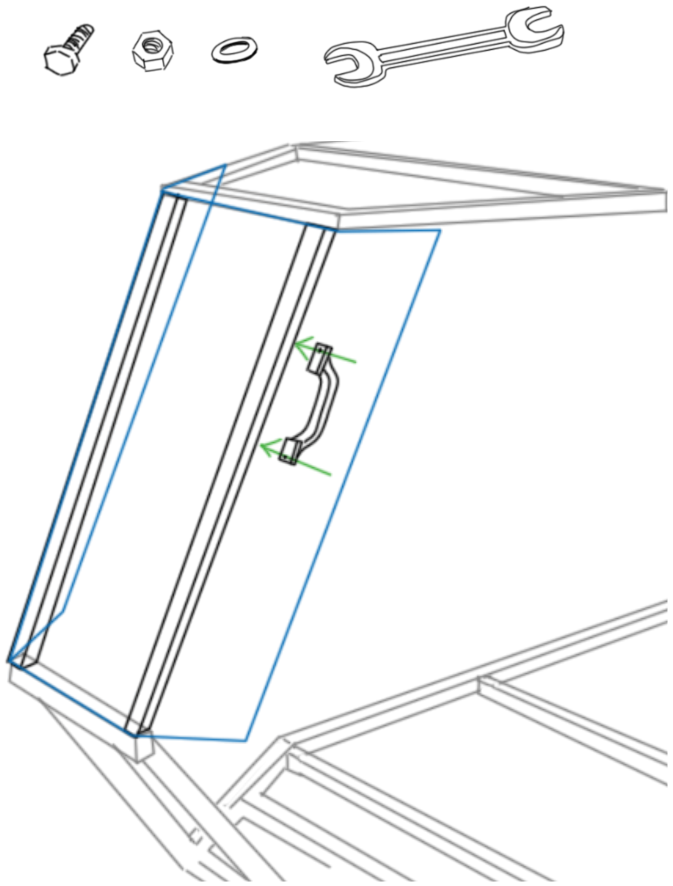
Step	Instructions	Visual Assistance
Step 4.1-8	Components: • Tack welded profiles on front panel support Tools: • Tape measure • Protractor • Spirit level Process: a) Measure if the wind screen profiles are according to the measurement plans. b) If measurements are correct, proceed with step 4.1-9. c) If measurements are incorrect, separate the profiles and start again at step 4.1-7.	

Funded by
the European Union

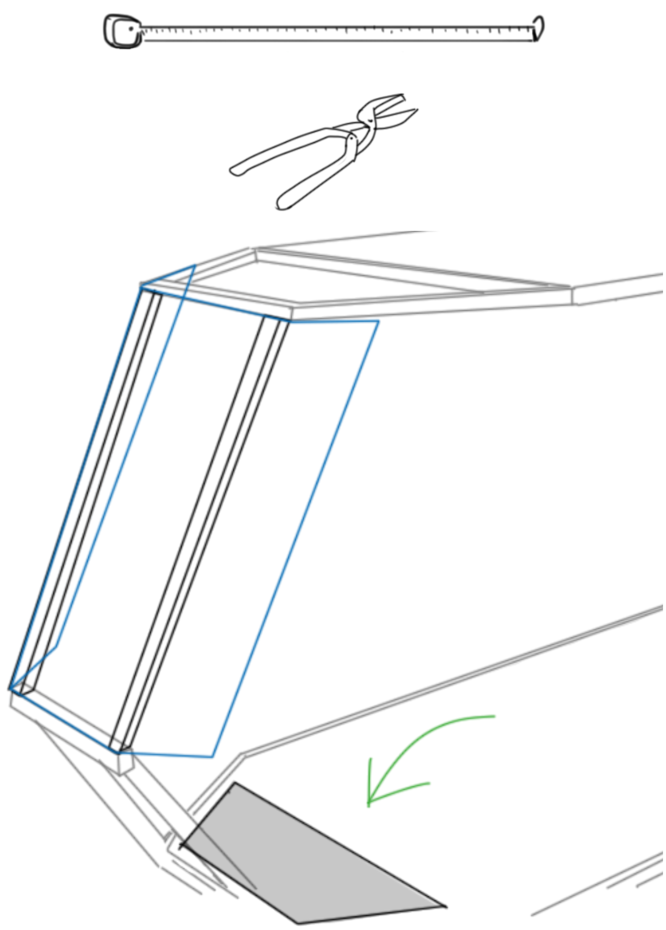
Step	Instructions	Visual Assistance
Step 4.1-9	Components: • Frame Tools: • Cardboard • Saw (preferably band saw) • Pencil • Something to heat, for example burner Process: a) Use a cardboard box to determine the dimensions of the windscreen. b) Transfer the dimensions from the cardboard to the plexiglass windscreen. c) Saw out the transferred contour. d) Place the plexiglass pane on the intended position on the vehicle and estimate the bending points, which can be realized by subsequent heating and careful bending.	 

Funded by
the European Union

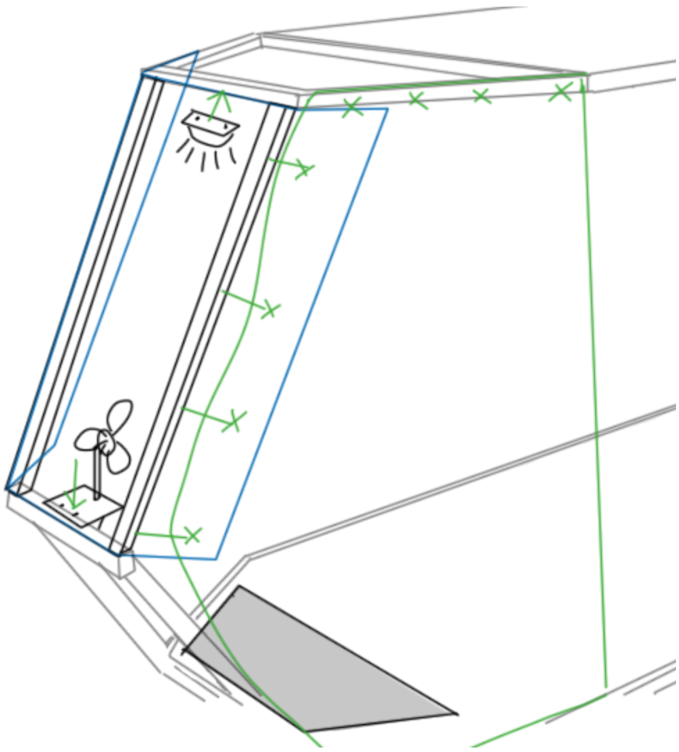
Step	Instructions	Visual Assistance
Step 4.1-10	Components: • Plexiglass windscreen Tools: • Screwdriver • Screws • Drilling machine Process: a) With the windscreen in place, drill holes through the windscreen that end on the wooden profile frame. Screw screws through the holes in the wooden profiles. Underlay seals can increase the splash protection.	

Step	Instructions	Visual Assistance
Step 4.1-11	Components: • Frame Tools: • Screws • Screwdriver Process: a) Screw handles to the windscreen frame at a suitable point to help with access.	

Funded by the European Union

Step	Instructions	Visual Assistance
Step 4.1-12	Components: • Floor mats Tools: • Tape measure • Scissor / knife Process: a) Install rubber mats to prevent slipping on wet floors.	

Funded by the European Union

Step	Instructions	Visual Assistance
Step 4.1-13	Components: • Accessories • Screws Tools: • Tape measure • Screwdriver • Drilling machine • Clamps Process: a) Install various accessories such as a fan, mobile phone holder, interior lighting or a rain cover as you wish.	
Quality Gate	Confirm that seat and windshield are firmly secured.	

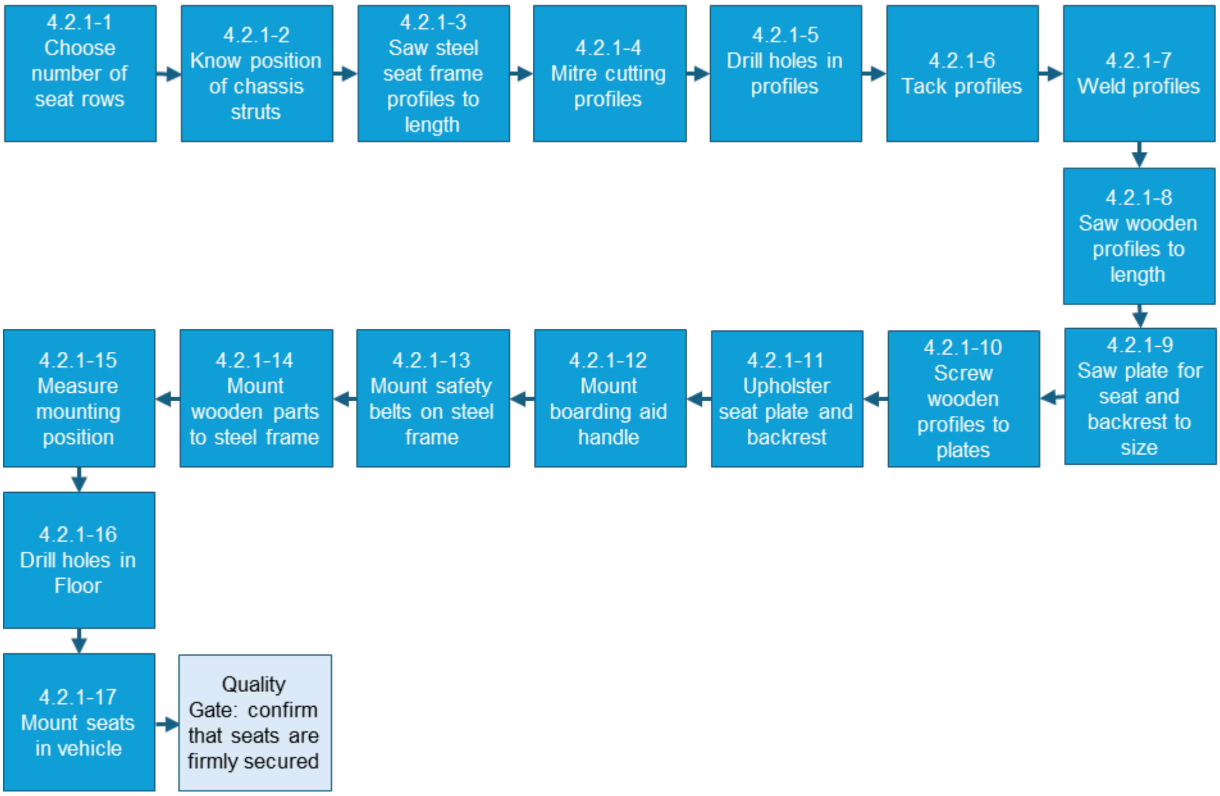
Funded by the European Union

4.1.4.2 Rear Compartment

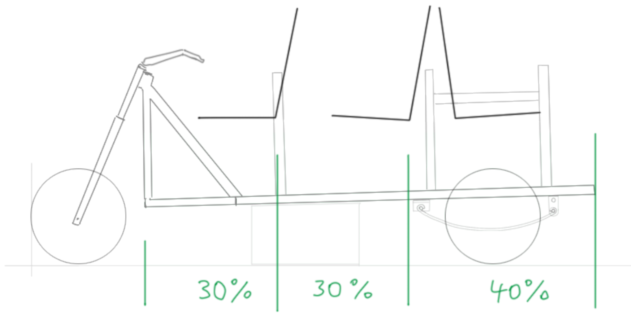
The rear compartment contains the modular body, which enables the eTukTuk to be used for transporting people or goods. Various attachments, such as the rain cover, are also described below.

4.1.4.2.1 Passenger Area

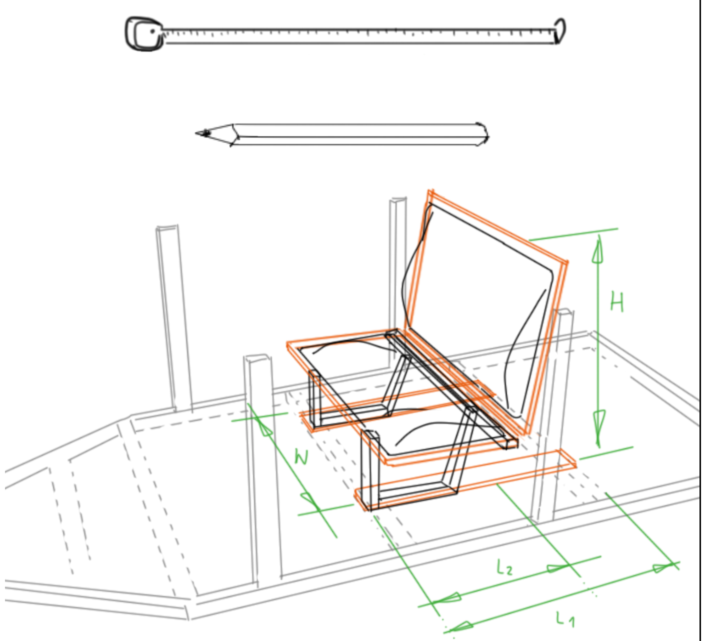
The passenger area is located behind the driver's compartment in the center and rear of the vehicle. The passenger area provides seating and comfort for passengers during the journey and contributes to the overall capacity of the vehicle. In the overall vehicle manufacturing process, the passenger area is finished after the assembly of the frame, the chassis, drivetrain, energy storage and the driver's compartment and is crucial for the usability and comfort of the vehicle for the occupants.



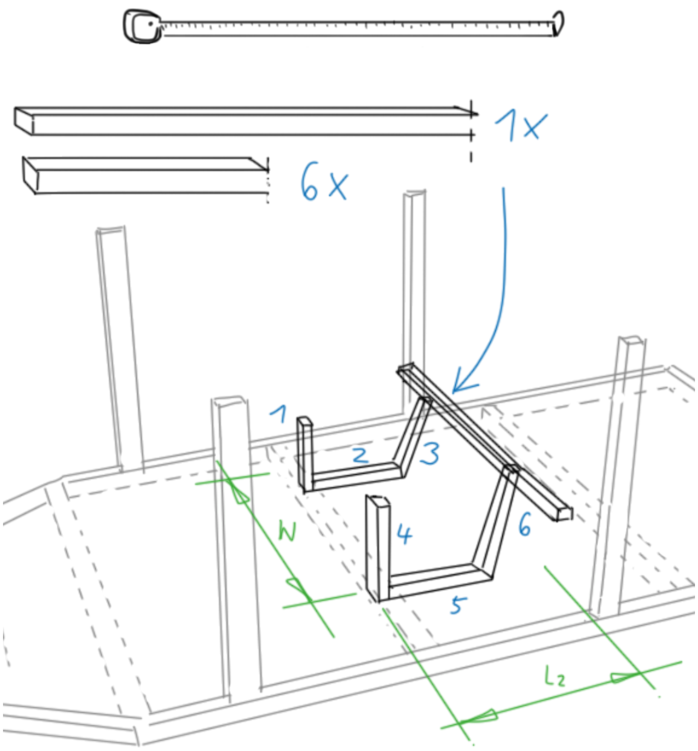
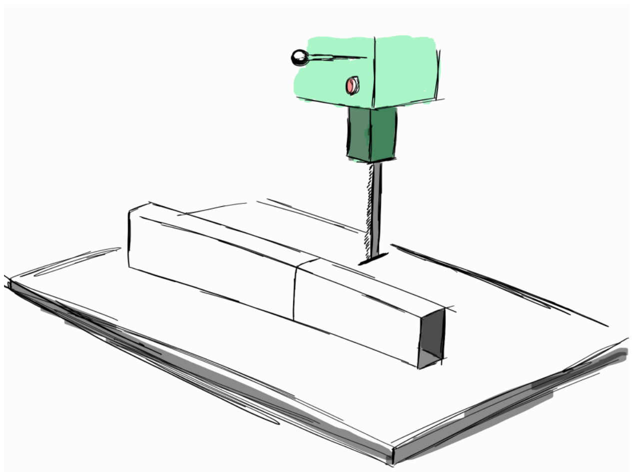
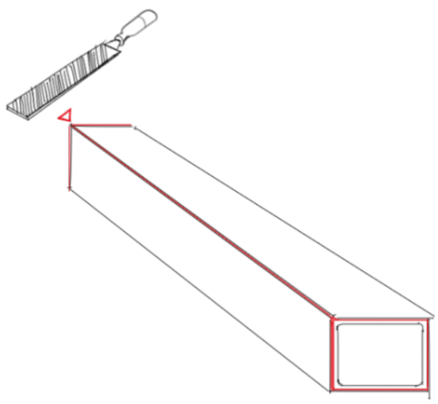
Funded by the European Union

Step	Instructions	Visual Assistance
Step 4.2.1-1	Components: • See step **4.2.1-3** to **4.2.17** Process: a) For two rows of passenger seats, carry out steps 3 to 17 twice. b) The second row of seats is placed back-to-back to the row shown in the next steps. Passengers face against the direction of travel.	

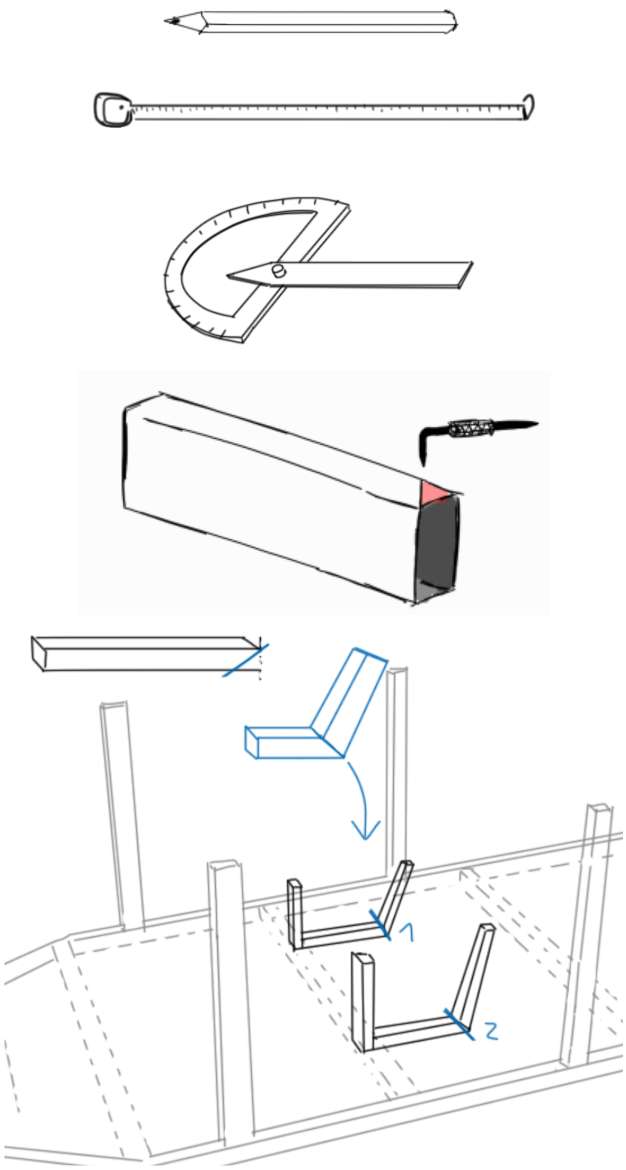
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.2.1-2	Components: • Base Frame with floor Tools: • Chassis plans • Chalk • Tape measure Process: a) The Seats must be mounted through the chassis struts. If no struts are in reach use mounting plates as shown. b) Mark position of struts in the area where the seats will be on the floor inside the vehicle. (See 4.1.4.1) c) Measure the distance between two symmetrical struts that are at least half the planned bench length apart.	

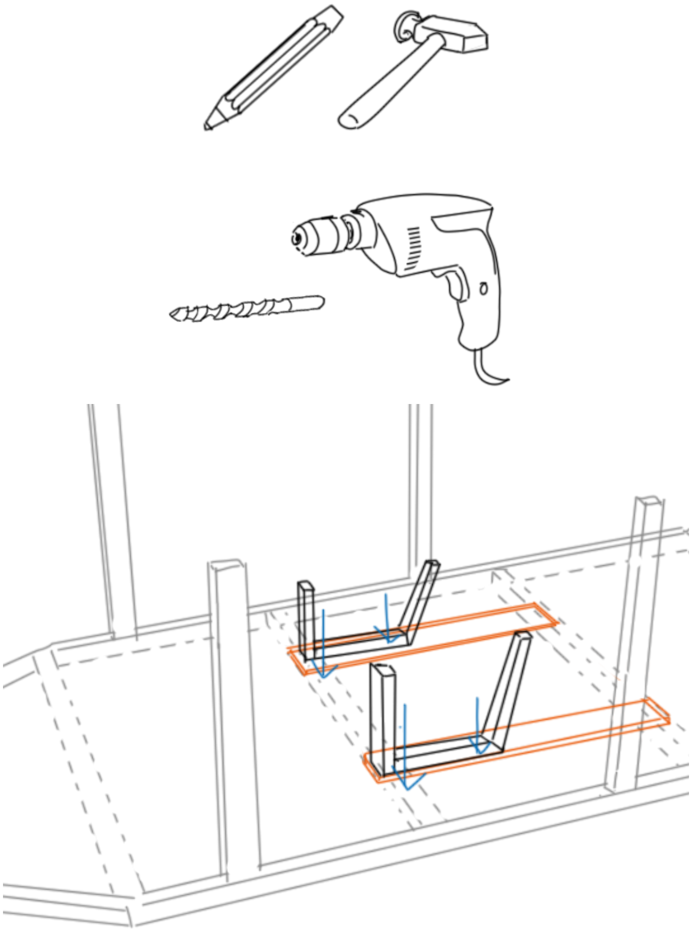
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.2.1-3	Components: • Rectangular profiles 60 mm x 30 mm; t = 3 mm Tools: • Tape Measure • Scriber • Saw (preferably band saw) • File (used for deburring) Process: a) Measuring profiles b) Mark profile length according to plan c) Saw profile d) Deburr cutting edges	  

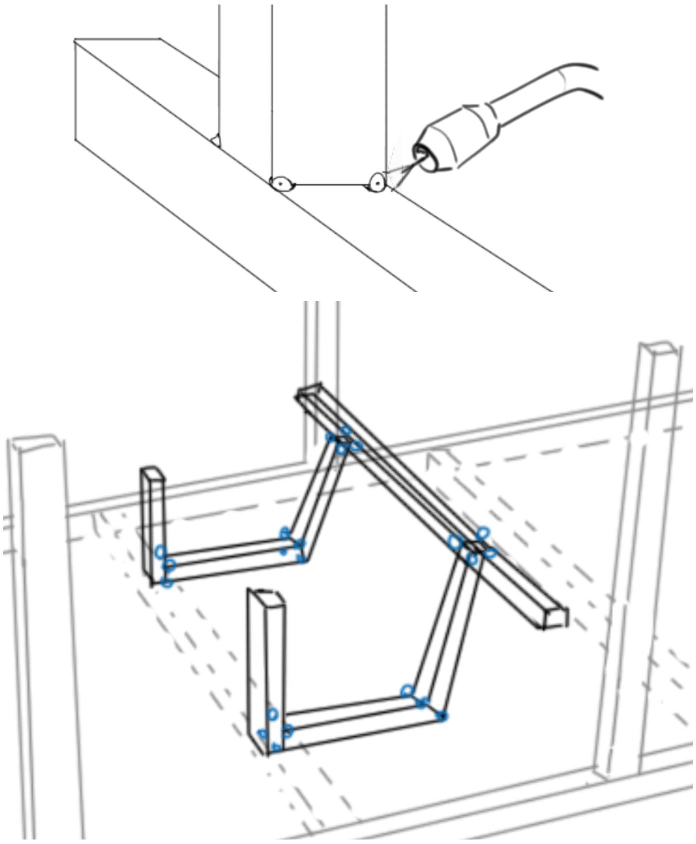
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.2.1-4	Components: • Cut rectangular profiles Tools: • Saw (preferably band saw) • File (used for deburring) • Tape Measure • Scriber Process: a) Mark profile length according to plan b) Saw profile to mitre c) Deburr cutting edges	

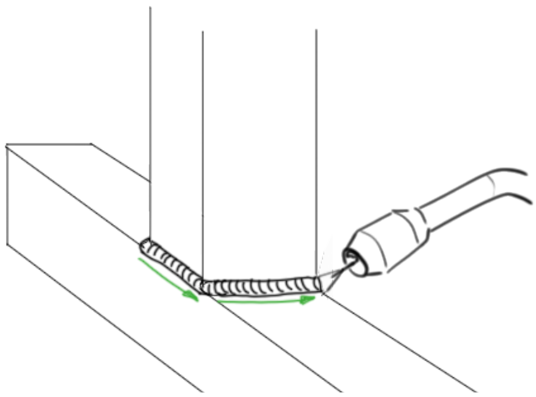
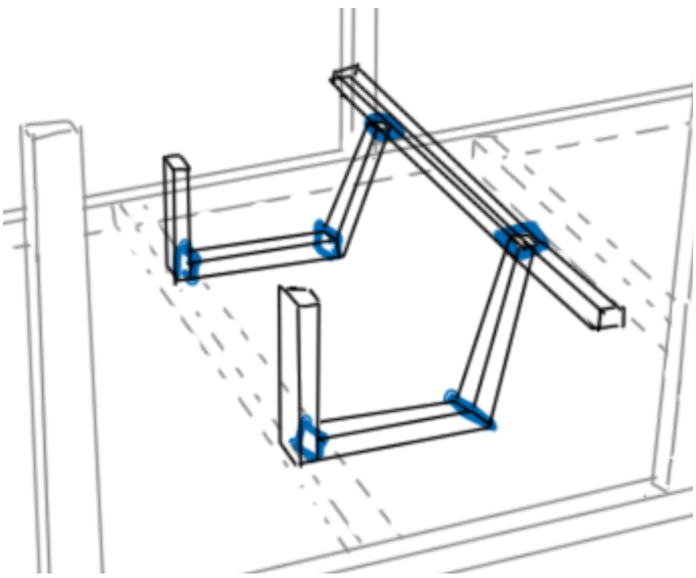
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.2.1-5	Components: • Cut and mitred profiles Tools: • Drilling machine • Center punch Process: a) Drill the marked points for all mounting points.	

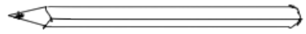
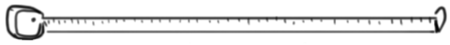
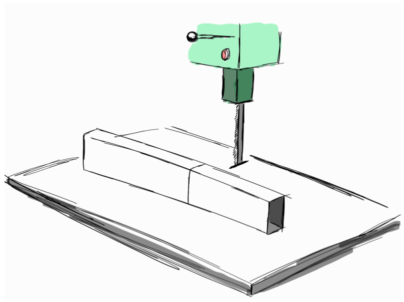
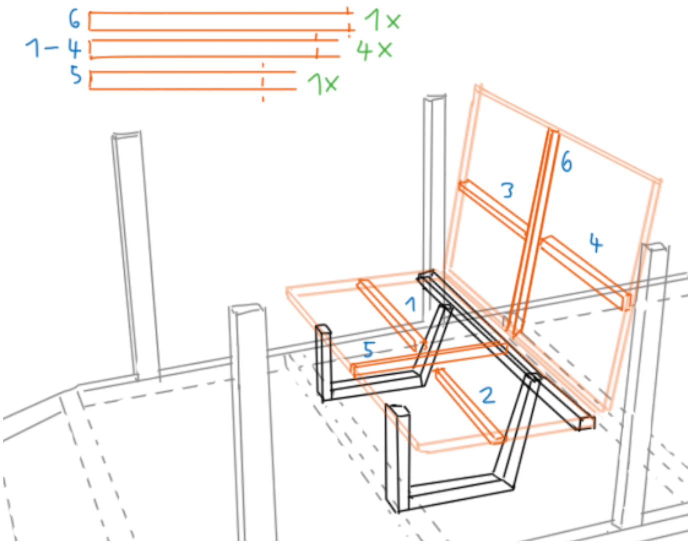
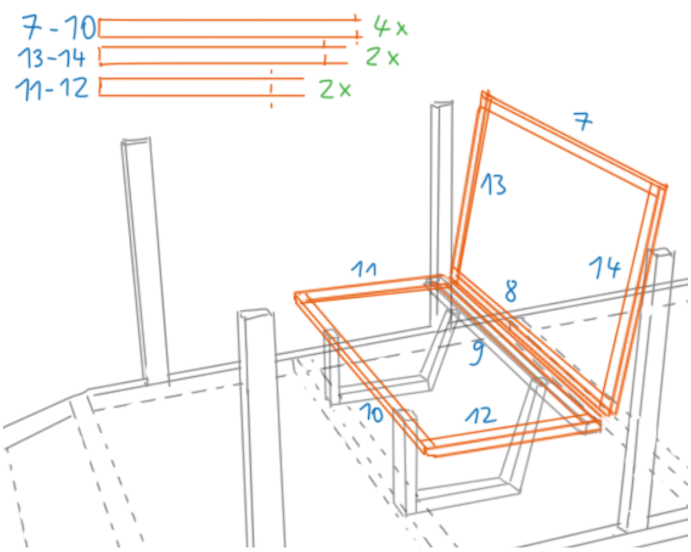
Funded by the European Union

Step	Instructions	Visual Assistance
Step 4.2.1-6	Components: • Cut to mitre rectangular profiles Tools: • MIG welding machine Process: a) Tack weld the edges of the profile together. b) Use at least 4 tacks at each joint.	

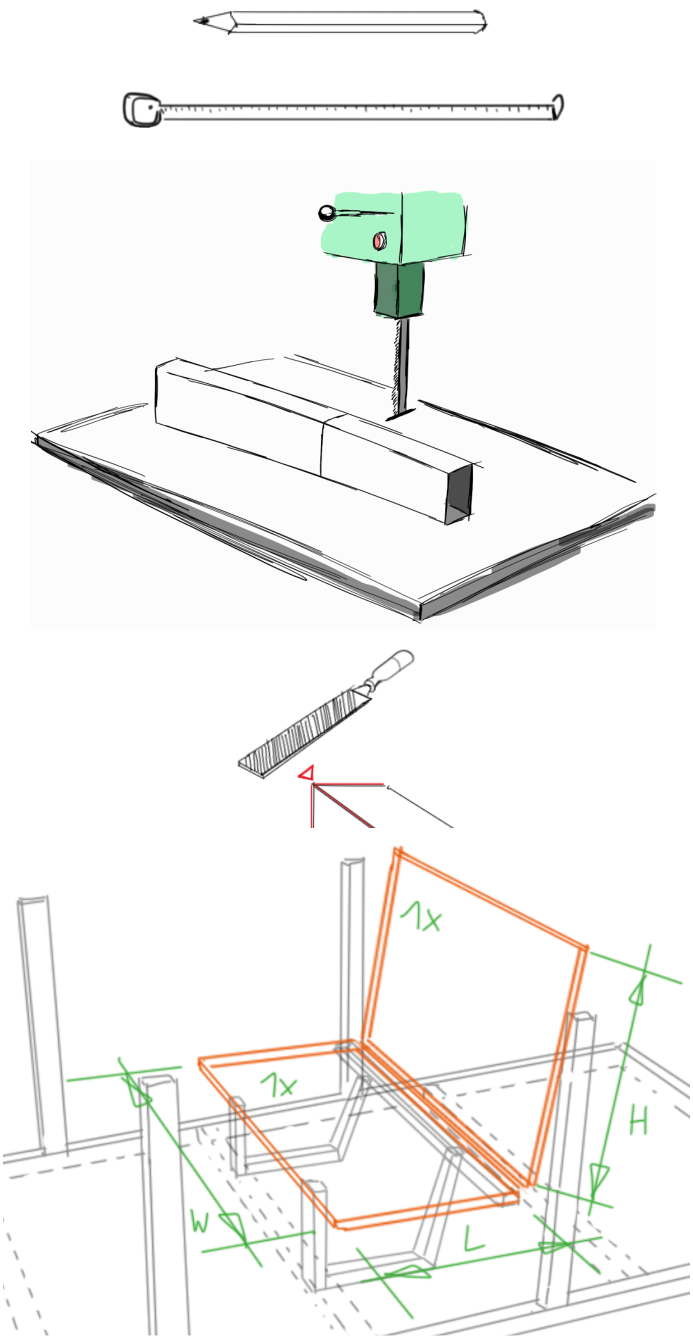
Funded by the European Union

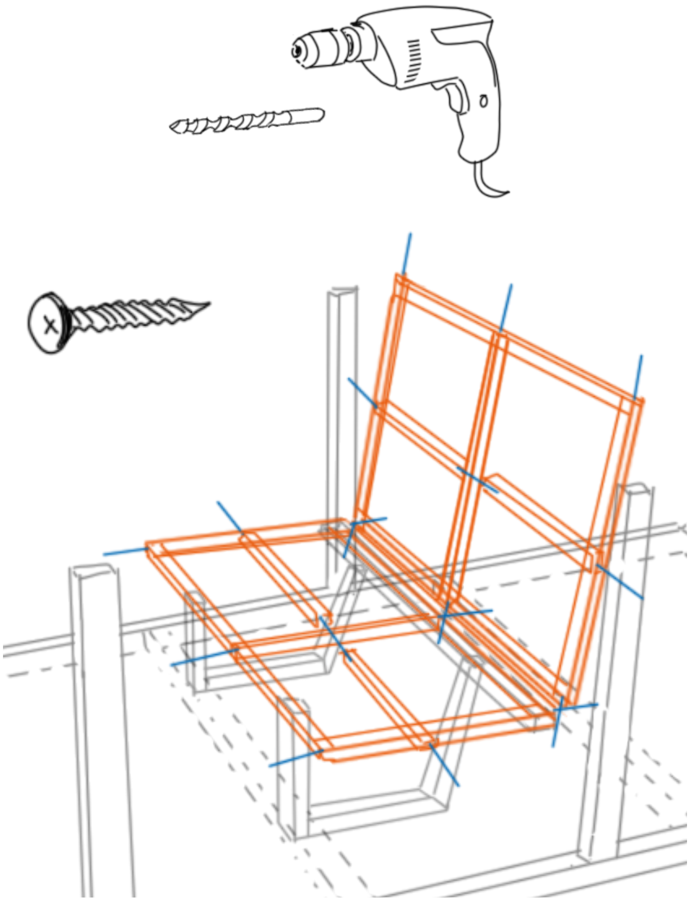
Step	Instructions	Visual Assistance
Step 4.2.1-7	Components: • Tack welded seat Frame Tools: • MIG welding machine Process: a) Fully weld all joints of the Base Frame. b) Follow Quality Gate to check the quality of the welding seams and the Base Frame regarding welding distortions.	 

Funded by
the European Union

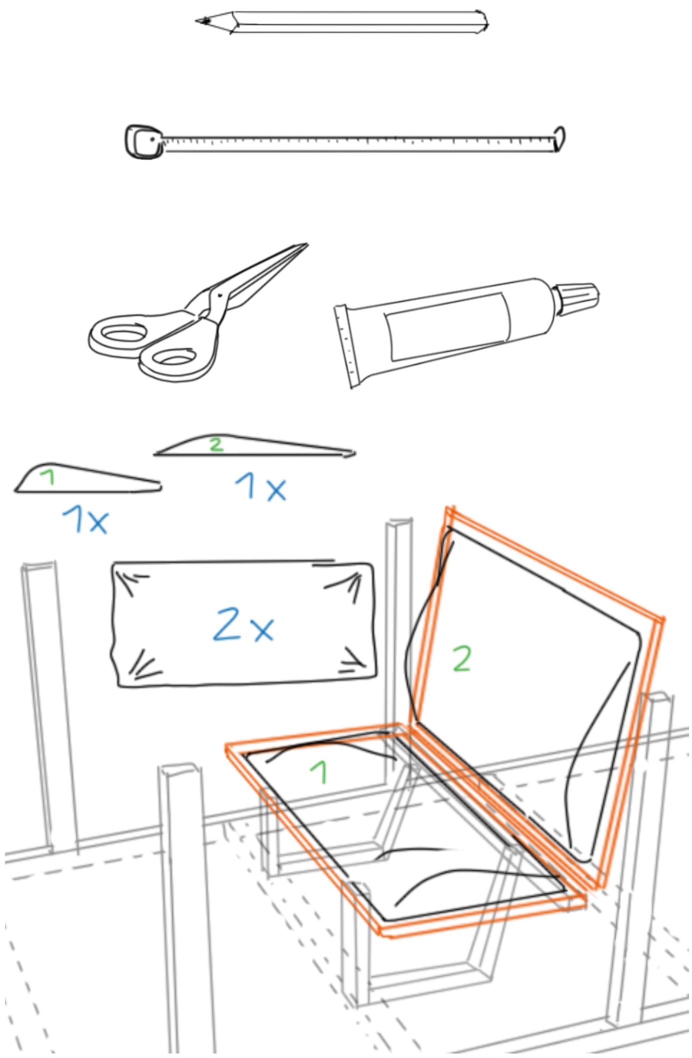
Step	Instructions	Visual Assistance
Step 4.2.1-8	Components: • Rectangular wood profiles 60 mm x 30 mm Tools: • Tape Measure • Scriber • Saw (preferably band saw) • File (used for deburring) Process: a) Measuring profiles b) Mark profile length according to plan c) Saw profile d) Deburr cutting edges	    

Funded by the European Union

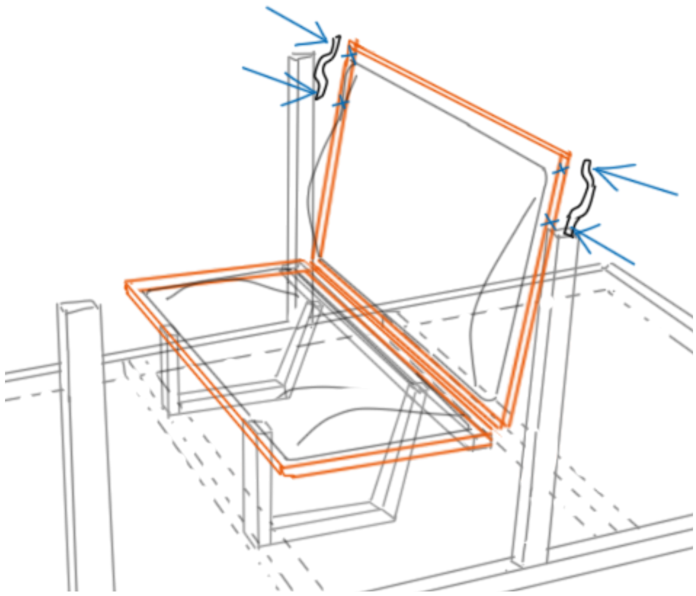
Step	Instructions	Visual Assistance
Step 4.2.1-9	Components: • Wood plates t = 3 mm • Cut wood profiles Tools: • Tape measure • Saw (preferably band saw) • File (used for deburring) Process: a) Measuring wood profiles leave room to ensure access to safety belts b) Mark plates length according to plan c) Saw plates d) Deburr cutting edges	

Step	Instructions	Visual Assistance
Step 4.2.1-10	Components: • Cut wood plates • Cut wood profiles • Screws Tools: • Drill • Screwdriver Process: a) Lay wood profiles in desired shape b) Position wood plate c) Drill pilotholes for screws d) Screw from the top side	

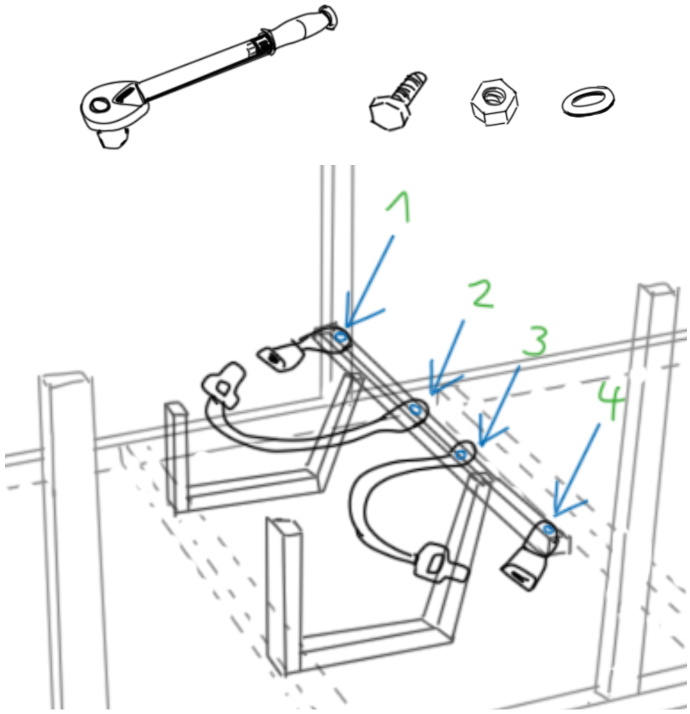
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.2.1-11	Components: • Wooden assembly Tools: • Upholstery material • Upholstery fabric • Glue • Stapler • Scissors • Knife Process: a) Cut upholstery material in shape b) Glue Material to Plates c) Cover upholstery material with fabric d) Secure fabric with staples	

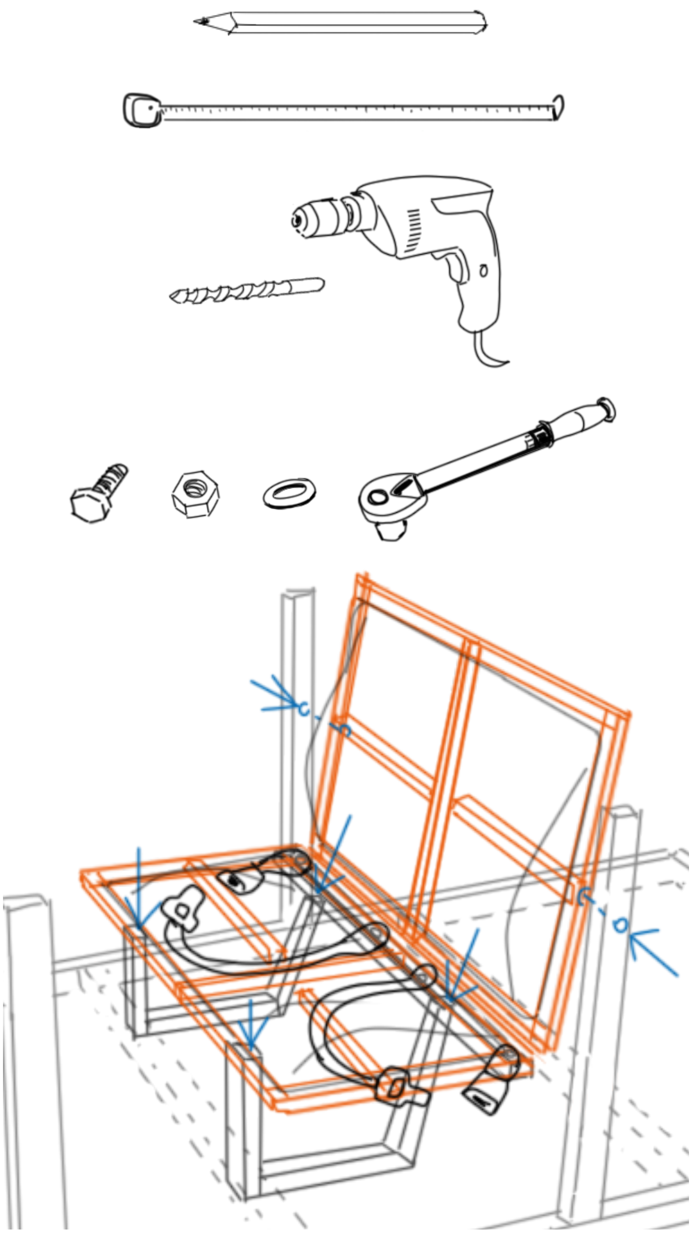
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.2.1-12	Components: • Boarding aid handle • Backrest assembly Tools: • Screws • Screwdriver Process: a) Use screw to attach Handle to the side of the backrest on a helpful position.	

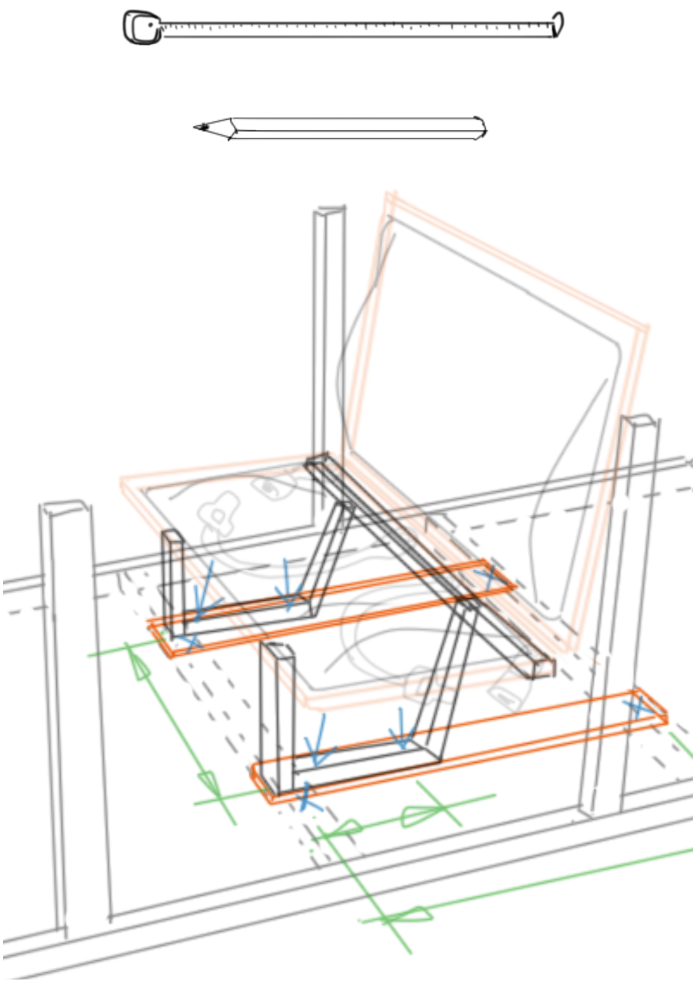
Funded by the European Union

Step	Instructions	Visual Assistance
Step 4.2.1-13	Components: • Painted seat frame with mounting holes • Safety belts Tools: • Wrench • Bolts • Nuts Process: a) Mount safety belts according to supplier's manual.	

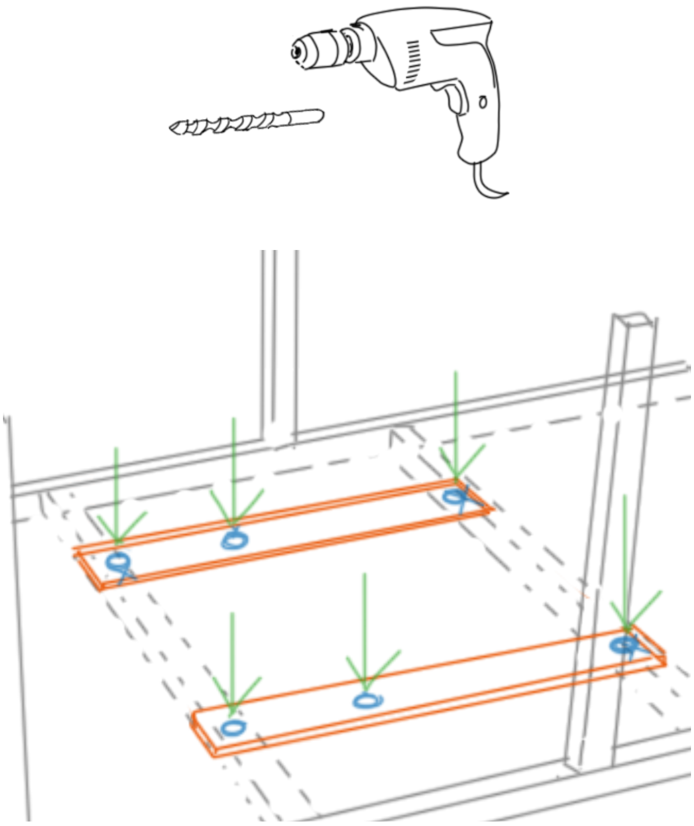
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.2.1-14	Components: • Wooden assembly • Painted seat frame with mounting holes Tools: • Drill • Screws • Screwdriver/Wrench Process: a) Drill pilot holes in wood b) Screws backrest to seat plate c) Position wood assembly in steel frame d) Screw assembly in place	

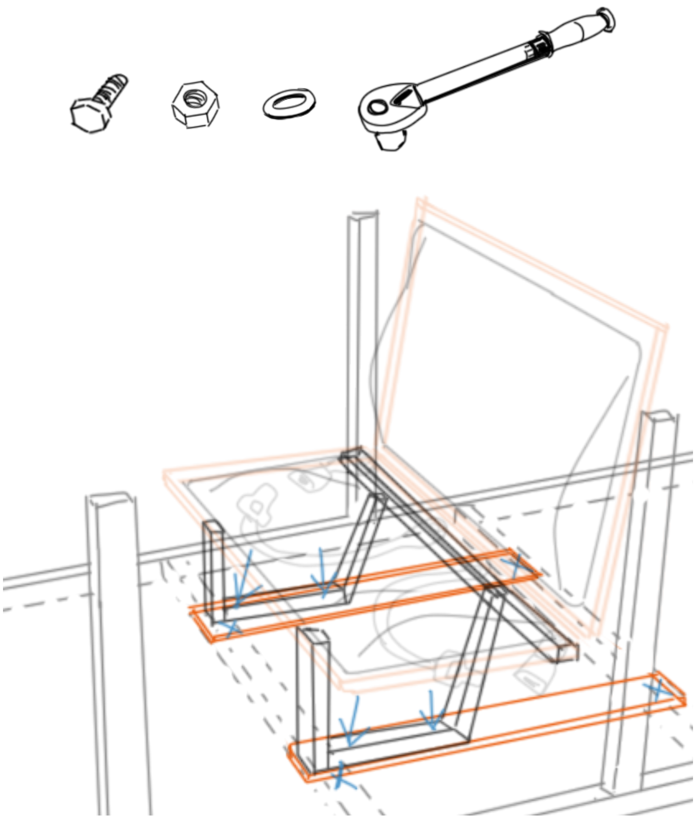
Funded by the European Union

<table>
<tr><th>Step</th><th>Instructions</th><th>Visual Assistance</th></tr>
<tr><td>Step 4.2.1-15</td><td>Components:
Marked base frame with floor Step 4.2.1-1
Seat assembly
Tools:
Tape measure
Marker
Process:
a) Measure distance of mounting holes of the seat assembly.
b) Seats must be mounted through base frame struts.
c) Mark mounting points in desired location.</td><td></td></tr>
</table>

Funded by the European Union

Step	Instructions	Visual Assistance
Step 4.2.1-16	Components: • Marked base frame with floor Tools: • Drill Process: a) Drill mounting holes through base frame struts.	

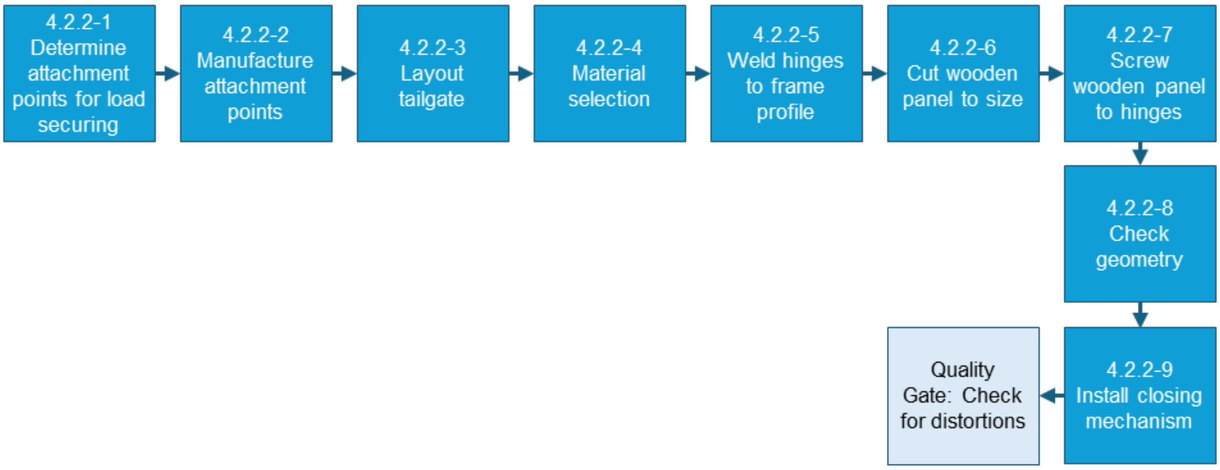
Funded by the European Union

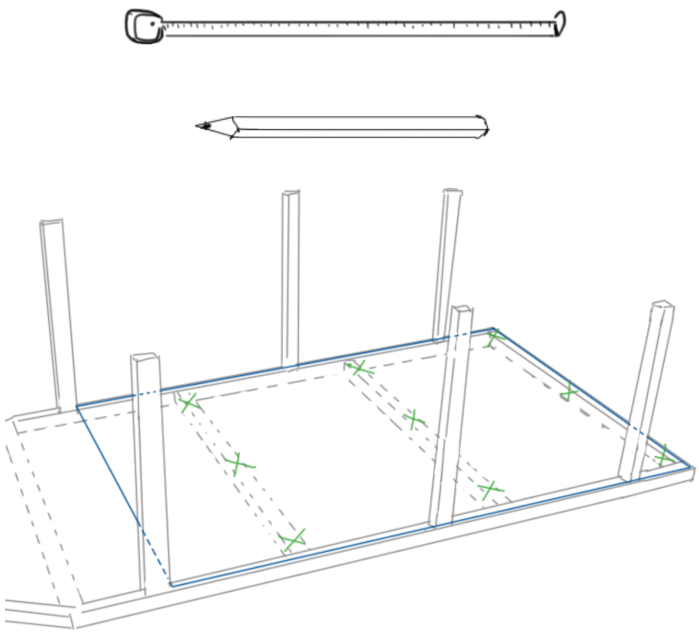
Step	Instructions	Visual Assistance
Step 4.2.1-17	Components: • Base frame with mounting holes • Seat assembly Tools: • Wrench • Bolts • Nuts Process: a) Position seat to align mounting holes b) Insert bolt from the top c) Fasten assembly with nut from beneath	
Quality Gate	Confirm that seats are firmly secured	

Funded by the European Union

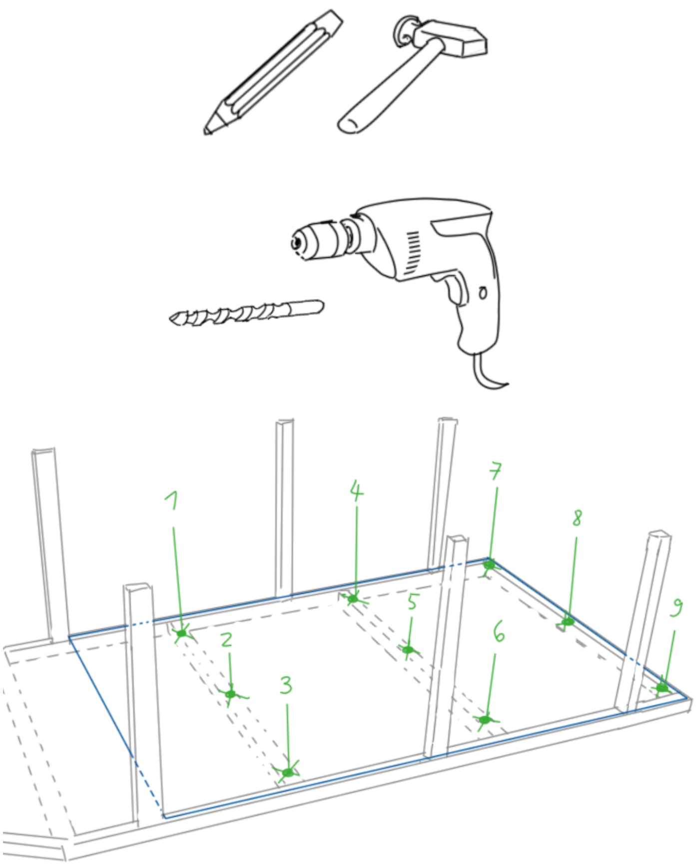
4.1.4.2.2 Cargo Area

The cargo area behind the driver's compartment in the center and rear of the vehicle is implemented and enables the transport of goods, thereby increasing the payload capacity of the vehicle. In the overall vehicle manufacturing process, the cargo area is installed after the assembly of the frame, the chassis, drivetrain, energy storage and the driver's compartment and is crucial to the functionality and versatility of the vehicle.

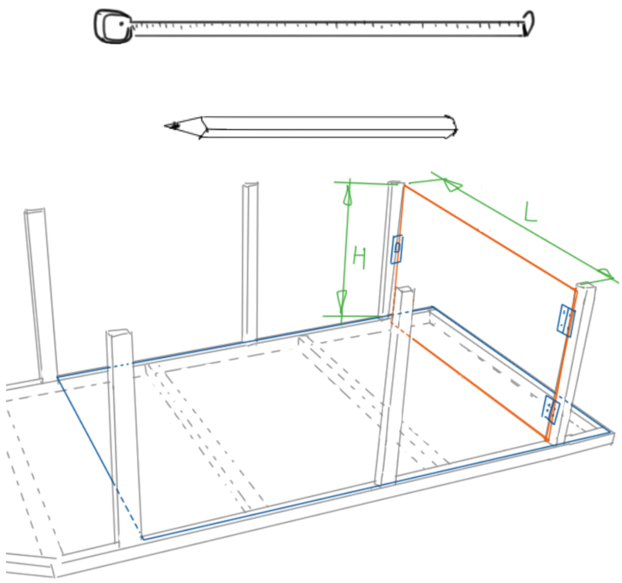


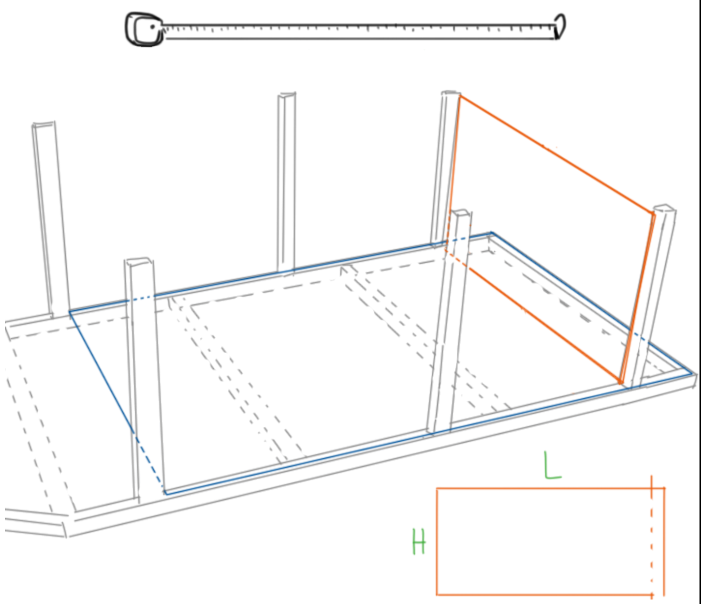
Step	Instructions	Visual Assistance
Step 4.2.2-1	Components: • None Tools: • Tape measure • Calculator • Scriber needle Process: a) Provide an anchor point for securing the load at least every 500 mm on the right and left inside of the vehicle.	

Funded by the European Union

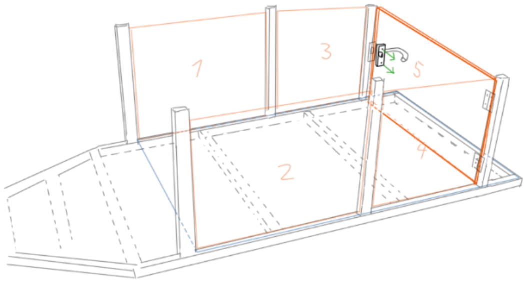
Step	Instructions	Visual Assistance
Step 4.2.2-2	Components: • Threaded eyelets Tools: • Drilling machine • Tap • Center punch Process: a) Drill the marked points for the stop points and insert a thread with a tap. b) Insert the threaded eyelets.	

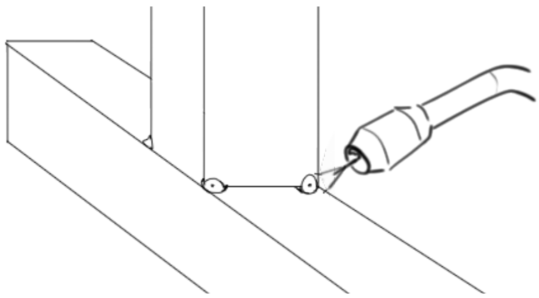
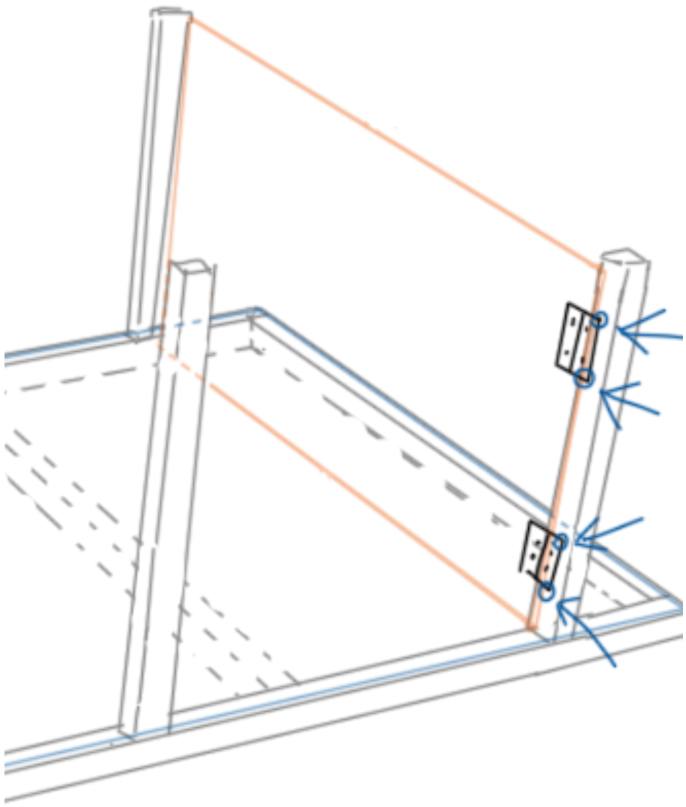
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.2.2-3	Components: • None Tools: • Tape Measure • Calculator • Pencil • Scriber needle Process: a) Determine the height, width and position of the tailgate.	

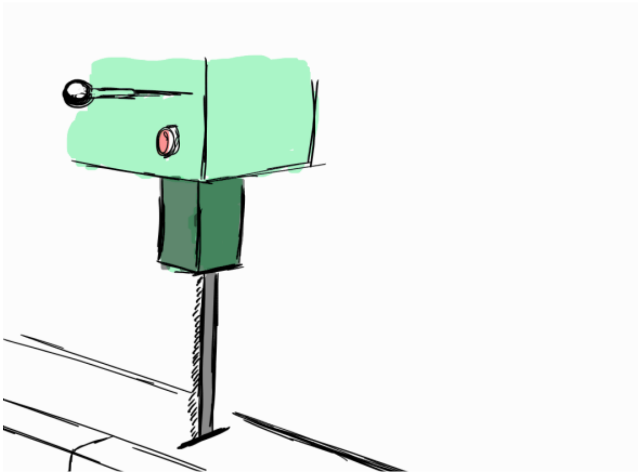
Step	Instructions	Visual Assistance
Step 4.2.2-4	Components: • None Tools: • Tape Measure • Calculator Process: a) Select the material for the plate of the tailgate depending on availability. b) Recommended: Wood. Alternatively, this can also be made from plastic or metal. In the following steps the manufacturing process with a wood panel is shown.	

Funded by
the European Union

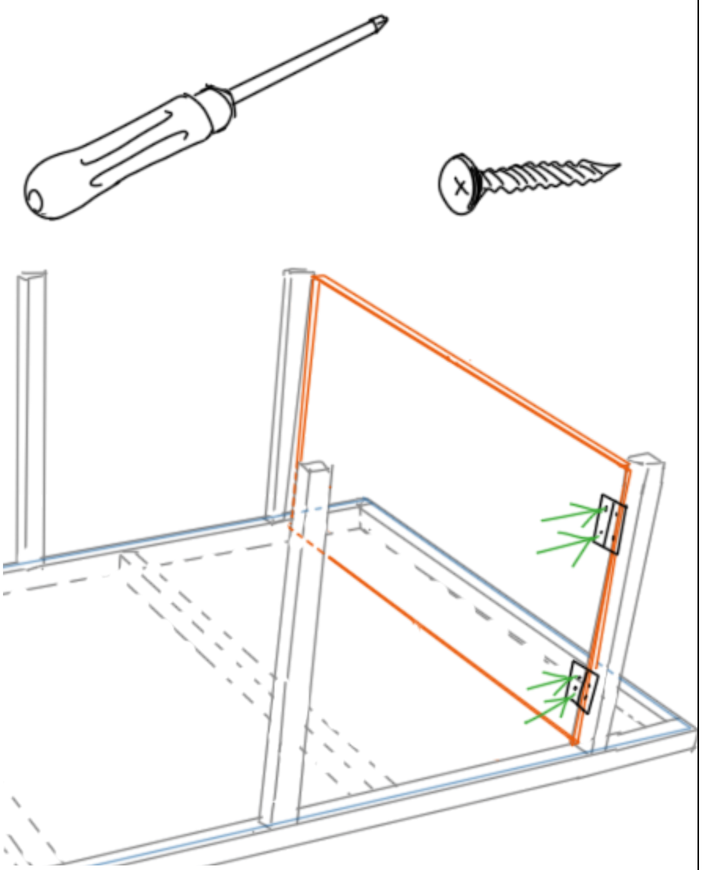
		1 3 5 2 4

Step	Instructions	Visual Assistance
Step 4.2.2-5	Components: • Frame • Hinges Tools: • MIG welding machine Process: a) Tack weld the hinges at the determined position on the vertical metal profiles of the frame.	 

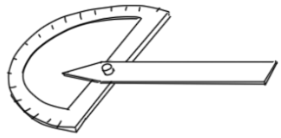
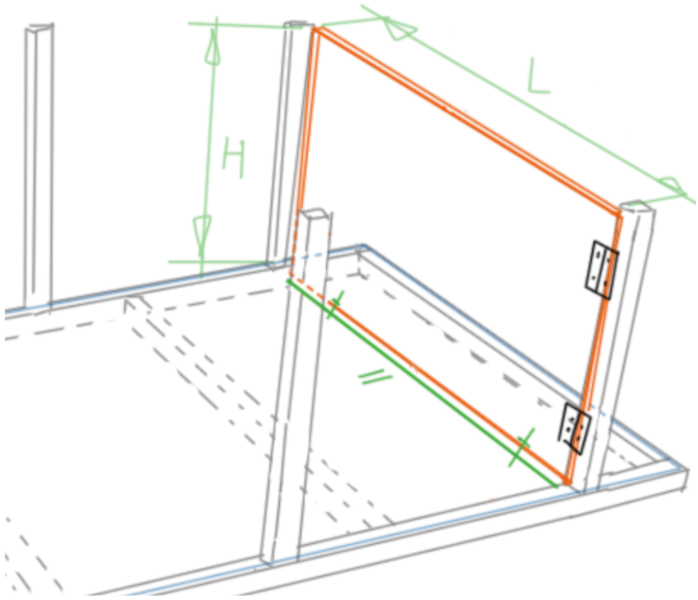
Funded by
the European Union

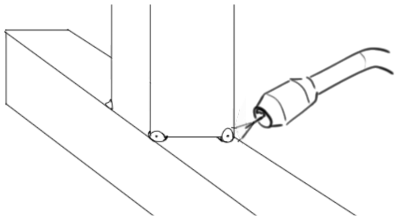
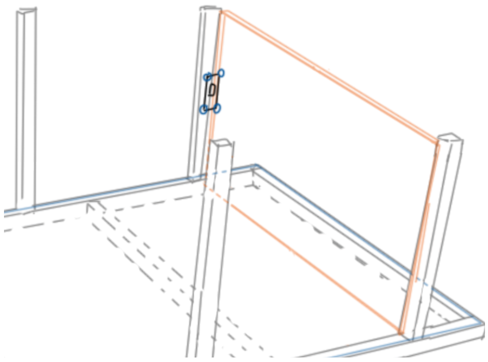
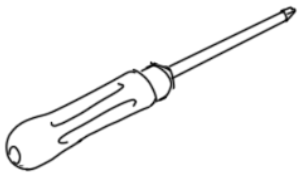
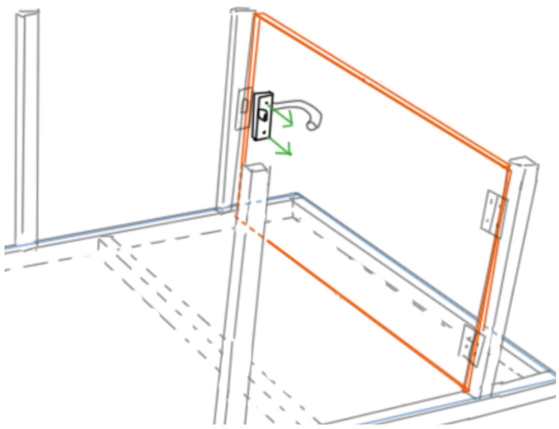
Step	Instructions	Visual Assistance
Step 4.2.2-6	Components: • Wood panel Tools: • Saw Process: a) Cut the wooden panel according to the specified dimensions in Step 4.2.2-3.	

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.2.2-7	Components: • Wood panel • Wood screws Tools: • Screwdriver Process: a) Screw the wooden panel to the hinges.	

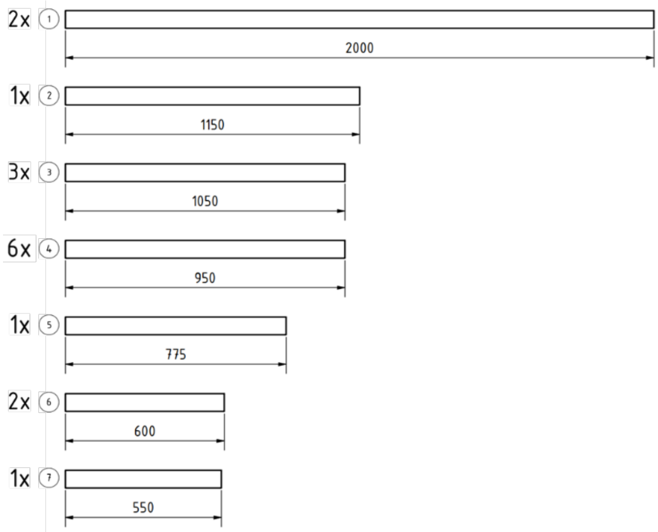
Funded by
the European Union

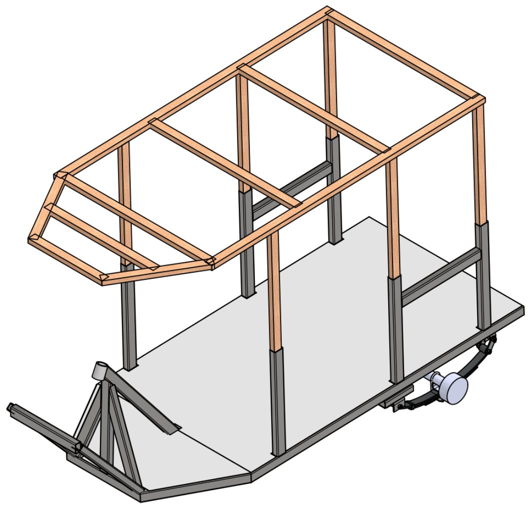
Step	Instructions	Visual Assistance
Step 4.2.2-8	Components: • Tack welded hinges and mounted wood panel Tools: • Tape measure • Protractor • Spirit level Process: a) Measure if the wood panel is parallel to the floor and in the correct height. b) If measurements are correct, proceed with step 4.2.2-9. c) If measurements are incorrect, separate the panel, hinges and start again at step 4.2.2-5.	   

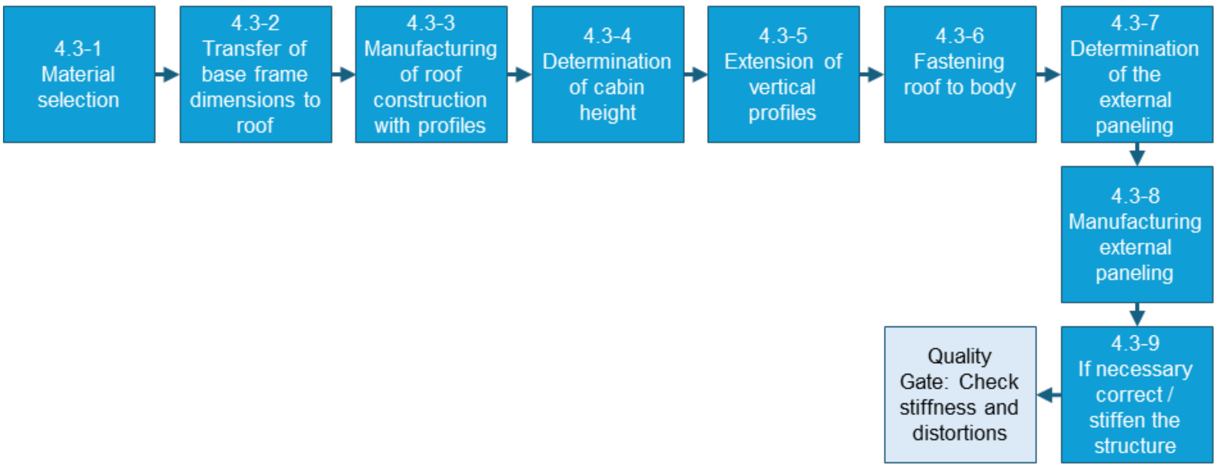
Step	Instructions	Visual Assistance
Step 4.2.2-9	Components: • Frame with tailgate Tools: • Drilling machine • Screws • Tap • MIG welding machine Process: a) Screw or weld a locking mechanism of the tailgate to the vertical profile of the frame.	    
Quality Gate	Check for distortions	

4.1.4.3 Roof

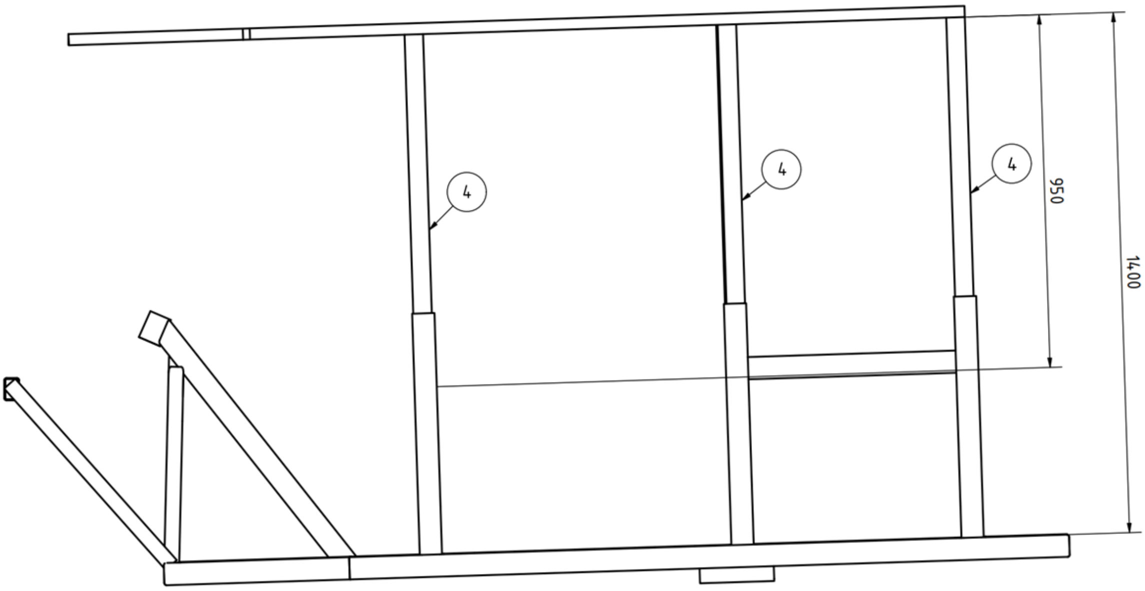
The roof is fitted to the upper part of the vehicle and covers the driver and passenger or the cargo area. The roof provides protection from the elements and increases the structural integrity of the vehicle. In the overall vehicle manufacturing process, the roof is installed after the base frame, driver's compartment, passenger or cargo area and other major components and completes the exterior structure of the vehicle.

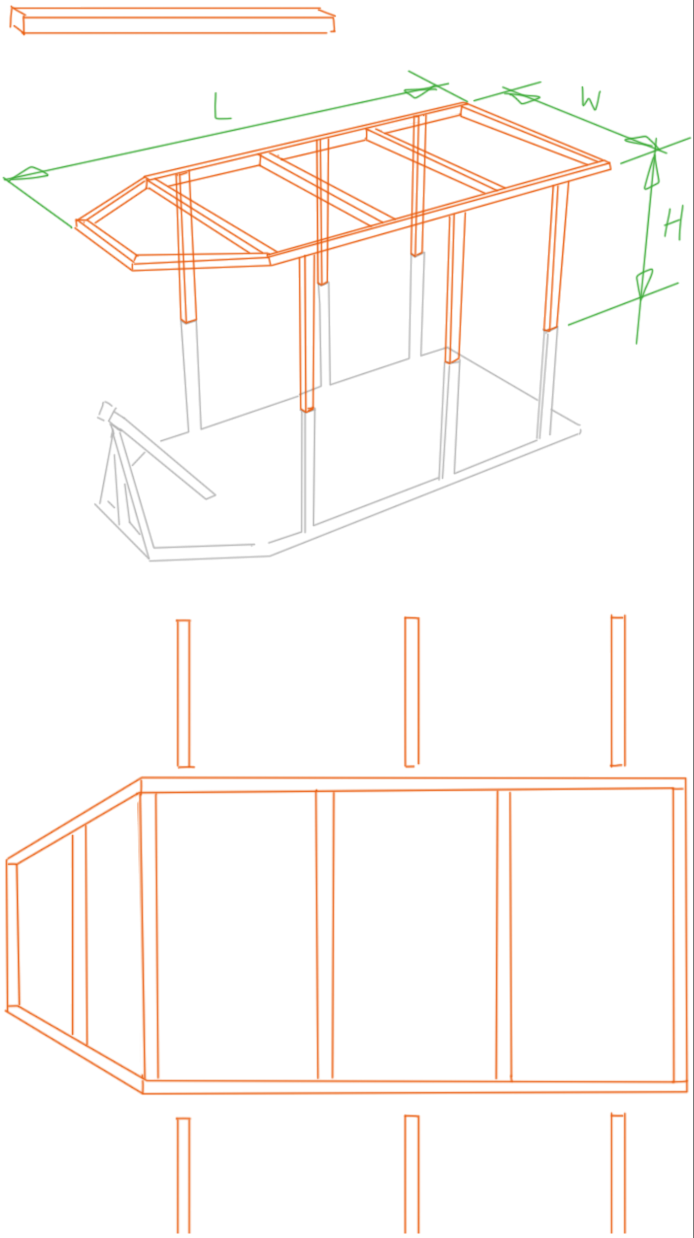




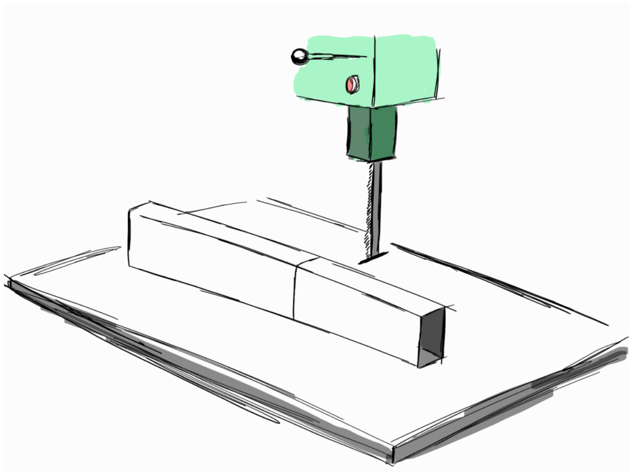
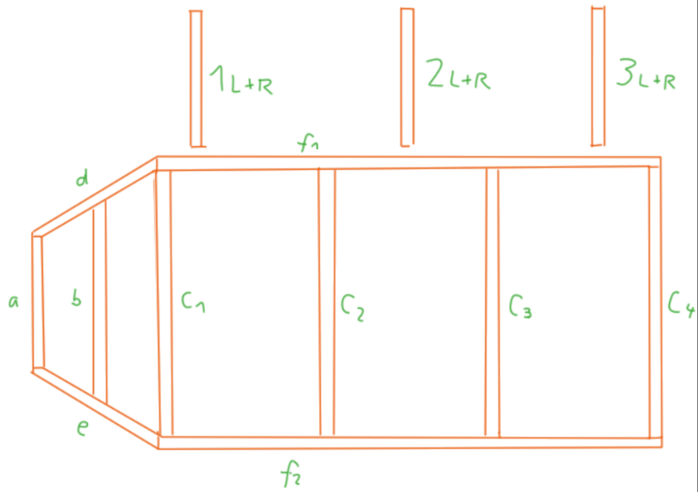


Funded by
the European Union

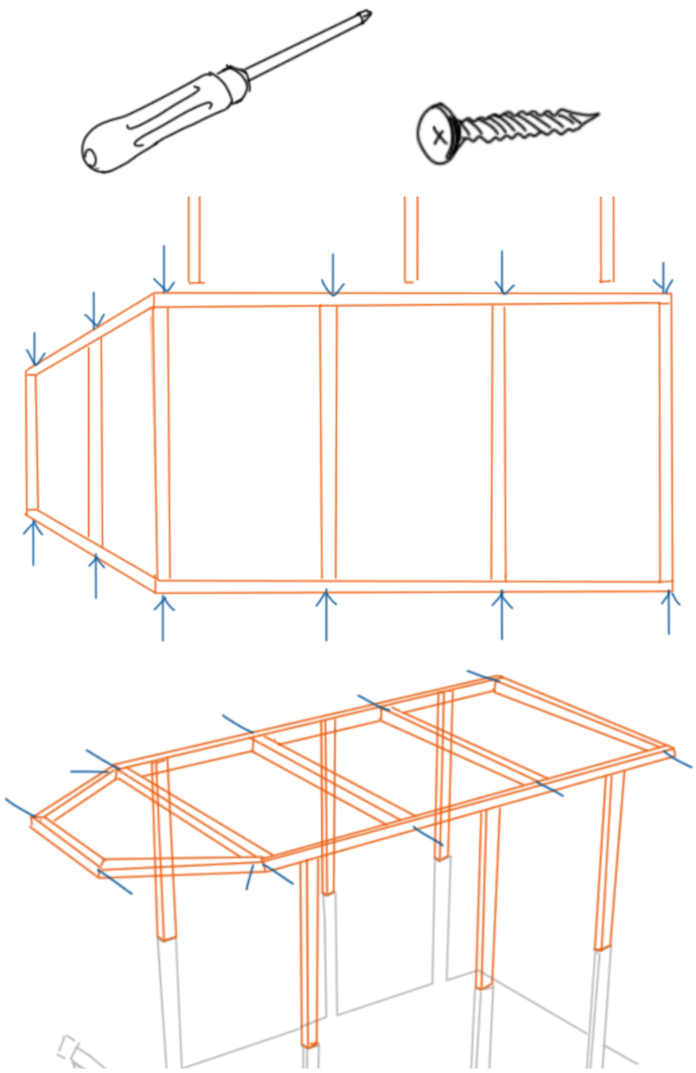

4
4
4
950
1400

Step	Instructions	Visual Assistance
Step 4.3-1	Components: • None Tools: • None Process: a) Choose the correct material for the structure of the roof and the vertical profiles depending on availability. b) Recommended: Rectangular wood profile that fits into the profile of the vertical struts of the support frame. (e.g. 50 mm x 30 mm wood profiles for given support profiles 60 mm x 40 mm x 3 mm). The manufacture of a wooden roof is described below. For production with metal profiles, proceed as for base frame.	

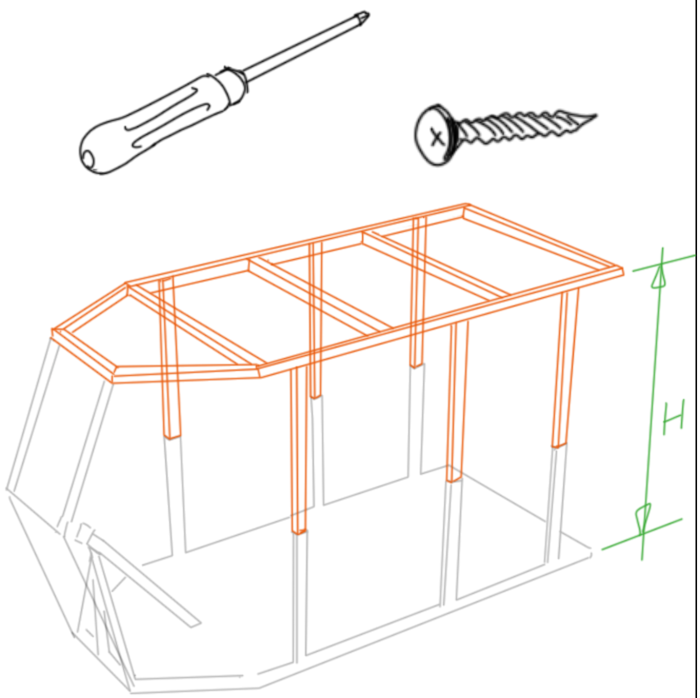
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.3-2	Components: • None Tools: • Saw (preferably band saw) • Tape Measure Process: a) Take the dimensions and number of profiles from the base frame and transfer them to the roof construction. Use the profiles selected in Step 4.3-1 for this.	  

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.3-3	Components: • Wood profiles Tools: • Wood screws • Screwdrivers Process: a) Screw the wooden profiles together according to the specified dimensions.	

Funded by the European Union

Step	Instructions	Visual Assistance
Step 4.3-4	Components: • None Tools: • None Process: a) Set the height of the interior in the range of 1200 mm - 1500 mm based on personal preference.	

Funded by the European Union

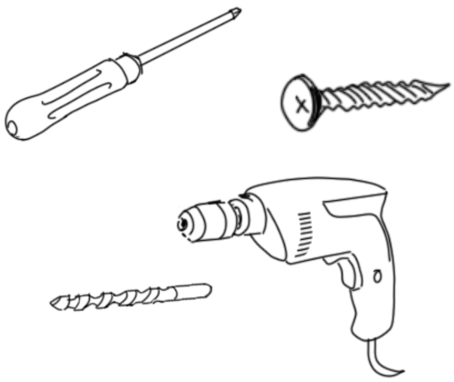
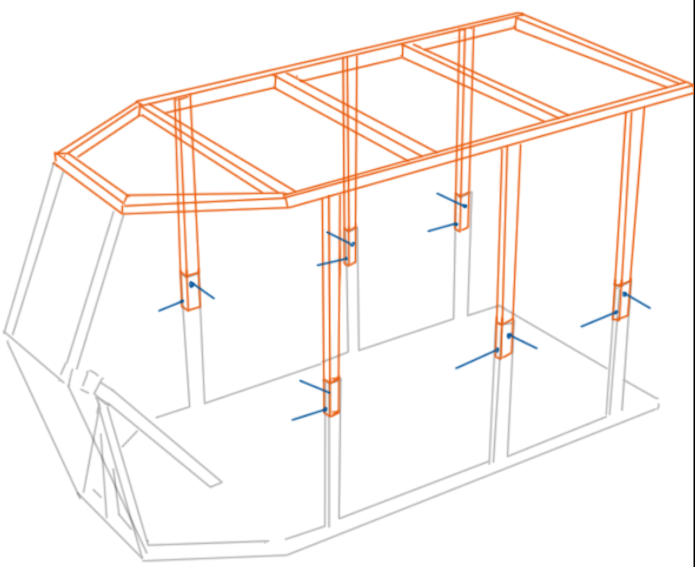
<table>
<tr><th>Step</th><th>Instructions</th><th>Visual Assistance</th></tr>
<tr><td>Step
4.3-5</td><td>Components:

• Wood profiles
• Frame

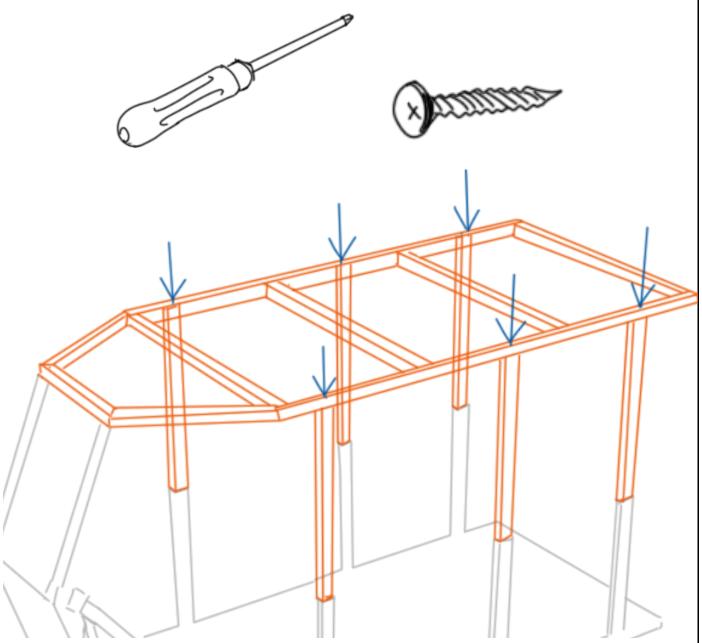
Tools:

• Drilling Machine
• Screwdriver
• Wood screws

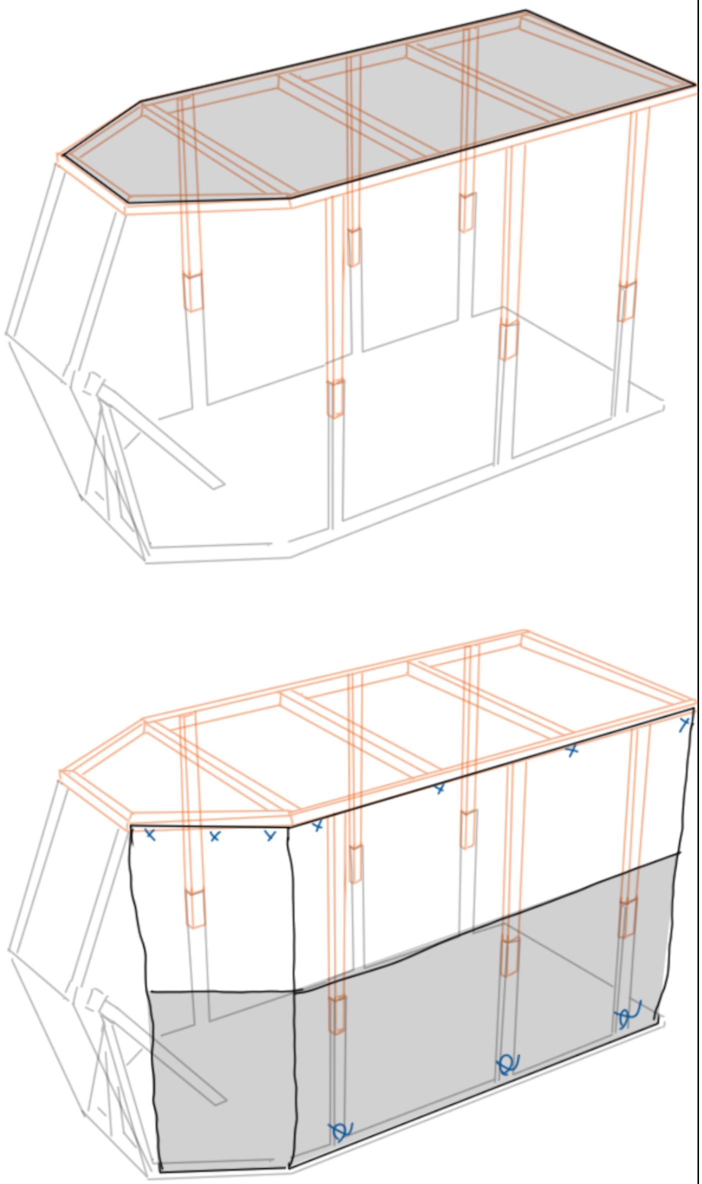
Process:

a) Determine the length of the vertical timber profiles based on the height determined in point 4.3-4. The wood profiles should be able to be inserted approx. 200 mm into the vertical support frame profiles.
b) Fasten the vertical wooden profiles in the vertical metal profiles using at least 4 screws. The screws should be screwed crosswise in 2 different planes through the metal profile into the wooden profile. Drill the through-holes in the metal profile with an allowance opposite the nominal diameter of the screws.</td><td>
</td></tr>
</table>

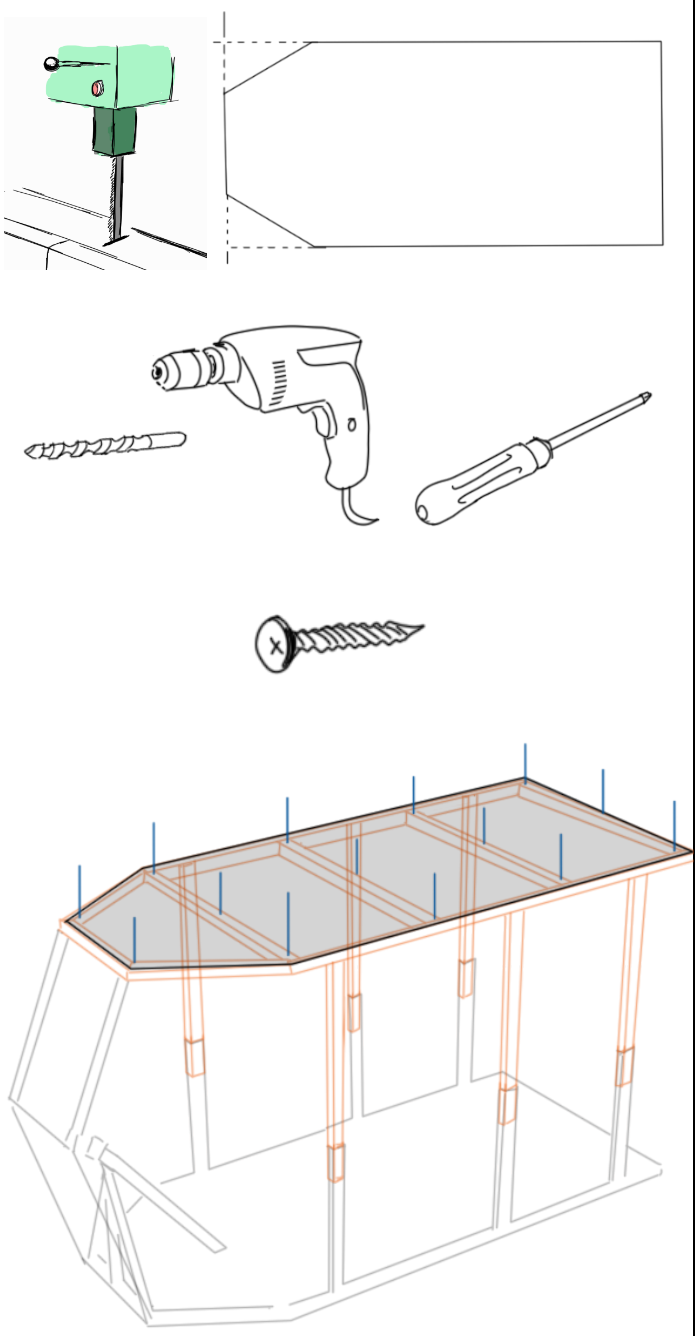
Funded by
the European Union

<table>
<tr><th>Step</th><th>Instructions</th><th>Visual Assistance</th></tr>
<tr><td>Step 4.3-6</td><td>Components:
Roof
Base frame
Tools:
Screwdriver
Wood screws
Process:
a) Fasten the roof to the vertical wooden profiles with wood screws. Use at least one vertical screw per fixing point and 3 screws set at different 45° angles.</td><td></td></tr>
</table>

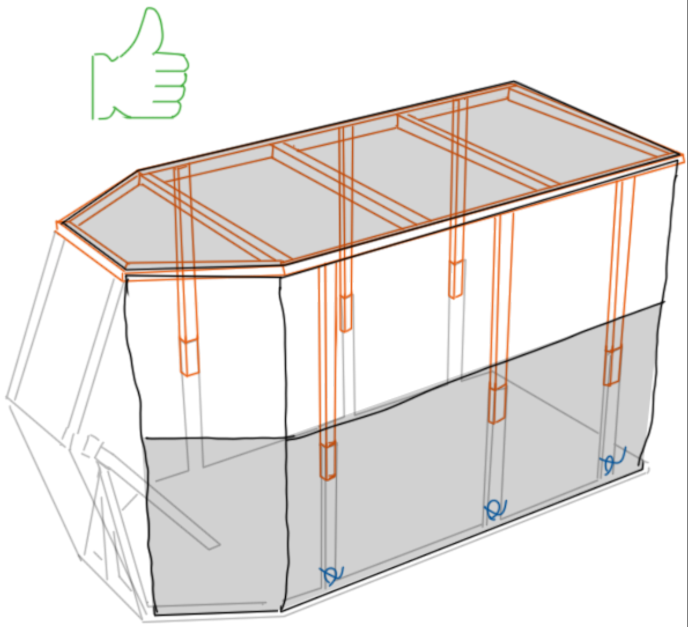
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.3-7	Components: • None Tools: • None Process: b) Select the material for the outer paneling according to your own ideas and local resources. The design of the side paneling is also optional. A wooden substructure is generally suitable for fastening the external paneling. c) The following instruction shows a covering with aluminum, steel sheet or wood paneling (roof) and fabric as external paneling.	

Funded by the European Union

Step	Instructions	Visual Assistance
Step 4.3-8	Components: • Material for external paneling • Frame • Wood profiles • Wood Screws • Nails Tools: • Hammer • Drilling machine Process: a) If required create a substructure of wooden profiles to which the outer roof or side paneling can be attached. The fastening method can be selected depending on the material pairing of the fastening points. For example, timber profiles are connected to timber profiles with wood screws or timber profiles to metal profiles by drilling, tapping if necessary, or direct screwing with wood screws. b) Stretch the fabric outer skin onto the substructure or mount the paneling with wood screws.	

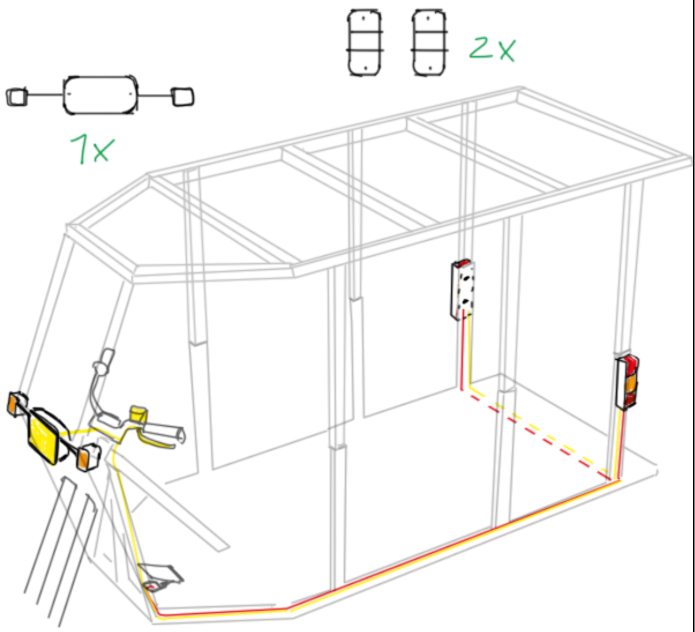
Funded by the European Union

Step	Instructions	Visual Assistance
Step 4.3-9	Components: • Frame • Wood profiles Tools: • Wood Screws • Nails • Hammer • Drilling machine • Top Process: a) In the case of distortion, loosen the affected joints, realign and reattach the structures. b) If there is a lack of rigidity, carry out stiffening again in accordance with steps 4.3-4 and 4.3-8.	
Quality Gate	Check stiffness and distortions	

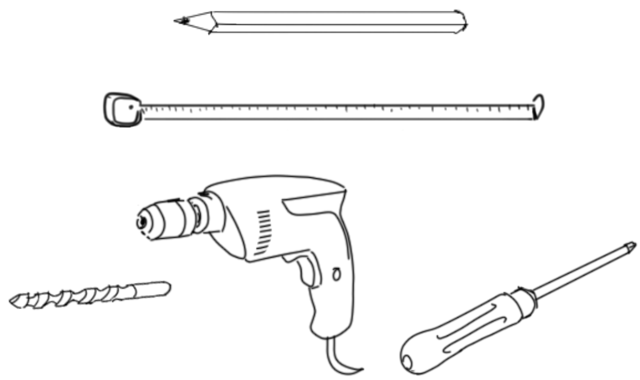
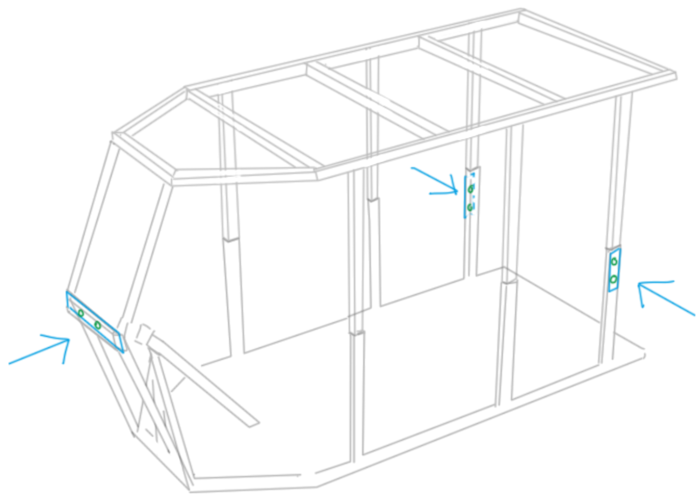
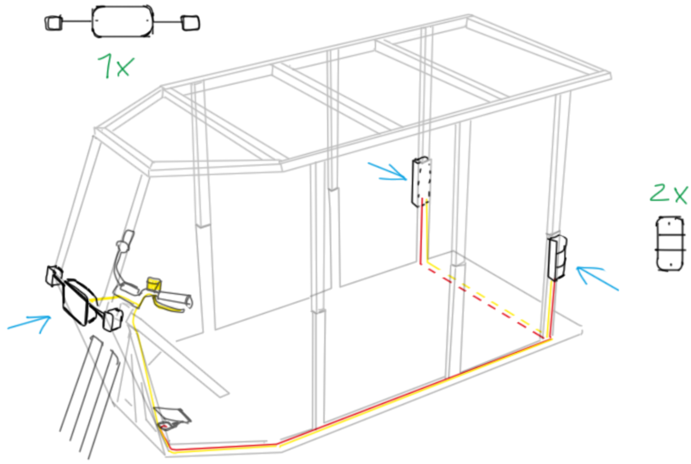
Funded by the European Union

4.1.4.4 Lighting

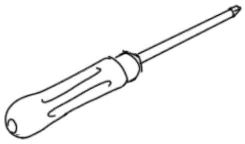
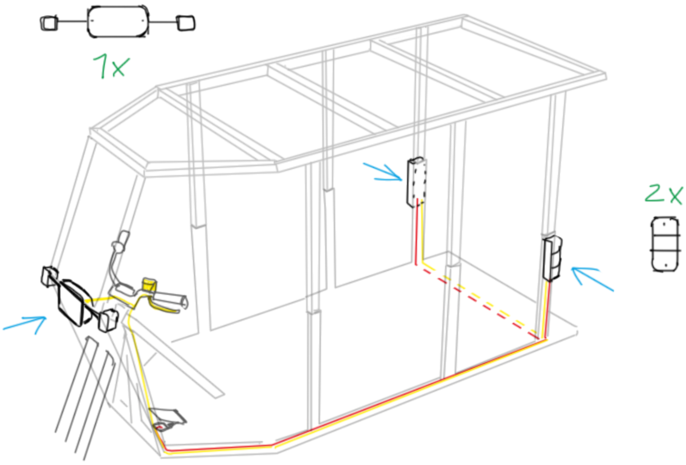
The lighting system is installed at the front, rear and partly on the sides of the vehicle. The lighting improves the visibility of the vehicle in poor lighting conditions and contributes to the safety of both the driver and other road users. In the overall vehicle production process, the lighting system is one of the final production operations and is crucial for road approval and the safe use of the vehicle in all lighting conditions.

Step	Instructions	Visual Assistance
Step 4.4-1	Components: • None Tools: • Calculator Process: a) Select suitable headlights, indicators, taillights and brake lights in accordance with the legal requirements at the place of use.	

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.4-2	Components: • Headlight, indicators, tail and brake lights Tools: • Tape measure • Calculator • Scriber needle • Drilling machine • Screws Process: a) Select suitable mounting points for the various lighting devices and install them by drilling and screwing. b) Fit switches for the headlight and indicators on the handlebars. The brake lights are controlled via a switch on the brake lever. c) Make sure that the headlights provide sufficient illumination of the area in front of the vehicle and do not dazzle oncoming traffic.	  

Funded by
the European Union

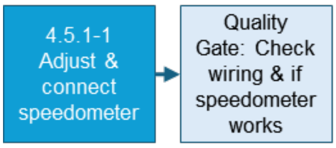
Step	Instructions	Visual Assistance
Step 4.4-3	Components: • Headlight, indicators, tail and brake lights • Cables Tools: • Tape measure • Calculator • Zip ties • Soldering cobles • Solder Process: a) Plan suitable routes for laying the cables of the lighting equipment protected from environmental influences. b) Fasten the cables with the help of zip ties or alternative mounting options. c) Solder the cables or use connectors to connect the rear lights, headlights and indicators to the power source and the signaling devices. (More detailed in 4.1.5)	  
Quality Gate	Check cables and lighting equipment	

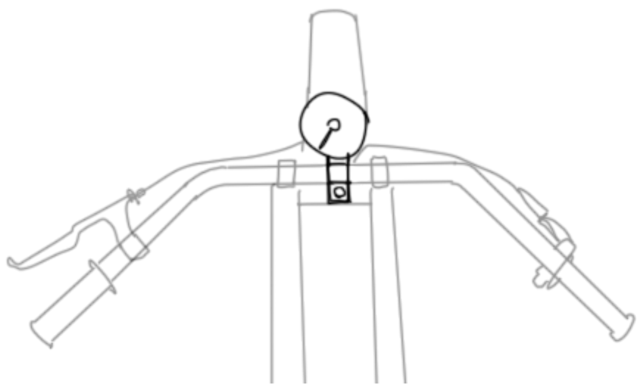
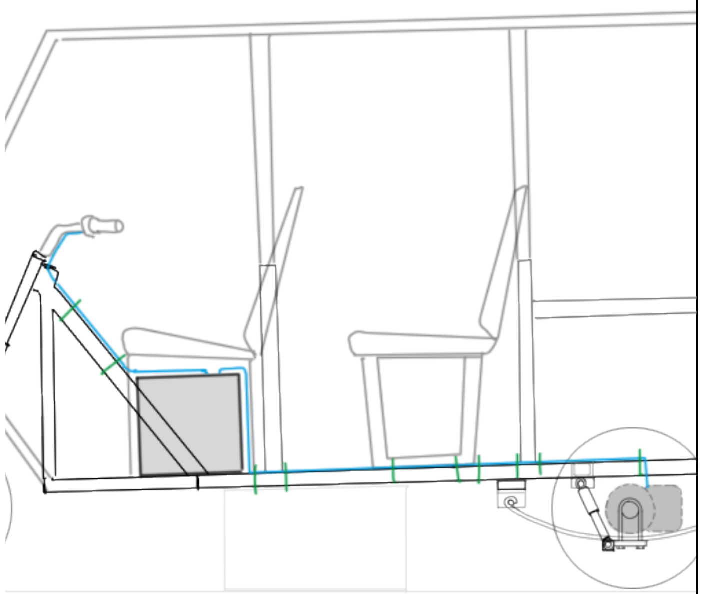
Funded by
the European Union

4.1.5 Assembly

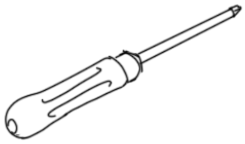
The various work packages required to complete the vehicle are described below. These include the speedometer, brakes, electrical wiring and further accessories.

4.1.5.1 Speedometer



Step	Instruction	Visual Assistance
Step 4.5.1-1	Components: • Speedometer including Clamp • Cable from Drive Train Unit Tools: • Screwdriver • Wrench • Screws • Bolts • Screw nut Process: a) Adjust the speedometer in the middle of the handling bar. b) Tighten the clamp with the Bolts and Screw nuts. c) Identify the Cable from the Drivetrain Unit. d) Connect the Cable from the Drivetrain Unit with the speedometer.	 

Funded by the European Union

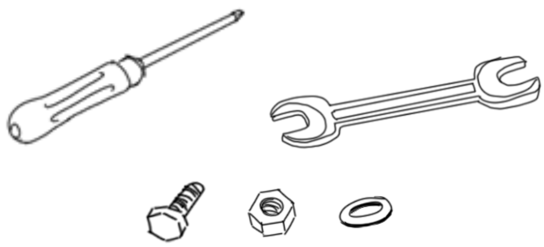
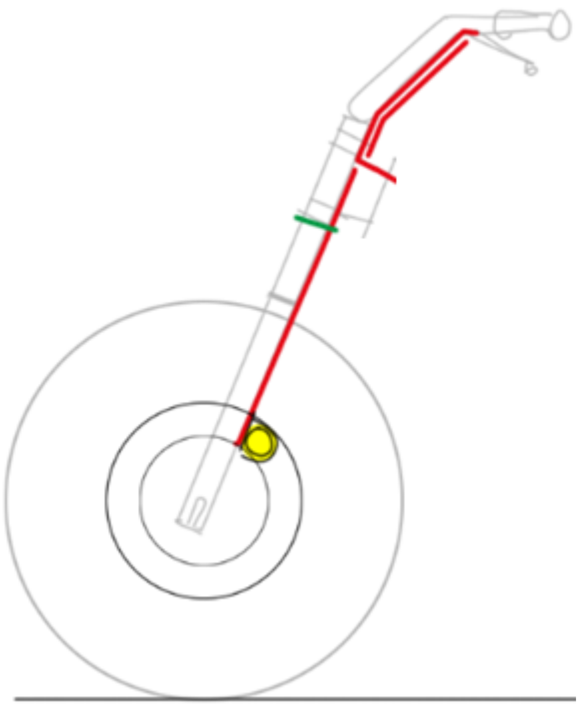
	e) Secure the cable with a suitable cable management system at regular intervals.	
Quality Gate	Check that speedometer is firmly attached and works out	

Funded by
the European Union

4.1.5.2 Brakes

If available, **use screw adhesive** for each screw connection of the brake!

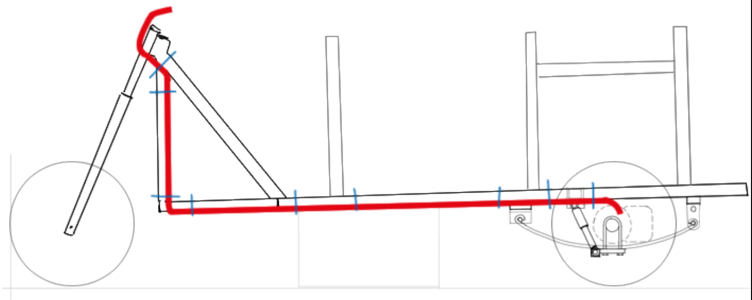
5.2-1 Attach front brake caliper & brake lever → 5.2-2 Attach rear brake caliper & brake lever → Quality Gate: Check that brakes work properly

Step	Instructions	Visual Assistance
Step 5.2-1	Components: • Front brake • Base frame Tools: • Screwdriver • Wrench • Bolts • Screw nut • Screws • Open-end spanner Process: a) Attach the front brake caliper to the designated position on the suspension fork. b) In the next step, attach the brake lever to the handlebars. Make sure it is in a suitable position for comfortable and safe braking when you are sitting on the vehicle. c) Secure the brake line with cable	 

Funded by the European Union

	ties, straps or similar to prevent it from slipping. Pay particular attention to the suspension travel of the suspension fork and the associated displacement of the brake hose.	

Funded by
the European Union

<table>
<tr><th>Step</th><th>Instructions</th><th>Visual Assistance</th></tr>
<tr><td>Step 5.2-2</td><td>Components:
Base Frame with all attachments from before
Tools:
Screwdriver
Cable ties/cable routing
Process:
a) Install the brake lines from the rear axle to the Driver Compartment.
b) Secure the brake line with a suitable cable management system at regular intervals.
c) Make sure that the brake line is routed as protected as possible from stone chips etc. Provide additional protection if necessary.
d) Mount the brake lever on the handlebars.
e) If using a hydraulic brake system, bleed the brake system according to the instructions.</td><td></td></tr>
</table>

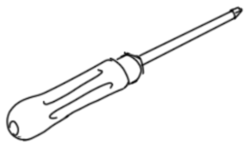
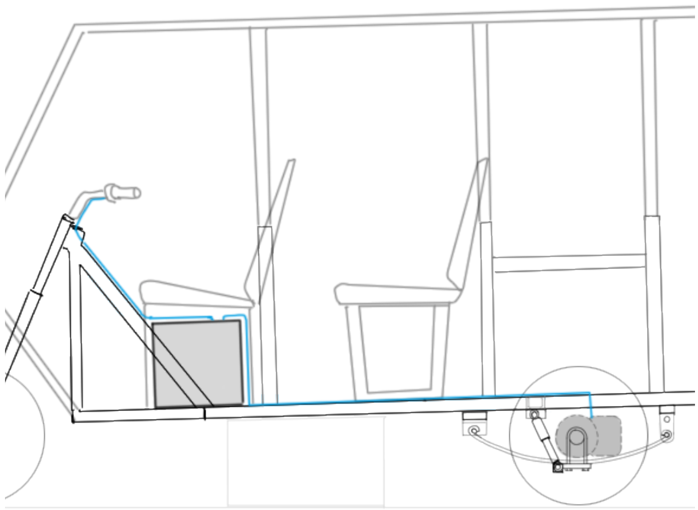
Funded by
the European Union

Quality Gate	Check the quality of the welding seams and the Base Frame regarding welding distortions	

Funded by the European Union

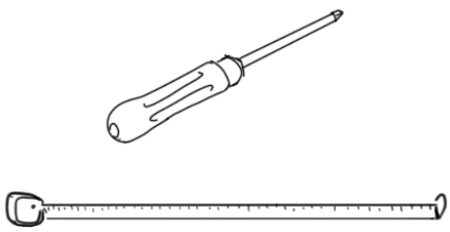
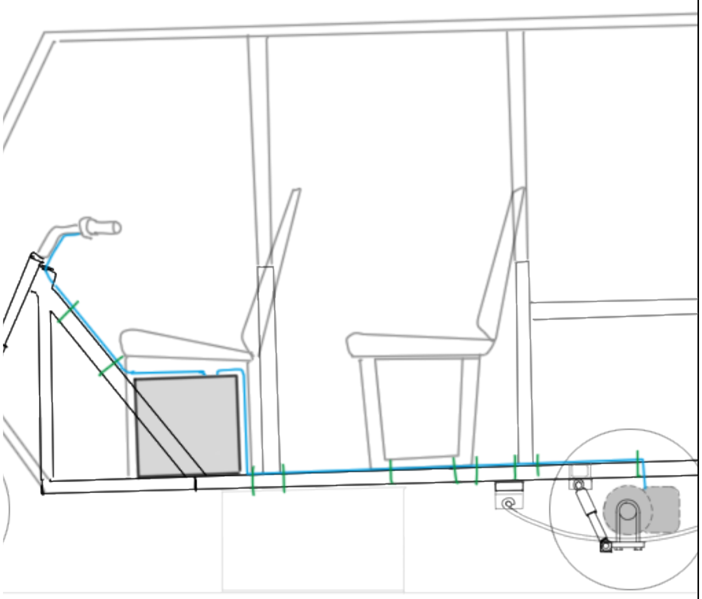
4.1.5.3 Electrical wiring

4.5.3-1 Wiring drivetrain cables → 4.5.3-2 Install driving relevant components → 4.5.3-3 Connect cables with components & battery → Quality Gate: Check wiring & if speedometer works

Step	Instructions	Visual Assistance
Step 4.5.3-1	Components: • Suitable cables for drivetrain – battery connection • Suitable cables for drivetrain control signals Tools: • Screwdriver • Cable ties/cable routing Process: a) Wiring of the Drivetrain control unit according to the manufacturer's information. b) Bundle the relevant cabling for the driver compartment (ignition key, gearshift (forward/reverse), power sensor, ignition), extend if necessary and route to the driver compartment. c) Bundle relevant cabling for power supply, extend if	 

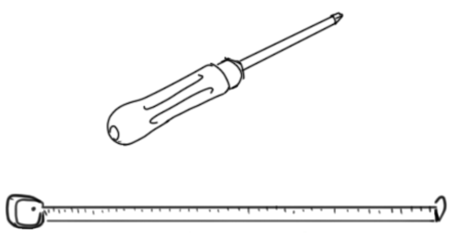
Funded by the European Union

	necessary and route to the battery. d) Secure the cables with a suitable cable management system at regular intervals. e) Make sure that the cables are routed as protected as possible from stone chips etc. Provide additional protection if necessary.	

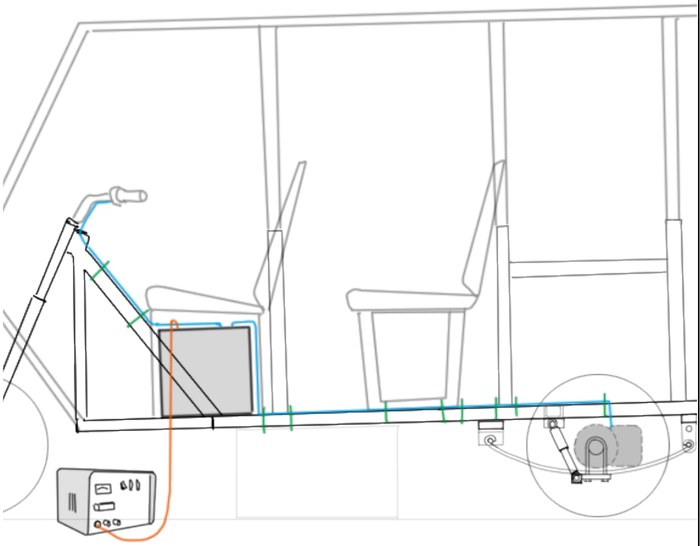
Step	Instructions	Visual Assistance
Step 4.5.3-2	Components: • Driving relevant components (ignition key, gearshift (forward/reverse), power sensor, ignition) • Cables for driving relevant components (ignition key, gearshift (forward/reverse), power sensor, ignition) • Assembled handlebar in drivers compartment Tools: • Screwdriver • Wrench • Screws • Bolts • Tape measure	 

Funded by
the European Union

	Process: a) Determination of the installation locations for the individual components (ignition key, gearshift (forward/reverse), power sensor, ignition) after ergonomic alignment. b) Route the corresponding cables for the relevant components to the specified installation locations. c) Secure the cables with a suitable cable management system at regular intervals. d) Connect cable and corresponding component. e) Attach component to corresponding installation location.	

Step	Instructions	Visual Assistance
Step 4.5.3-3	Components: • Battery • Battery charger • Cables for power supply Tools: • Screwdriver • Wrench • Screws • Bolts	

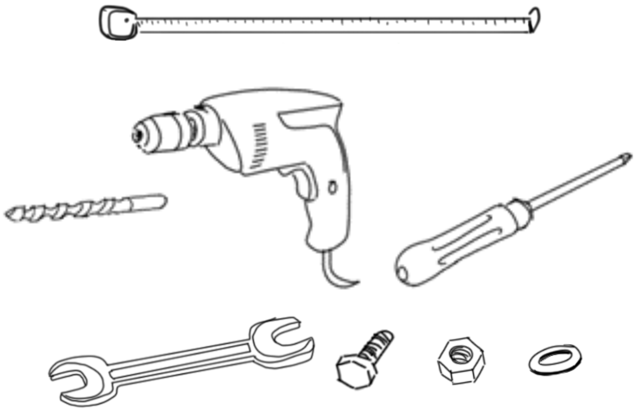
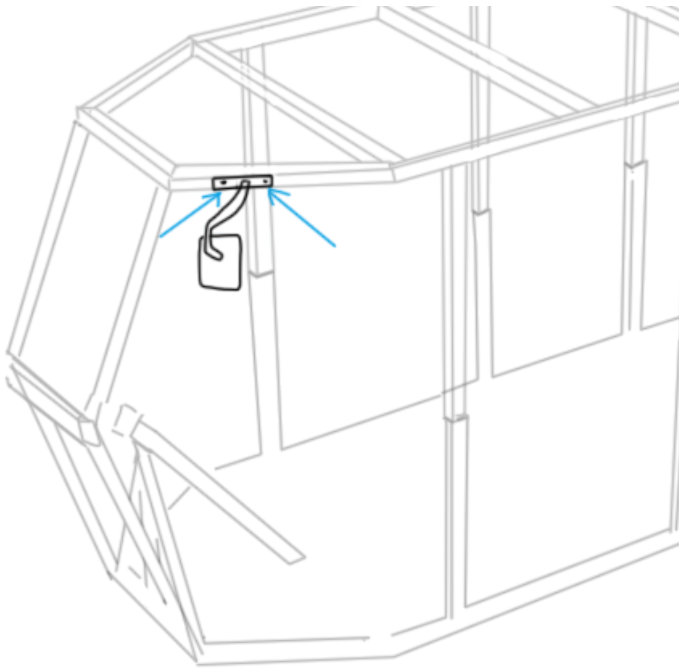
Funded by
the European Union

	• Tape measure Process: **Be careful when working with high-voltage components** a) Identification of the cables for input and output power supply (charging and motor). b) Connect cables for the power supply of the motor and the battery (output connector). c) Connect cables for the battery charging and the battery (input connector).	
Quality Gate	• Check battery voltage and the correctness of the wiring. • Turn on the motor, the ignition and test if the motor is running with power supply; if not: check the voltage at the motor input. • Check the motor wiring again according to manufacturer's information.	

Funded by
the European Union

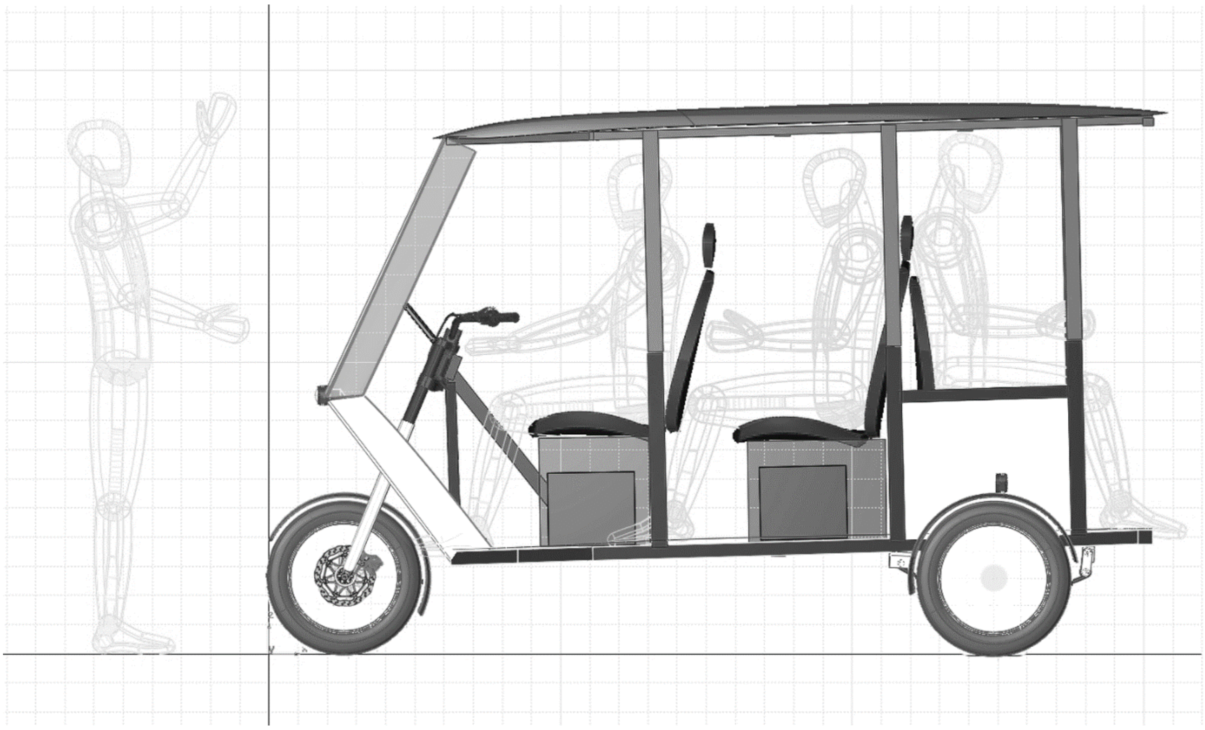
4.1.5.4 Accessories

4.5.4-1 Mounting side mirrors at fitting → Quality Gate: Check whether side mirrors are firmly secured

Step	Instruction	Visual Assistance
Step 4.5.4-1	Components: • Side mirror Tools: • Screwdriver • Wrench • Drill • Screws • Bolts • Screw nut • Flat washer • Tape measure Process: a) Select a suitable mounting point for the two side mirrors. b) Drill a hole on each side of the front part of the roof frame. c) Insert the bolts (with washers) through these holes and attach the side mirrors to these bolts. d) Secure the bolts with nuts and tighten them firmly. e) Check the measurements and the viewing angle of the side mirrors and	 

Funded by
the European Union

	adjust them if necessary.	
Quality Gate	Check whether the side mirrors are firmly secured in place	



In addition to assembly, a quality assurance checklist should be run through to ensure the safety and functionality of the eTukTuk.

General inspection

- Check the completeness of the vehicle (all parts and components present).
- Ensure all connections and fastenings are tight and secure.

Frame and structure

- Inspect the frame for cracks or damage.
- Ensure the base frame and support frame are correctly assembled, noting specified dimensions and angles.

Suspension and wheels

- Check the installation of the steering and front fork suspension.
- Ensure that the wheels are securely mounted and spin freely.

Funded by
the European Union

- Inspect the rear springs and dampers for correct installation and functionality.

Drivetrain

- Ensure the drivetrain is properly assembled.
- Check the function of all moving parts and joints.

Energy storage

- Inspect the installation of energy storage components.
- Ensure all connections are secure.
- Test the function and charging capability of the battery/batteries.

Electrical wiring and lighting

- Check all cable connections for security and proper installation.
- Ensure the lighting systems (headlights, taillights, turn signals) are functioning correctly.

Braking system

- Inspect the brake components for correct installation.
- Test the brake function (including emergency braking).
- If a hydraulic brake is installed, ensure the brake fluid is at the correct level and the system is bled.

Steering and control

- Check the function of the steering.
- Ensure the steering operates smoothly and precisely.
- Test the alignment and adjustment of the front wheel.

Seats and seatbelts

- Ensure all seats are securely mounted.
- Check the function and installation of the seatbelts.

Final Inspection and Test Drives

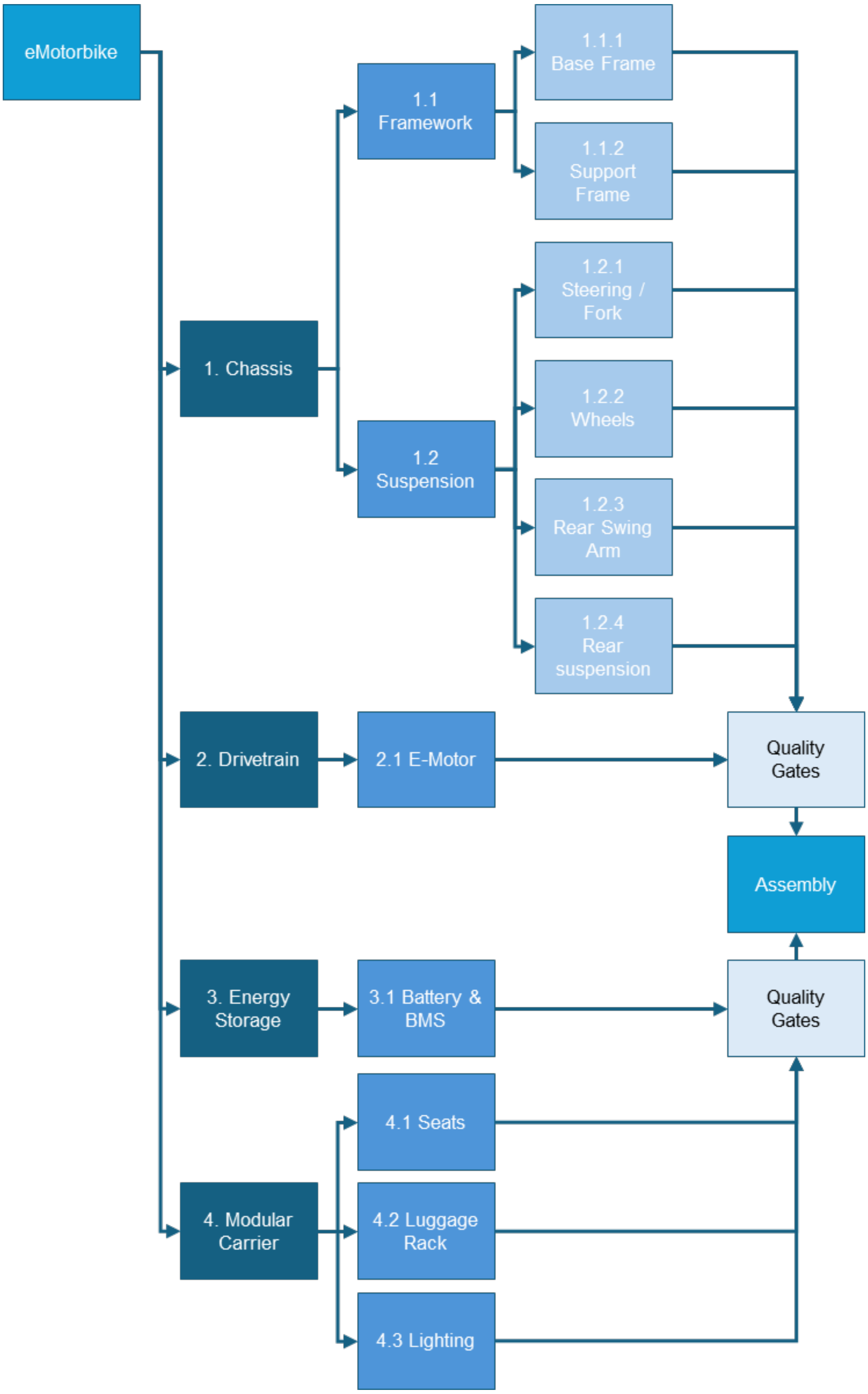
- Conduct a comprehensive test drive to check the functionality and safety of the vehicle.
- Inspect all systems during the test drive (brakes, steering, suspension, lighting, drivetrain).

Documentation and release

- Document all inspections and tests conducted.
- Ensure all user manuals and maintenance guides are provided.
- Release the vehicle for delivery if all tests are successfully passed.

Funded by
the European Union

4.2 eMotorbike



Knowledge of the weight distribution between the front and rear axles is essential for the chapters on designing the suspension and damping of the vehicle. The following is a schematic

Funded by
the European Union

representation of how a basic calculation of the axle load distribution can be carried out. A corresponding calculation is then carried out for the vehicle concept presented, thus laying the foundation for further calculations.

ATTENTION: The following calculations depend heavily on the individual vehicle concept, the weights of the individual components as well as the choice of materials, the wheelbase, etc. It is therefore essential that a calculation adapted to the individual concept is carried out, which serves as the basis for the design of the spring and damper system.

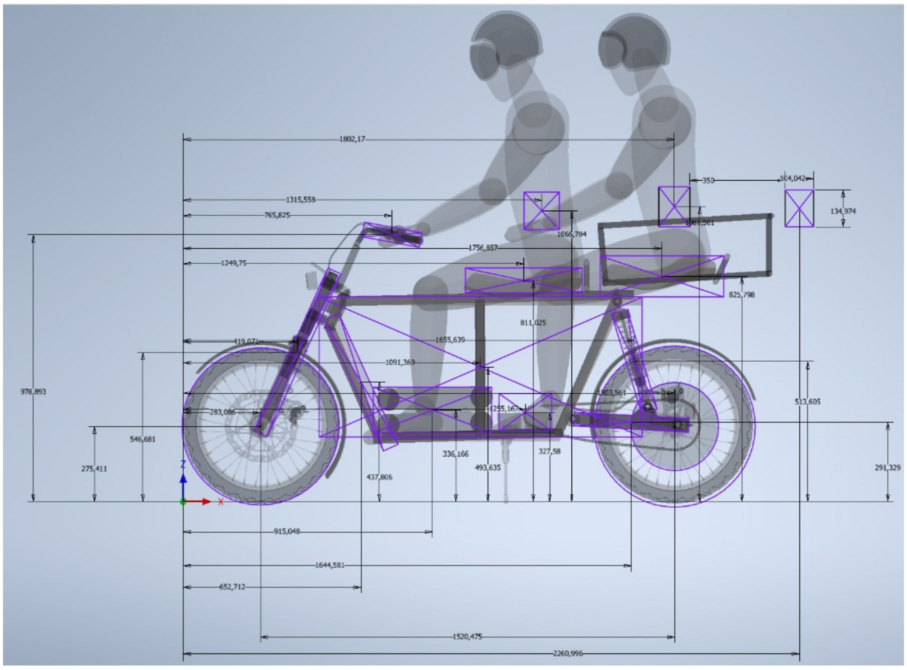


Figure 11: Concept Sketch of the eMotorbike

To calculate the axle load distribution, the parts and components relevant to the vehicle weight are required with their respective position in relation to a reference point (in this case the front of the vehicle) and the individual weight. An individual, geometric center of gravity (geometric center of the components) must be assumed for the individual parts and components. From this individual center of gravity, the position in relation to the reference point is calculated. The position of the center of gravity results from a summation of the individual weights and distances from the reference point divided by the total weight of the relevant component. A comparison with the position of the center of gravity and the wheelbase then results in the required axle load distribution. In this case, only the position of the center of gravity in x direction (longitudinal direction of the vehicle) is important for the axle load distribution.

$$m_{vehicle} = \sum m_i = 280\ kg$$

$$x_{gravitycenter} = \frac{\sum m_i \cdot x_i}{m_{vehcile}} \approx\ 1406\ mm$$

Funded by
the European Union

$$i_{axleload,rear} = \frac{x_{gravitycenter}}{x_{wheelbase}} \approx 74\%$$

$$i_{axleload,front} = 1 - \frac{x_{gravitycenter}}{x_{wheelbase}} \approx 26\%$$

4.2.1 Chassis eMotorbike

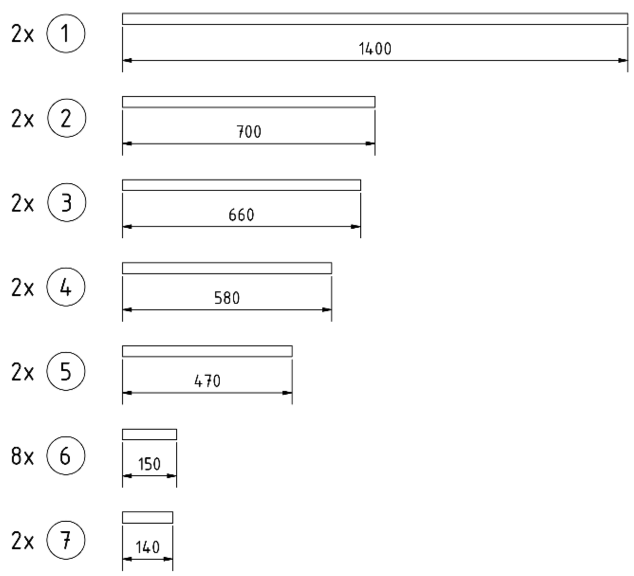
The following chapters will provide you with all the necessary information to build up the chassis of the eMotorbike, which will be the main assembly for works done at a later stage.

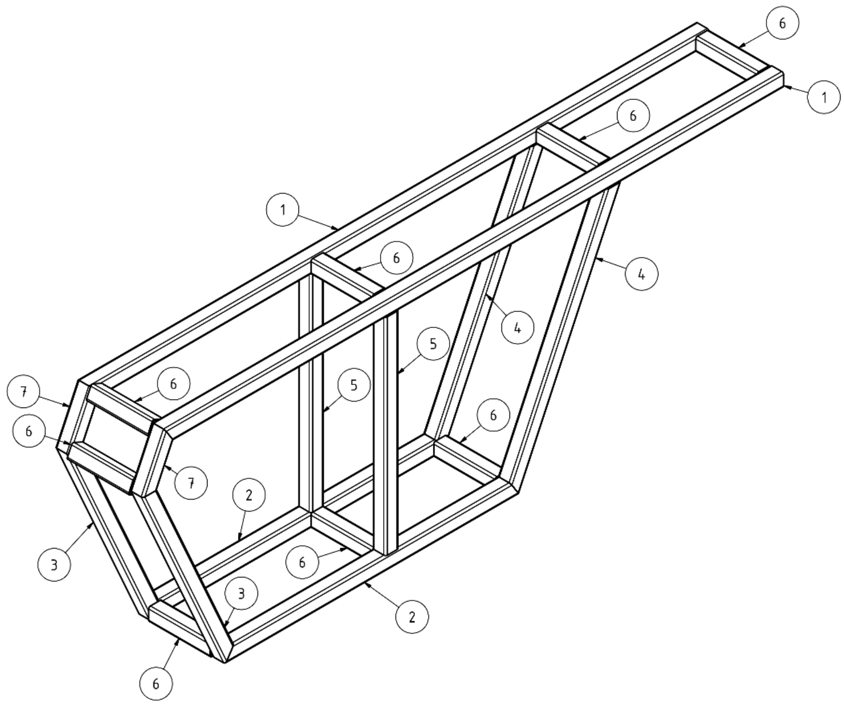
4.2.1.1 Framework

The framework forms the entire basic structure of the eMotorbike, on which various components such as the chassis and seats are mounted.

4.2.1.1.1 Base Frame

The base frame for an eMotorbike is manufactured to form the basic structure of the entire vehicle. The base frame significantly influences the stability and structural integrity of the eMotorbike. In the overall vehicle production process, the base frame is one of the first components to be assembled and serves as the basis for the further assembly of the vehicle parts.

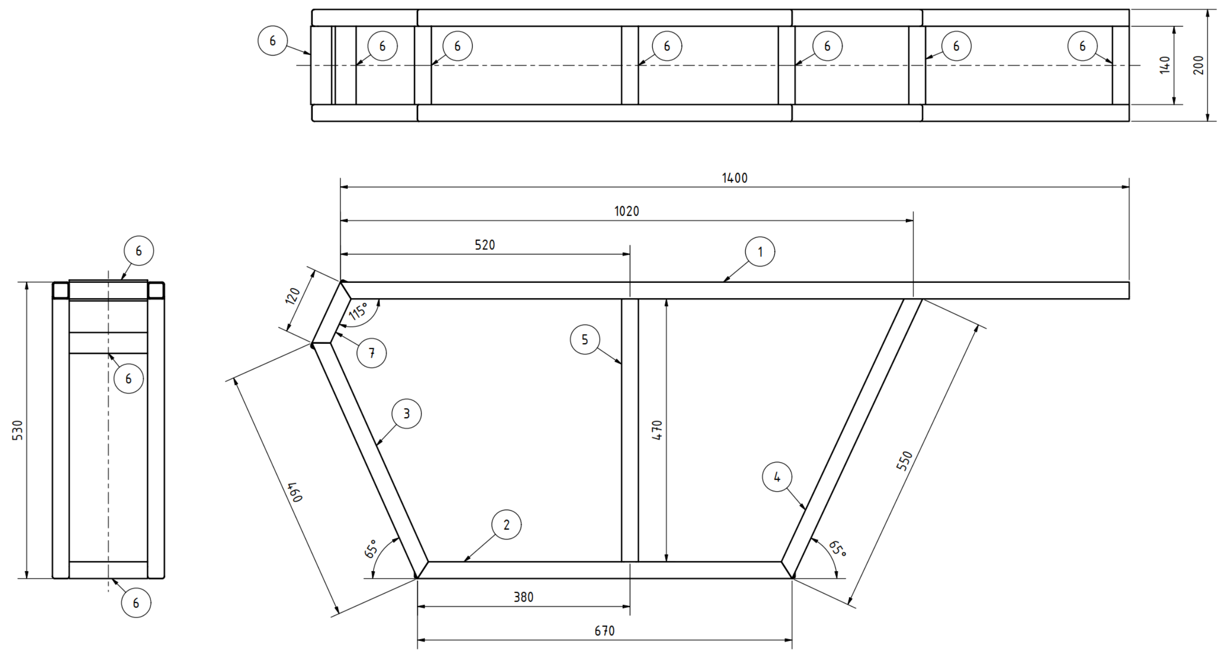


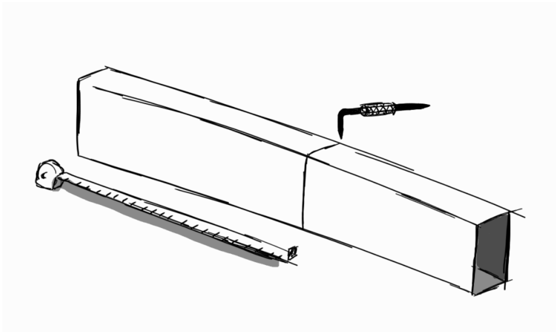
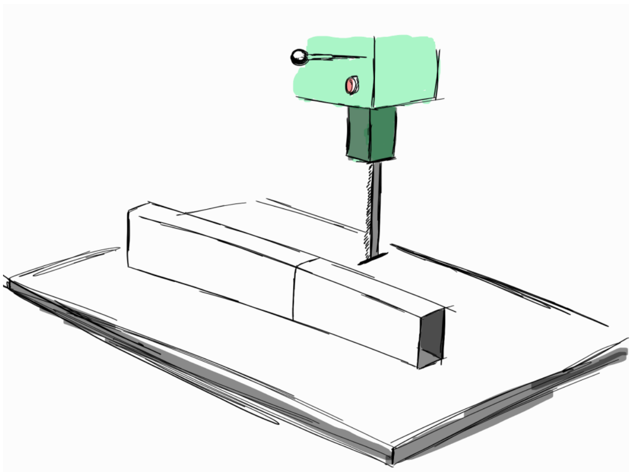
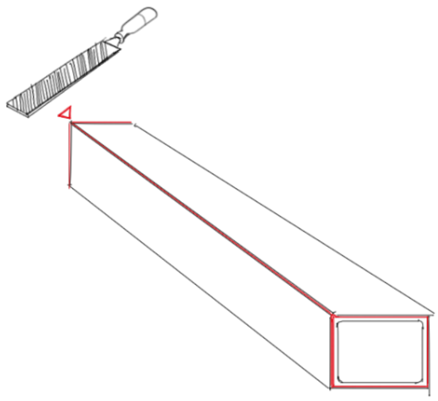


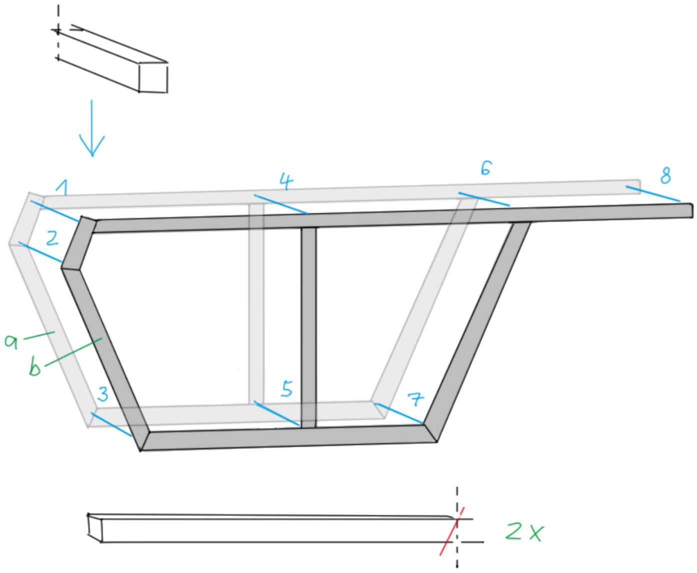
1.1.1-1 Saw profiles to length → 1.1.1-2 Put together 2 frame halfs & connecting → 1.1.1-3 Saw profiles to mitre → 1.1.1-4 Put together frame → 1.1.1-5 Tack weld frame → 1.1.1-6 Check Geometry → 1.1.1-7 Weld the frame

↓

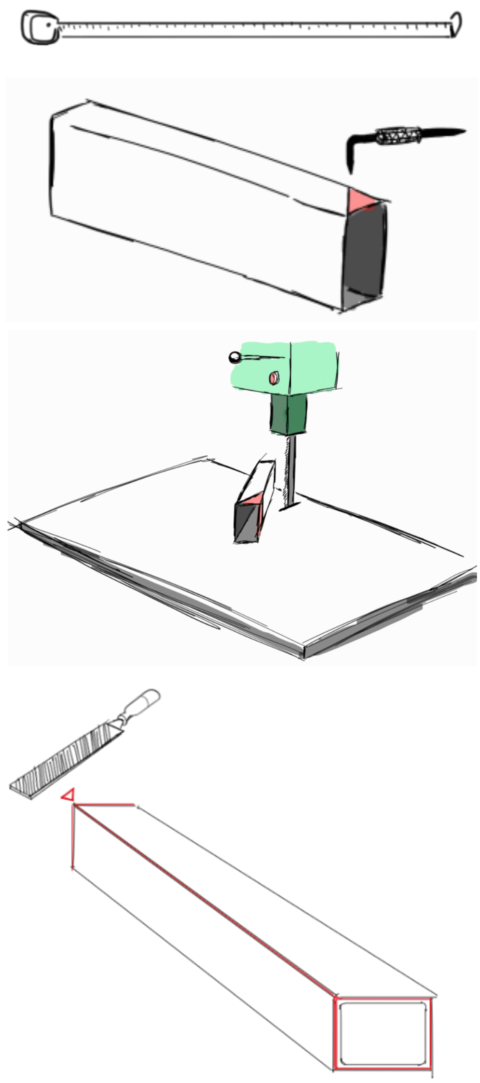
Quality Gate: Check welds and distortions



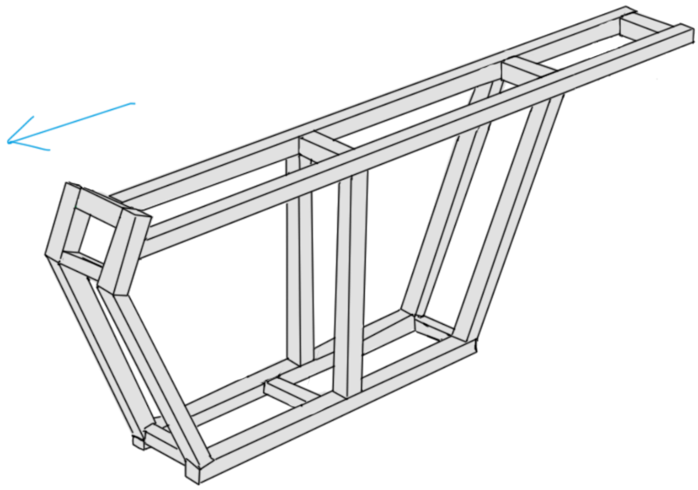
<table>
<tr><th>Step</th><th>Instructions</th><th>Visual Assistance</th></tr>
<tr><td>Step 1.1.1-1</td><td>Components:
Square profile 30 mm x 30 mm; t = 2 mm
Tools:
Tape Measure
Scriber
Saw (preferably band saw)
File (used for deburring)
Process:
a) Measuring profiles
b) Mark profile length according to plan
c) Saw profile
d) Deburr cutting edges</td><td>

</td></tr>
</table>

Step	Instructions	Visual Assistance
Step 1.1.1-2	Components: • Cut square profiles Tools: • None Process: a) First lay the cut profiles according to the two frame halves as shown in the plan. b) Then add the 8 connecting profiles for the two frame halves. c) Check layout.	

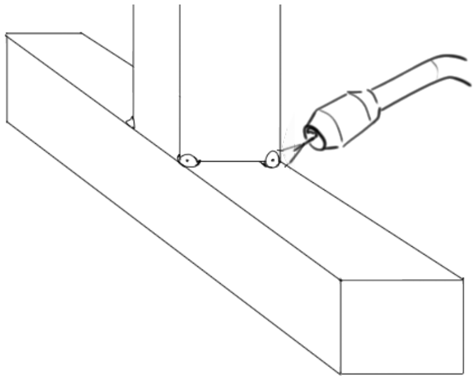
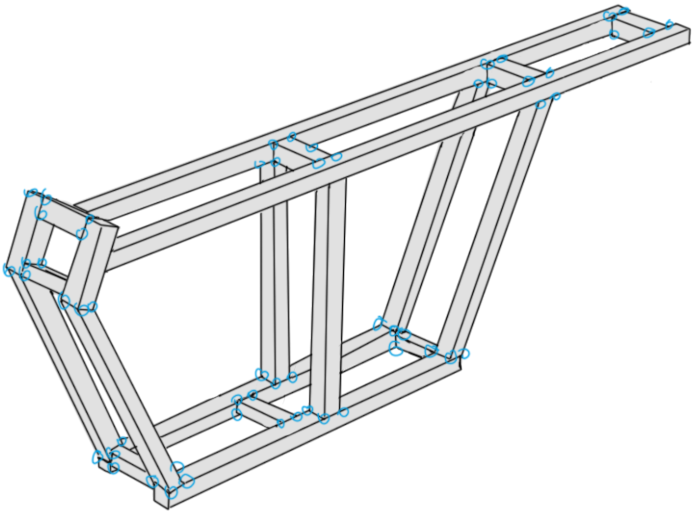
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.1.1-3	Components: • Cut square profiles Tools: • Saw (preferably band saw) • File (used for deburring) • Tape Measure • Scriber Process: a) Mark profile length according to plan b) Saw profile to mitre c) Deburr cutting edges	

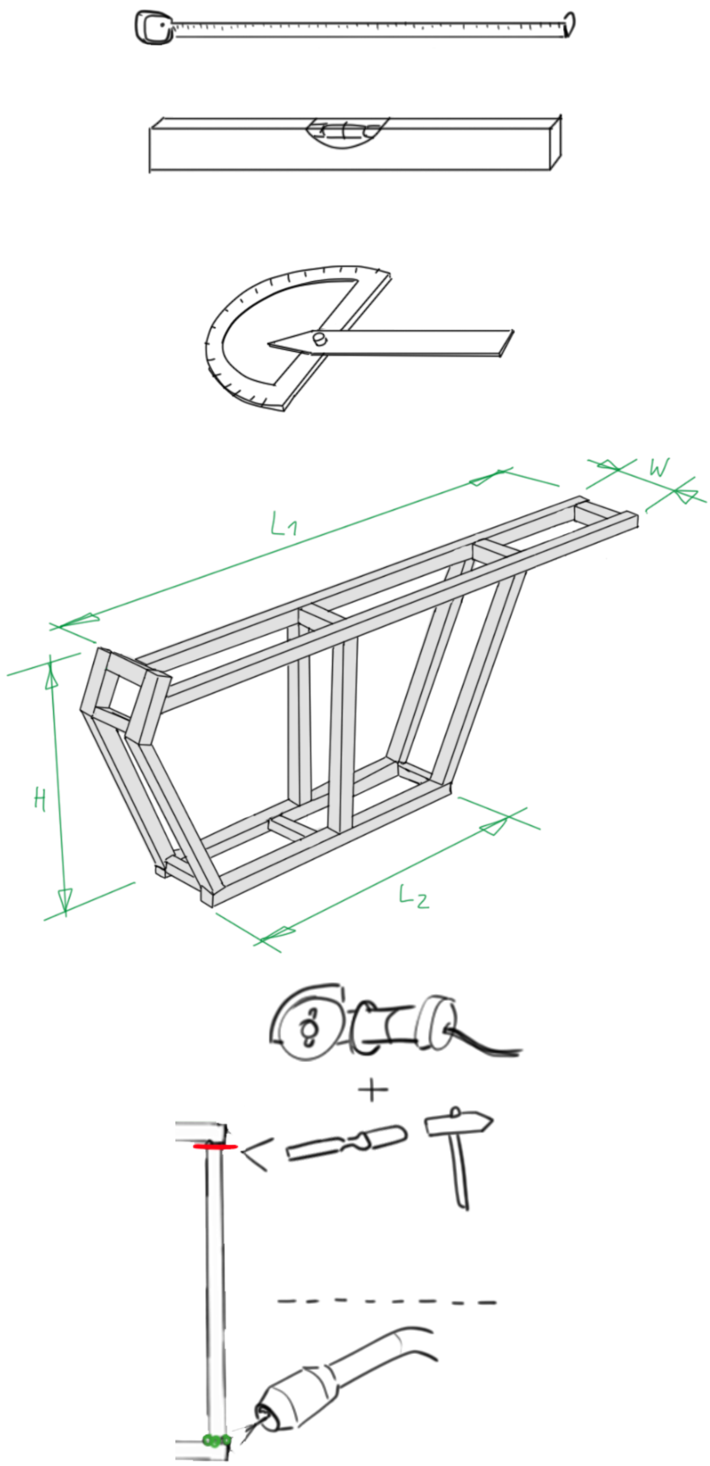
Funded by
the European Union

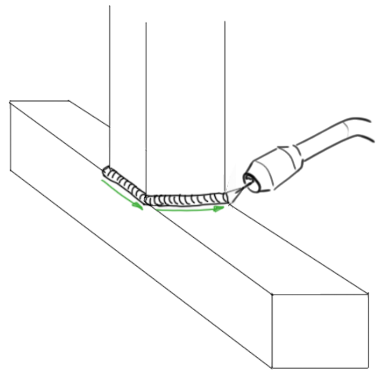
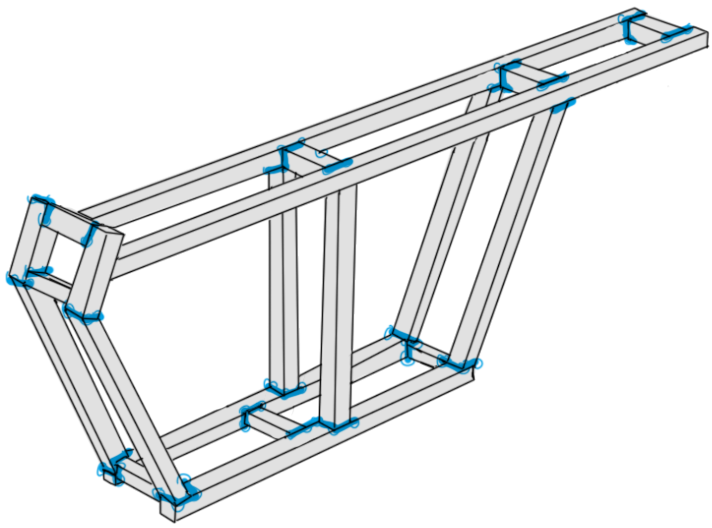
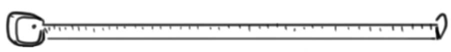
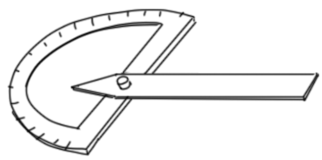
Step	Instructions	Visual Assistance
Step 1.1.1-4	Components: • Cut to mitre square profiles Tools: • None Process: a) Placing cut profiles according to plan b) Check layout	

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.1.1-5	Components: • Cut to mitre square profiles Tools: • MIG welding machine Process: a) Tack weld the edges of the profile together b) Use at least 4 tacks at each joint	 

Funded by the European Union

Step	Instructions	Visual Assistance
Step 1.1.1-6	Components: • Tack welded frame Tools: • Tape measure • Protector • Spirit level Process: a) Measure if the tack welded Base Frame is according to the measurement plans. b) If measurements are correct, proceed with step 1.1.1-7. c) If measurements are incorrect, separate the tack welds and start again at step 1.1.1-5.	

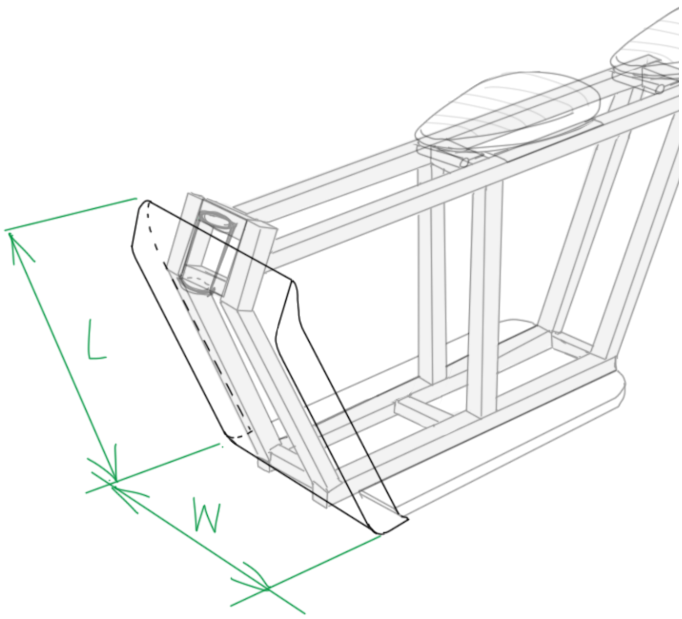
Step	Instructions	Visual Assistance
Step 1.1.1-7	Components: • Tack welded frame Tools: • MIG welding machine Process: a) Fully weld all joints of the Base Frame. b) Follow Quality Gate to check the quality of the welding seams and the Base Frame regarding welding distortions.	   
Quality Gate	Check welds and distortions	

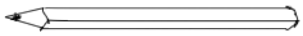
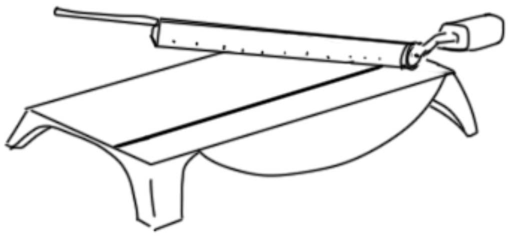
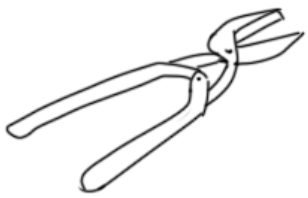
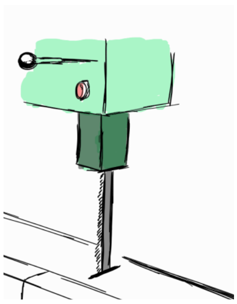
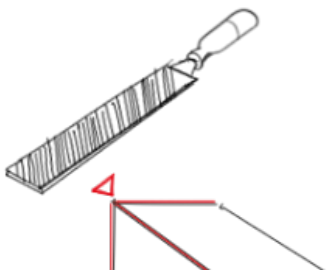
Funded by the European Union

4.2.1.1.2 Support Frame

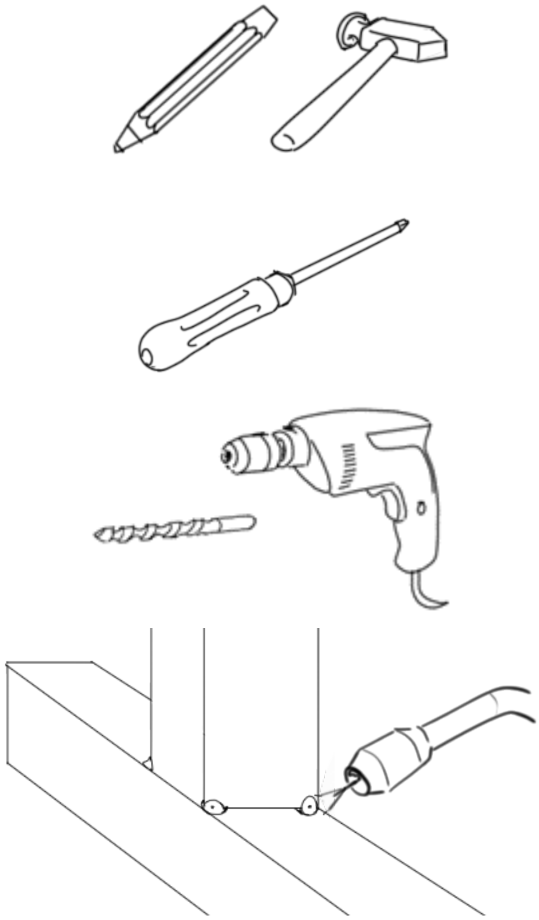
The support frame includes the front paneling and the footrest, which improves overall safety and occupant protection.

1.1.2-1 Determine dimensions front paneling → 1.1.2-2 Cut and edge sheet metal → 1.1.2-3 Fasten paneling → 1.1.2-4 Check geometry → 1.1.2-5 Determine the dimensions of the footrest → 1.1.2-6 Cut sheet metal and profiles → 1.1.2-7 Fix the footrest → Quality Gate: Check geometry

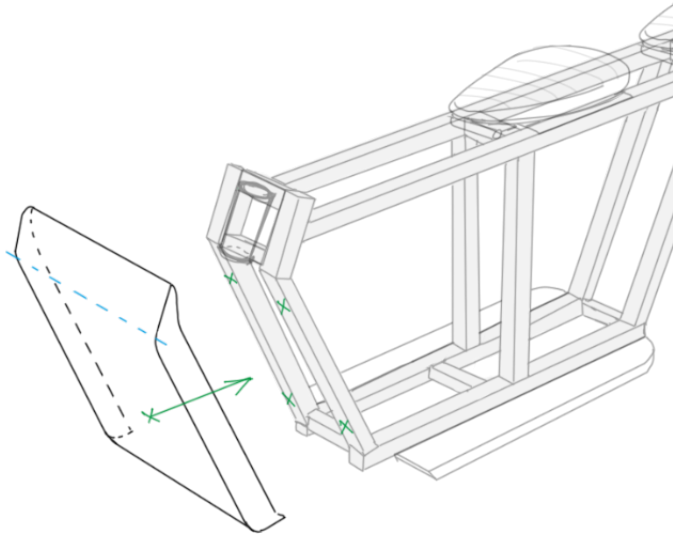
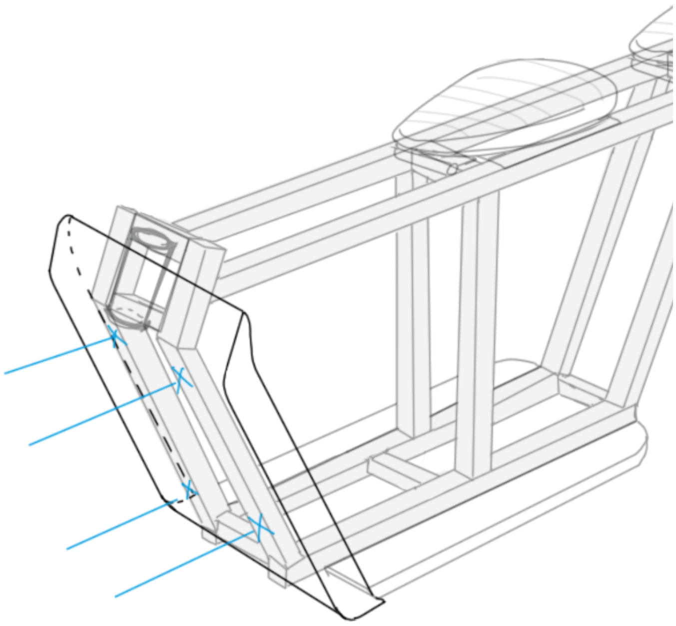
Step	Instructions	Visual Assistance
Step 1.1.2-1	Components: • None Tools: • Measuring tape Process: a) Determine geometry of front paneling.	 

Step	Instructions	Visual Assistance
Step 1.1.2-2	Components: • Sheet of metal (or plastic) Tools: • Tape Measure • Scriber • Saw • Tin snips • File (used for deburring) • Folding bench Process: a) Mark geometry of front paneling according to plan on the sheet of metal. b) Cut out geometry. c) Deburr cutting edges. d) If a folding bench is available, edge the sheet metal. Alternatively, make the paneling from several sheets and weld them together.	     

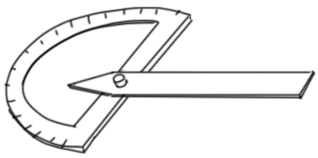
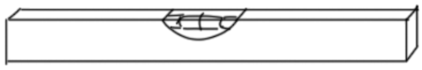
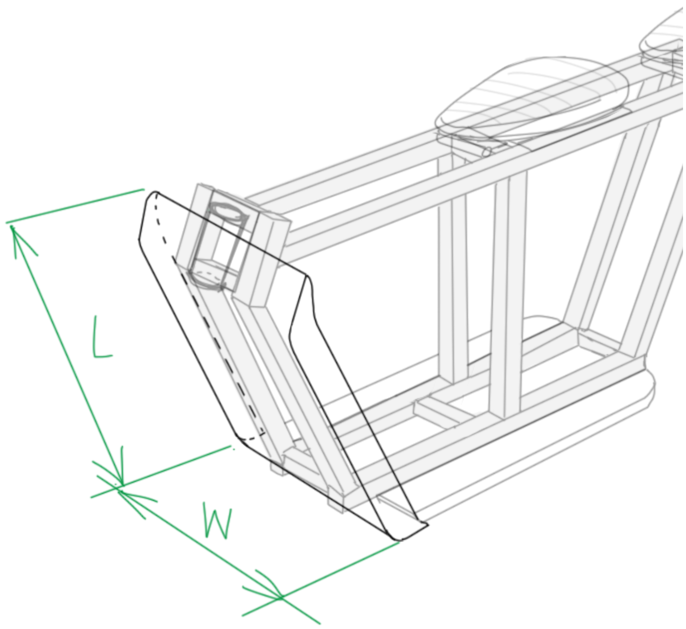
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.1.2-3	Components: • Trimmed and folded sheet of metal Tools: • MIG welding machine • Screwdriver • Drilling machine • Center punch • Hammer Process: a) Determine the attachment points on the base frame. b) Drill through the sheet of metal and fixing points and screw the front paneling in place. Alternatively, the front paneling can be welded to the base frame.	

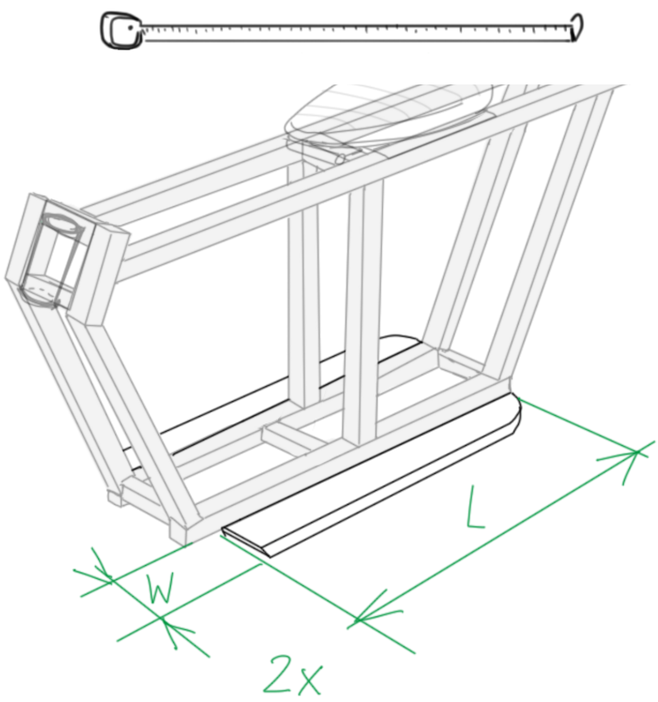
Funded by the European Union

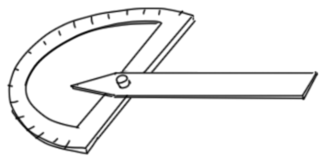
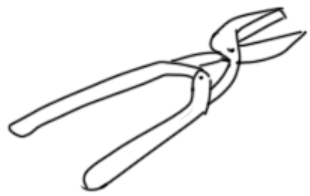
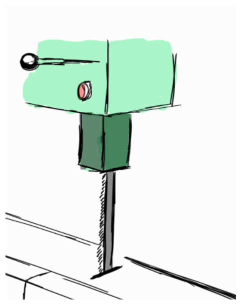
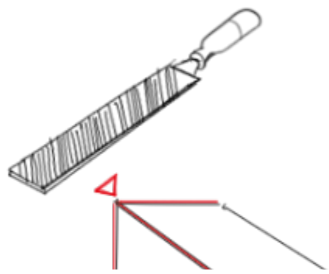
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.1.2-4	Components: • Tack welded profiles Tools: • Tape measure • Protractor • Spirit level Process: a) Measure, if the mounted front paneling is according to the measurement plans. b) If measurements are correct, proceed with step 1.1.2-5. c) If measurements are incorrect, separate the front paneling from the base frame and start again at step 1.1.2-3.	   

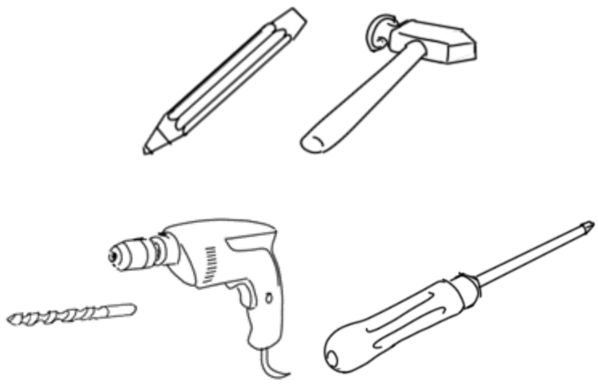
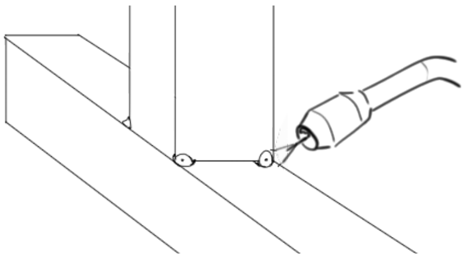
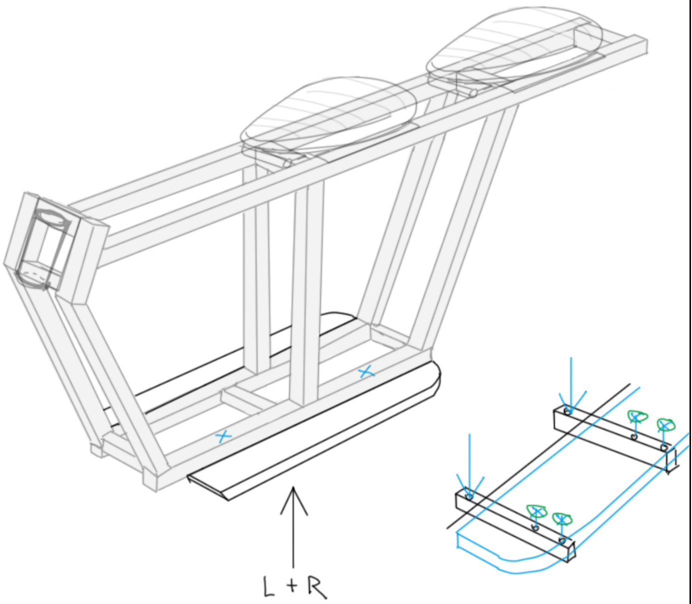
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.1.2-5	Components: • Base frame Tools: • Tape Measure Process: a) Determine the dimensions of the footrest on the base frame. Note that there must be sufficient space for a second person on the eMotorbike. Use profiles to stiffen the footrest.	

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.1.2-6	Components: • Base frame • Sheet metal • Square profile 30 mm x 30 mm; t = 2 mm Tools: • Scriber needle • Scribing angle • Measuring tape • Saw • File • Tin snips Process: a) Cut the sheets and profiles according to plan.	     

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.1.2-7	Components: • Scribed sheet metal Tools: • MIG welding machine • Screwdriver • Drilling machine • Center punch • Hammer Process: a) Attach the profiles and the sheet metal to the frame according to the plan. To do this, drill holes and screw the parts together. Alternatively, these can be welded on.	  
Quality Gate	Check geometry	

4.2.1.2 Suspension

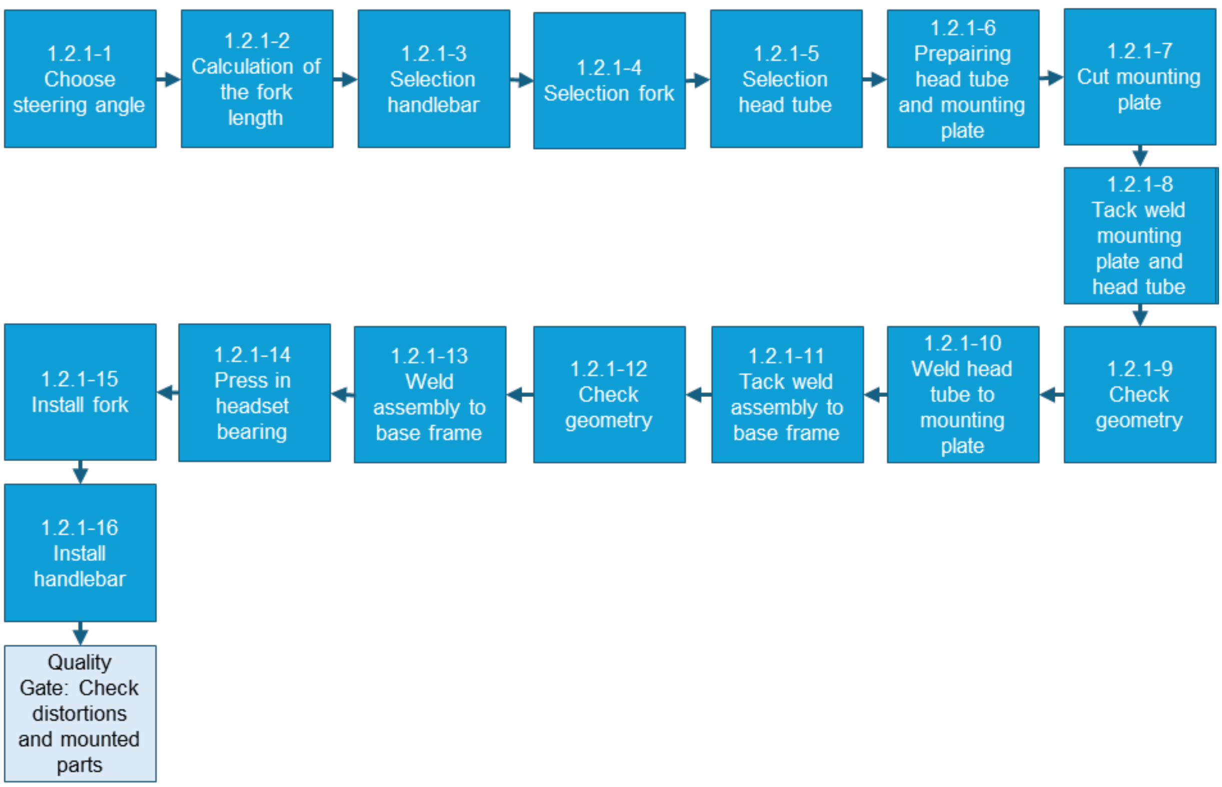
The suspension, including the shock absorber, springs, wheels and fork is designed, selected and installed below. The suspension is attached to the base frame and improves the ride comfort and road holding of the vehicle by absorbing shocks and vibrations. The front suspension provides the steering function. In the overall vehicle manufacturing process, the rear suspension is installed the base frame is assembled and plays a crucial role in the vehicle's driving dynamics and safety

4.2.1.2.1 Steering / Fork

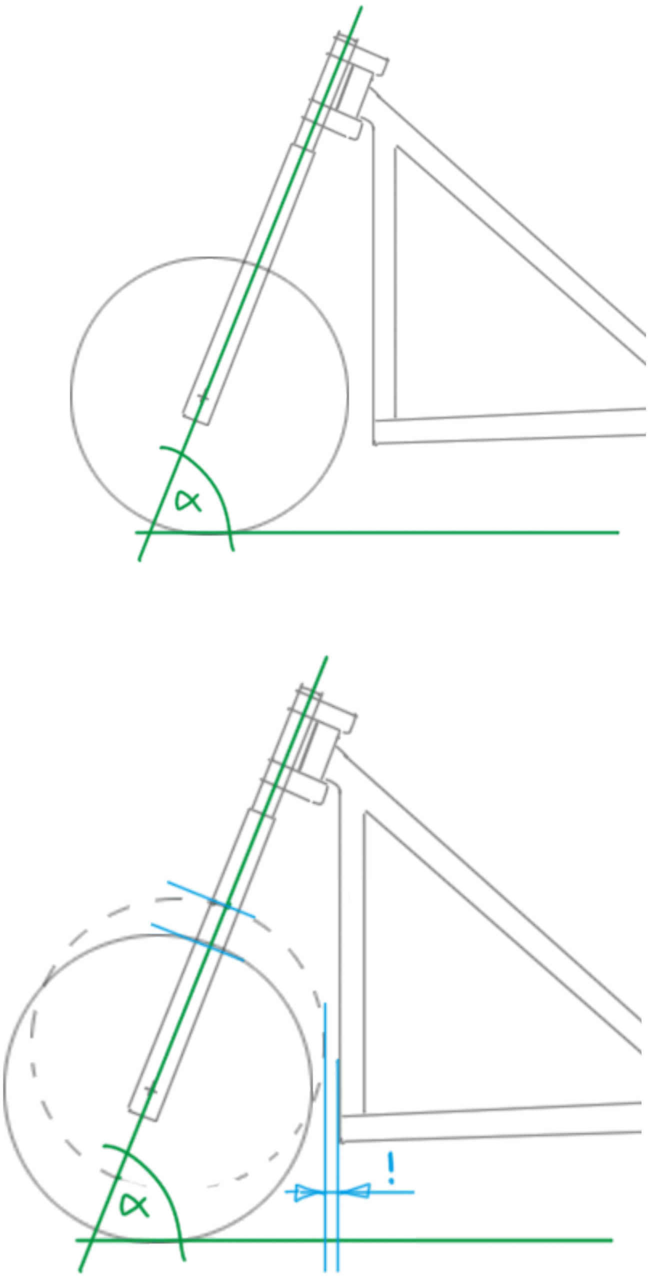
The steering system and suspension fork are installed at the front of the base frame and enable the vehicle to change direction. This System contributes significantly to driving stability and safety. In the overall vehicle production process, the steering and suspension fork are installed after the base has been assembled.

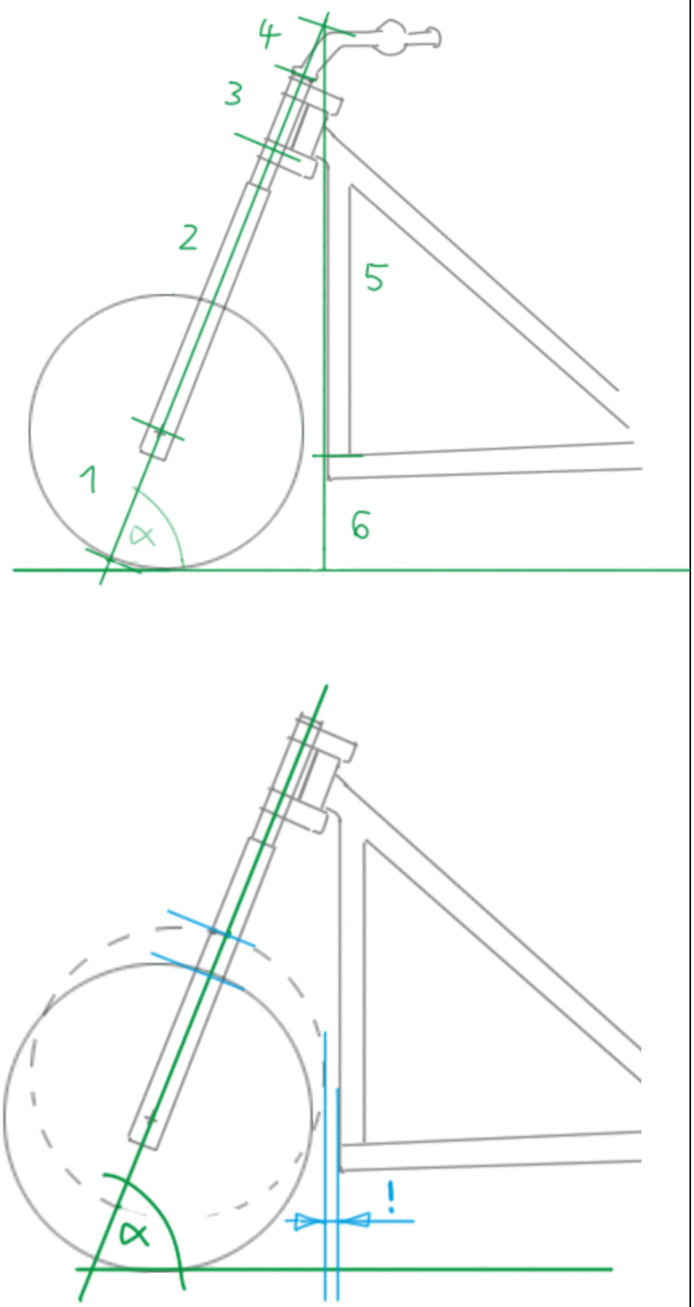
In the front wheel guidance of single-track vehicles, the steering head angle influences driving stability and general handling behavior.

The steering head angle refers to the angle between the steering axle of the front wheel and the ground. A steep steering head angle can lead to unstable handling, a flat steering head angle can restrict agility.

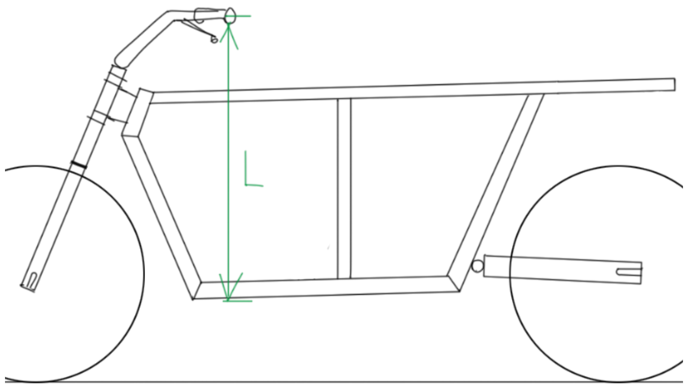
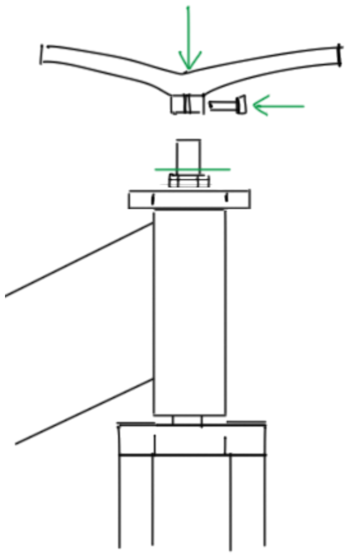
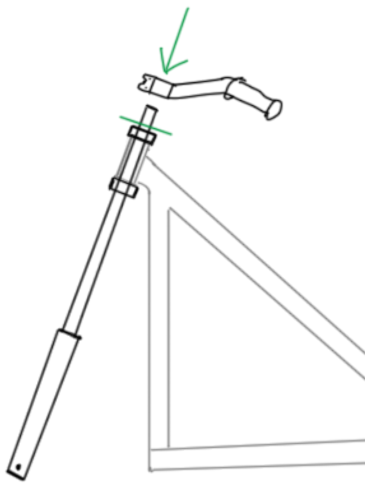


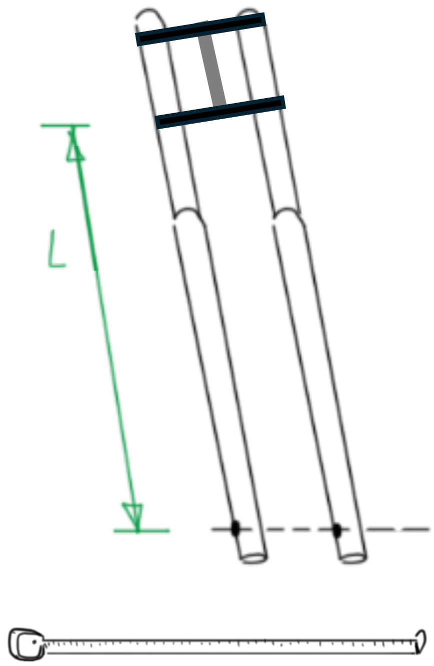
Funded by
the European Union

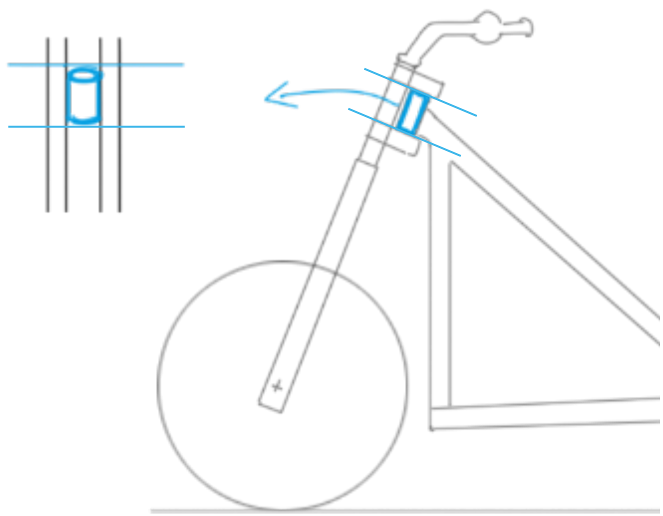
Step	Instructions	Visual Assistance
Step 1.2.1-1	Components: • None Tools: • Calculator • Pencil • Sheet of paper Process: a) Typical steering angles for Motorbikes are 62° - 66°. b) Select a steering angle that fits well with the prepared base frame. Ensure that the front wheel has sufficient clearance in compressed state to components in the steering area. For example, dirt build-up can reduce the clearance, which can lead to unwanted grinding marks, wear and dangerous influences on the steering, drive or brakes.	

Step	Instructions	Visual Assistance
Step 1.2.1-2	Components: • none Tools: • Calculator Process: **Consider deflection:** **When the suspension is compressed, the distance between the wheel and the frame is reduced; note the impact of the mudguard.** a) The installation length (L_2) of the suspension fork can be calculated by specifying the handlebar height (L_5), selecting a front wheel with radius XY (L_1), specifying the ground clearance (L_6) and the steering angle (alpha). Additionally, the possible range (L_3) of the triple clamp spacing and the distance between handlebars and the top triple clamp (L_4) must be taken into account, which varies depending on the fork and handlebar model. b) The length L_2 is calculated as follows: $L_2 = \frac{L_5 + L_6}{\sin(\alpha)} - L_1 - L_3 - L_4$	

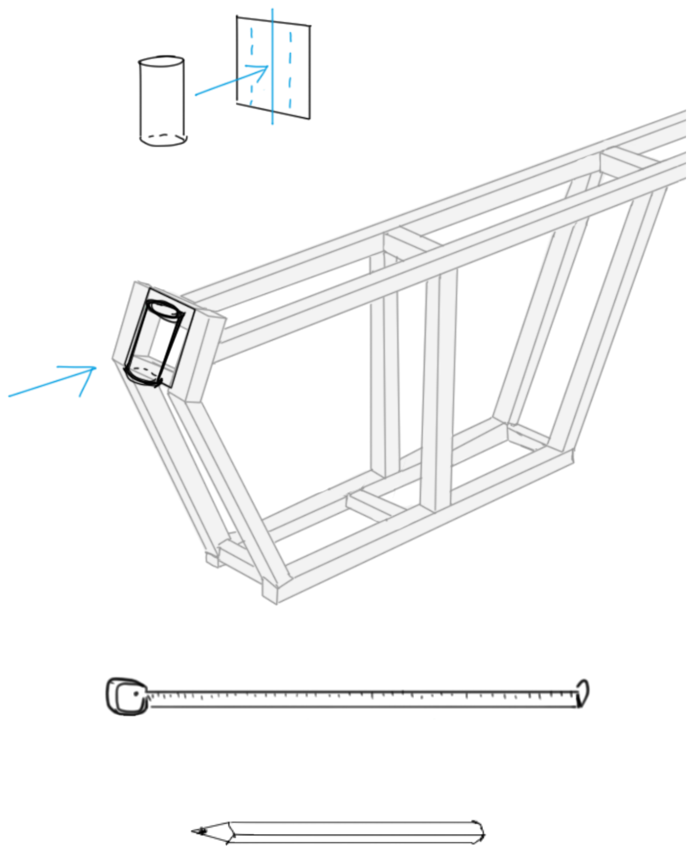
Funded by the European Union

Step	Instructions	Visual Assistance
Step 1.2.1-3	Components: • Base frame Tools: • Measuring tape Process: a) Determining the height of the end of the handlebar within the range of 700 – 850 mm. b) Choose a handlebar that meets your personal ergonomic expectations. c) Check the defined value for ergonomic plausibility and adjust it as required.	   

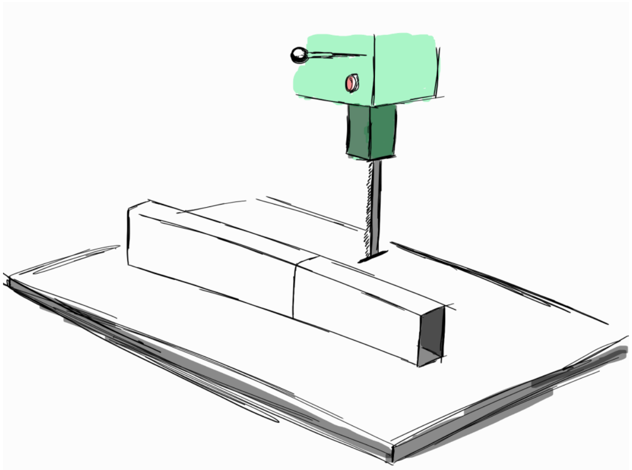
Step	Instructions	Visual Assistance
Step 1.2.1-4	Components: • None Tools: • Calculator Process: a) Selection of a suitable suspension fork based on minimum installation length (L), suspension travel and spring rate. The spring rate is calculated in chapter **4.2.1.2.4.1 Spring calculation**.	

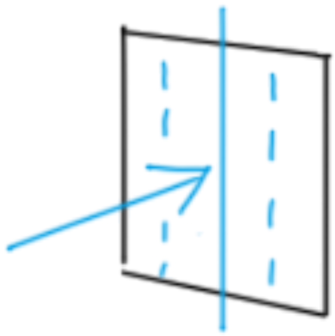
Step	Instructions	Visual Assistance
Step 1.2.1-5	Components: • Fork Tools: • None Process: a) Select a head tube that fits within the recommended spacing between the triple clamps and has an inner diameter that fits with the recommended bearing for the fork shaft.	

Funded by
the European Union

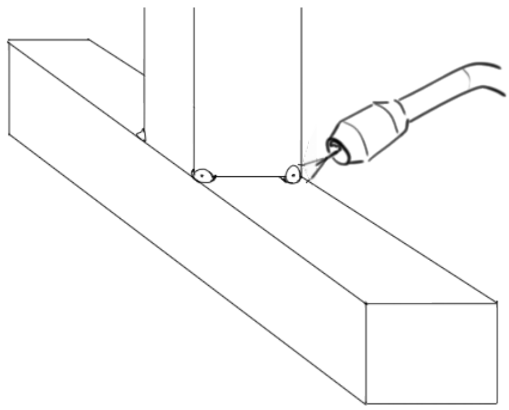
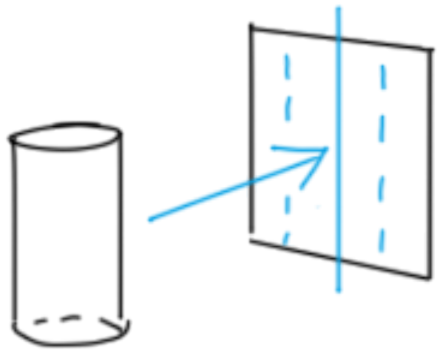
Step	Instructions	Visual Assistance
Step 1.2.1-6	Components: • Head tube • Base frame • Steel plate Tools: • Measuring tape • Scriber Process: a) Mark steel plate to the size of the base frame. b) Align Tube to be straight and centered. c) Adjust steering angle with steel plate cut offs.	

Funded by
the European Union

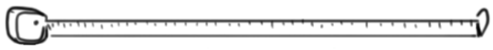
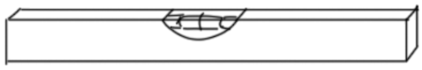
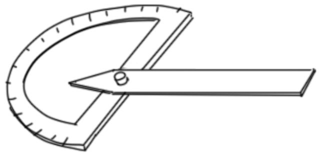
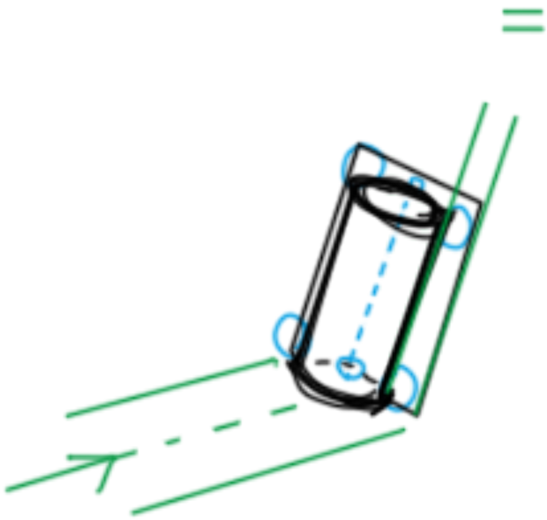
<table>
<tr><th>Step</th><th>Instructions</th><th>Visual Assistance</th></tr>
<tr><td>Step 1.2.1-7</td><td>Components:
• Marked steel plate
Tools:
• Saw (preferably band saw)
• File (used for deburring)
Process:
a) Saw plate
b) Deburr cutting edges</td><td>

</td></tr>
</table>

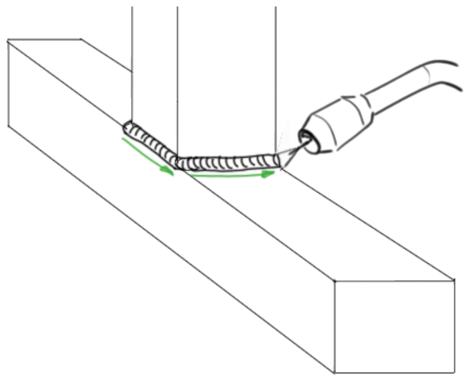
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.1-8	Components: • Head tube • Steel plate Tools: • MIG welding machine Process: a) Tack weld the head tube and steel plate. b) Use at least 2 tacks at each joint.	  

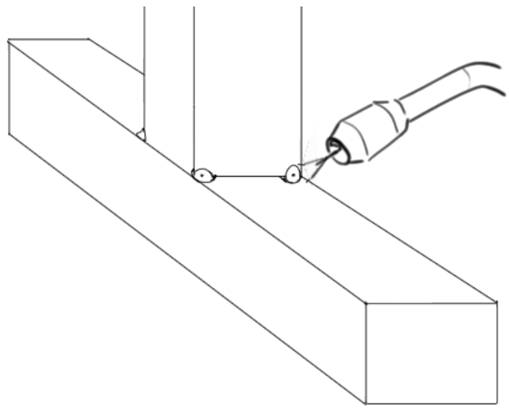
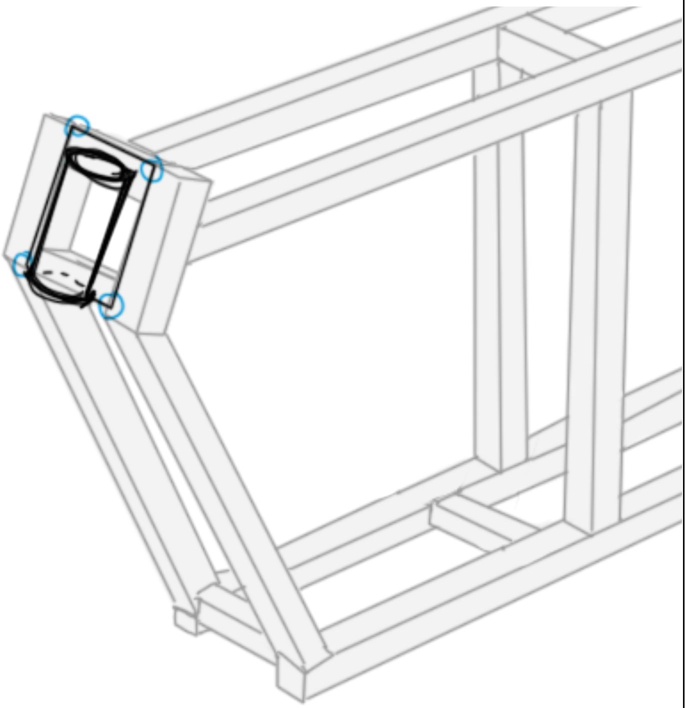
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.1-9	Components: • Tack welded head tube on mounting plate • Base frame Tools: • Tape measure • Protractor • Spirit level Process: a) Measure if the tack welded head tube is according to the measurement plans. b) If measurements are correct, proceed with step 1.2.2-10. c) If measurements are incorrect, separate the profiles and start again at step 1.2.2-8.	   

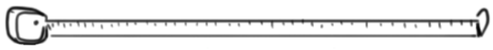
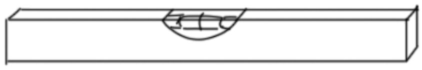
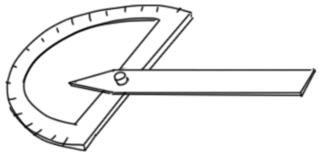
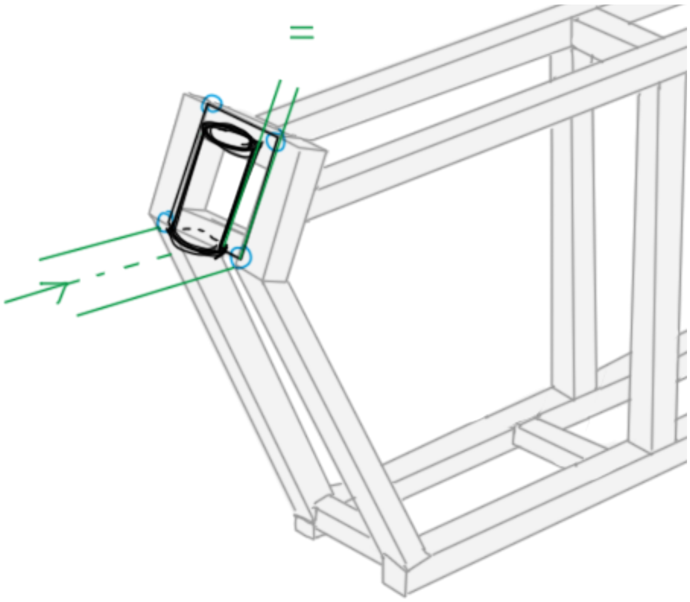
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.1-10	Components: • Tack welded head tube assembly Tools: • MIG welding machine Process: a) Fully weld all joints of the mounting plate and head tube.	 

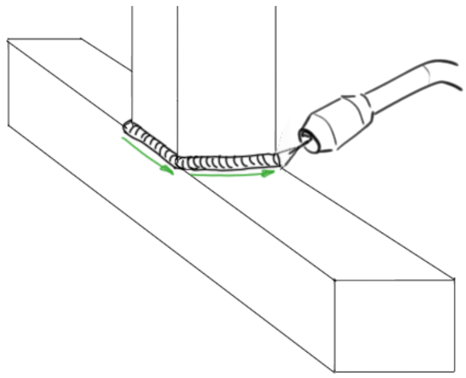
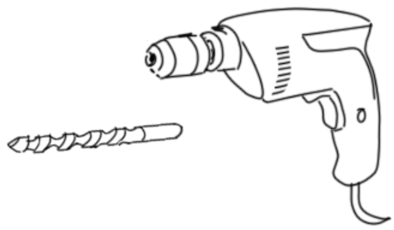
Funded by the European Union

Step	Instructions	Visual Assistance
Step 1.2.1-11	Components: • Welded head tube assembly • Base frame Tools: • MIG welding machine Process: a) Tack weld the head assembly and base. b) Use at least 2 tacks at each joint.	 

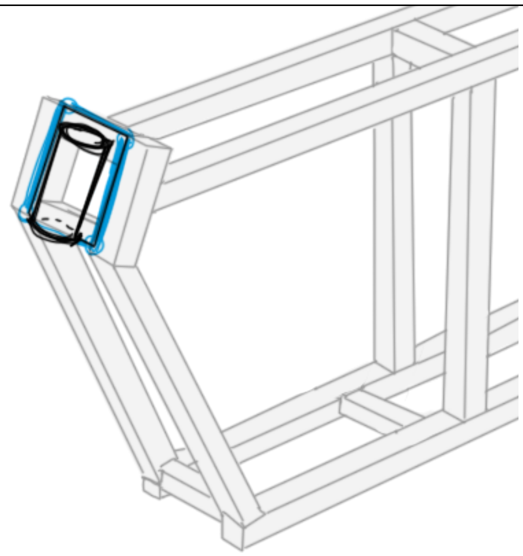
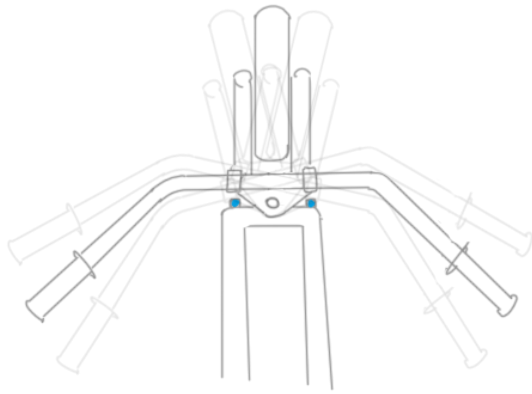
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.1-12	Components: • Tack welded base frame with head tube assembly Tools: • Tape measure • Protractor • Spirit level Process: a) Measure if the tack welded head tube assembly is according to the measurement plans. b) If measurements are correct, proceed with step 1.2.2-13. c) If measurements are incorrect, separate the profiles and start again at step 1.2.2-11.	   

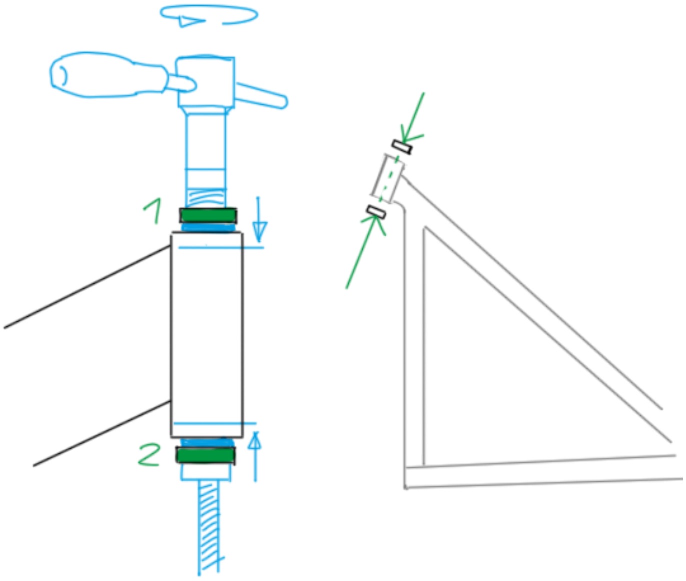
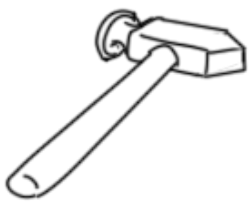
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.1-13	Components: • Tack welded base frame with head tube assembly • Rubber bumpers Tools: • MIG welding machine • Drill Process: a) Fully weld all joints of the mounting plate and head tube. b) Use rubber bumpers on the top tube of the frame as a steering angle limiter to prevent damage to the fork, the frame or the brake and power cables. The rubber bumpers can be attached by drilling and screwing.	 

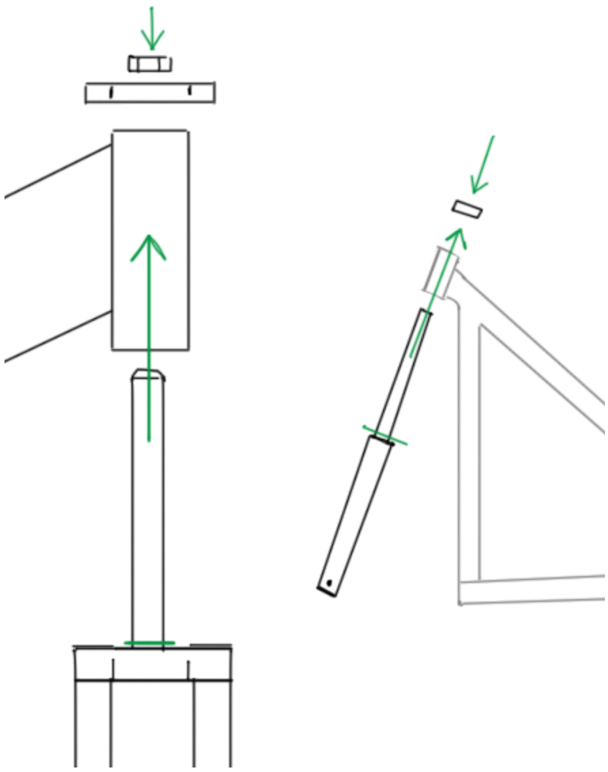
Funded by the European Union

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.1-14	Components: • Base Frame Tools: • Hammer or press in tool Process: a) The bearing has an outer and an inner bearing shell, which must be mounted separately. To integrate the bearing into the steering head, only the outer bearing shell needs to be pressed into the frame. One outer bearing shell is pressed into each side of the steering head. b) Position the upper and lower outer bearings shell on the head tube and press them in with the press-fit tool. Alternatively, one bearing at a time can be carefully hammered flat with a hammer and a board placed on top.	 

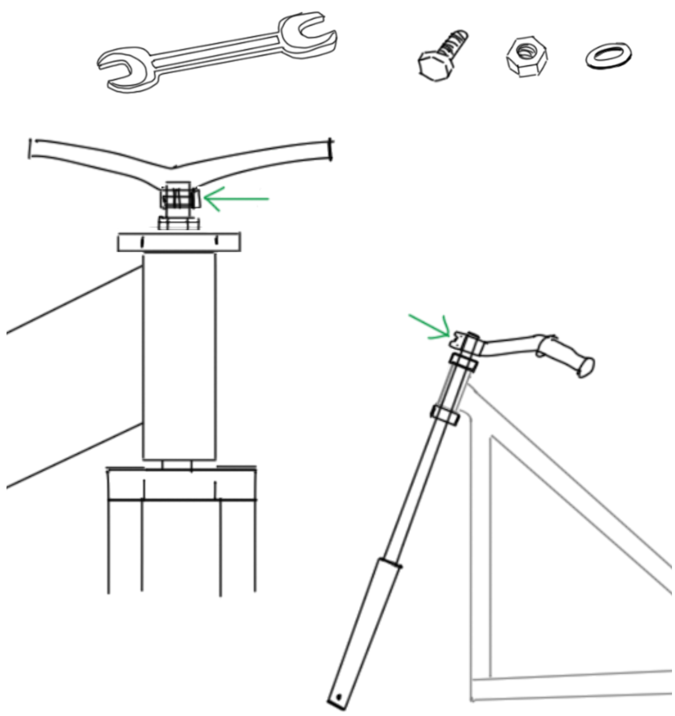
Funded by the European Union

Step	Instructions	Visual Assistance
Step 1.2.1-15	Components: • Fork • Frame Tools: • Hexagon socket screwdriver • Open-end spanner Process: a) Insert fork with lower fork crown into bearing of head tube. b) If there is a gap between the upper bearing and the upper fork crown, which leads to play in the bearing, this must be filled with spacers. For this purpose, a suitable tube with a suitable inner diameter can be shortened to the appropriate length according to the steerer tube and installed. In addition, depending on the design of the suspension fork and especially the bearing, a spacer may be required inside the steering head between the upper and lower bearings,	 

Funded by
the European Union

	otherwise the bearings could be damaged during use. Refer to the manufacturer's instructions. c) Mount the upper fork crown on the head tube and tighten firmly.	

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.1-16	Components: • Fork • Handlebar clamp Tools: • Screwdriver • Open-end spanner Process: a) Fit the handlebar to the clamp on the upper triple clamp.	
Quality Gate	Check welds, distortions and mounted parts. Correct if necessary.	

Funded by the European Union

4.2.1.2.1.1 Fork Selection

The spring stiffness, among other things, is important when selecting the right fork. The spring stiffness depends on the total vehicle weight when loaded. The maximum deflection of the fork spring for this vehicle is set at 80 mm. This value is composed of the static preload of the spring, which acts as a force on the spring due to the weight of the vehicle when stationary, and the dynamic component, which is applied by driving over uneven surfaces and load changes due to acceleration. The dynamic component is referred to as dynamic wheel load fluctuation and can be ±50 % in uneven road conditions. To protect against suspension failure, a safety factor of 1.5 (corresponding to ±50 %) is therefore assumed for the applied forces. In the following, the spring stiffness is calculated according to this assumption.

Static mass onto the front wheel:

$$m_{wheel,front} = m_{vehcile,loaded} \cdot x_{distribution,weight,front} = 280\,kg \cdot 0.26 = 72.8\,kg$$

Maximum deflection of the fork for this vehicle:

$$s = 80\,mm = 0.08\,m$$

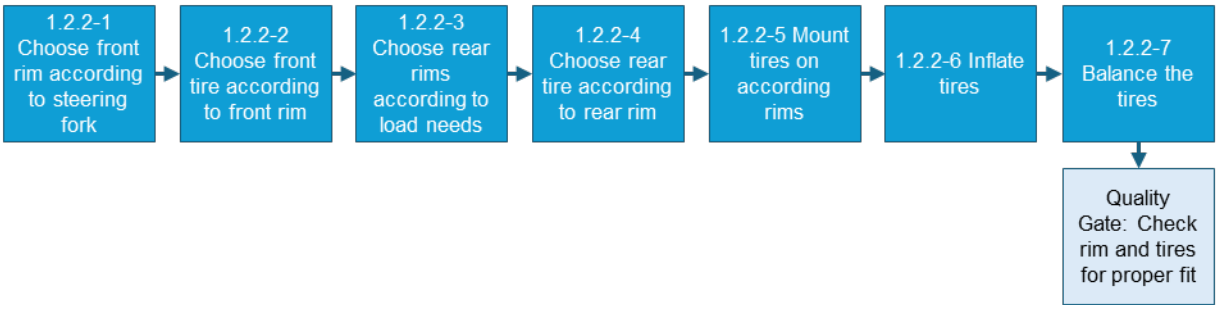
$$k = \frac{m_{wheel,front} \cdot g \cdot 1.5}{s} = \frac{72.8\,kg \cdot 9.81\frac{m}{s^2} \cdot 1.5}{0.08\,m} = 13390.65\frac{N}{m}$$

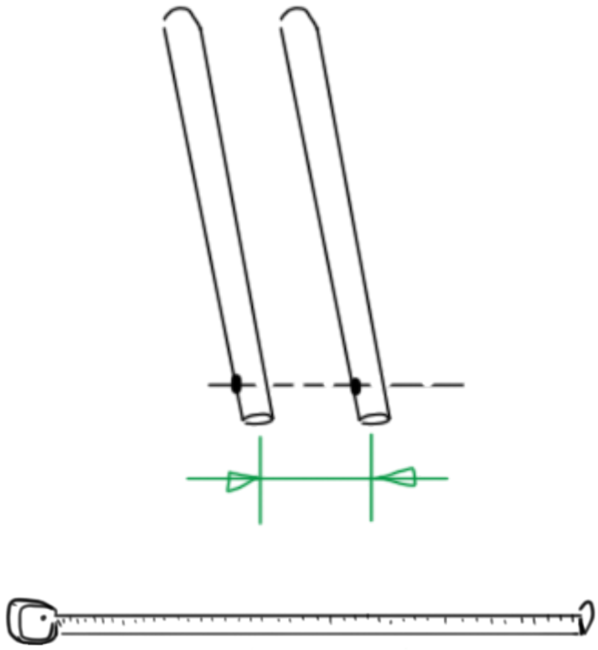
ATTENTION: The values specified above must be adapted to the individual concept for the design. The vehicle weight including payload may deviate from the concept presented here based on the materials selected, so that a calculation must be made at this point using the individual factors.

Funded by
the European Union

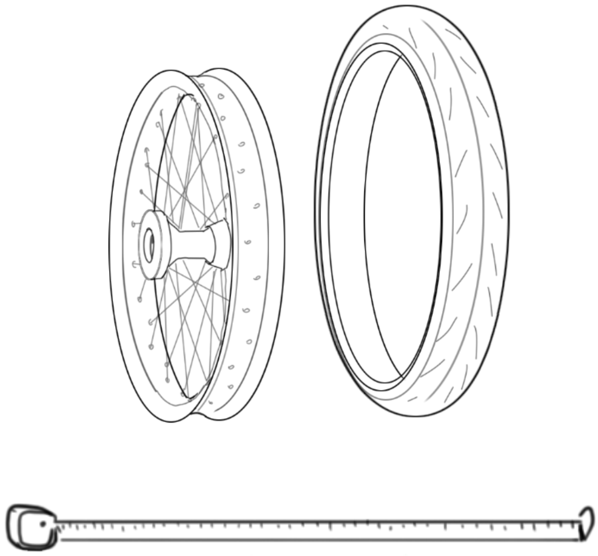
4.2.1.2.2 Wheels

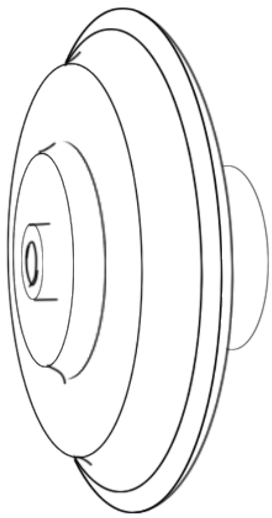
The wheels are assembled and mounted below. One is attached to the rear axle and one to the front axle at the fork of the eMotorbike and enable it to move, thereby influencing the driving dynamics and comfort.



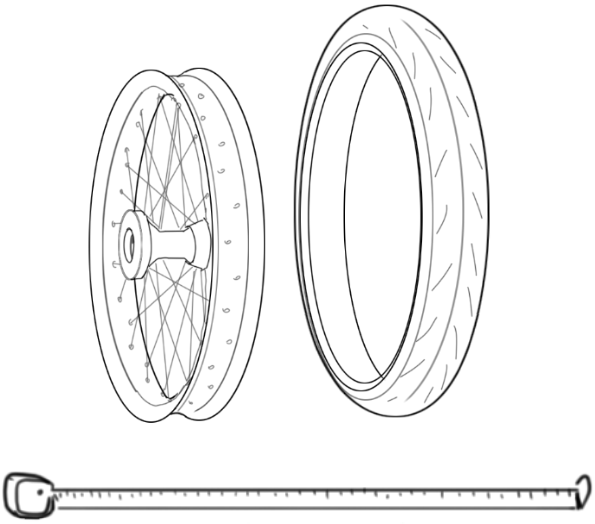
Step	Instructions	Visual Assistance
Step 1.2.2-1	Components: • Steering Fork Tools: • Tape Measure Process: a) Measure the space between the dampers of the Steering Fork. Also bear in mind the type of axle and, if used, a brake disk and brake caliper. They will increase the space needed between the rods of the fork. b) Choose the fitting 19” rim accordingly.	

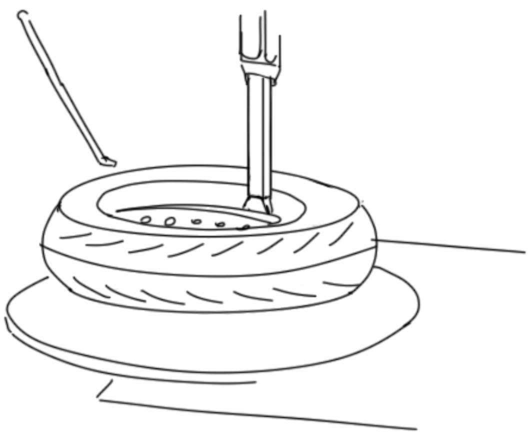
Funded by the European Union

Step	Instructions	Visual Assistance
Step 1.2.2-2	Components: • Front Rim Tools: • Tape Measure Process: a) Measure rim b) Choose the according front tire	

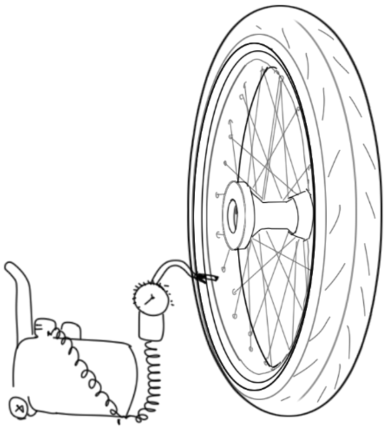
Step	Instructions	Visual Assistance
Step 1.2.2-3	Components: • None Tools: • None Process: a) Follow the process of choosing the right E-Motor with rim according to Section 4.2.4.1.1 E-Motor selection.	

Funded by
the European Union

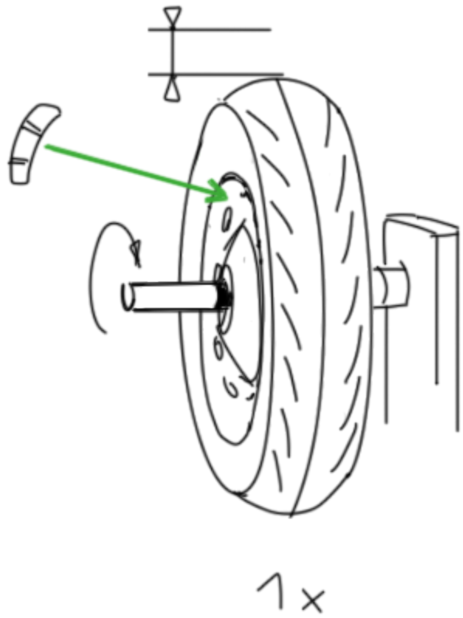
Step	Instructions	Visual Assistance
Step 1.2.2-4	Components: • Rear rim Tools: • Tape measure Process: a) Measure rim b) Choose the according rear tire	

Step	Instructions	Visual Assistance
Step 1.2.2-5	Components: • Front rim • Front tire • Rear rim • Rear tire Tools: • Tire fitting machine • Tire lever • Tire grease Process: a) Fit the tires to the rim according to the instructions on the tire fitting machine.	

Funded by
the European Union

<table>
<tr><th>Step</th><th>Instructions</th><th>Visual Assistance</th></tr>
<tr><td>Step 1.2.2-6</td><td>Components:
Front tire
Rear tire
Tools:
Compressor
Process:
a) Inflate the tires to their according pressure setting.
b) Check if the tires sit well on the rim and are inflated properly.</td><td></td></tr>
</table>

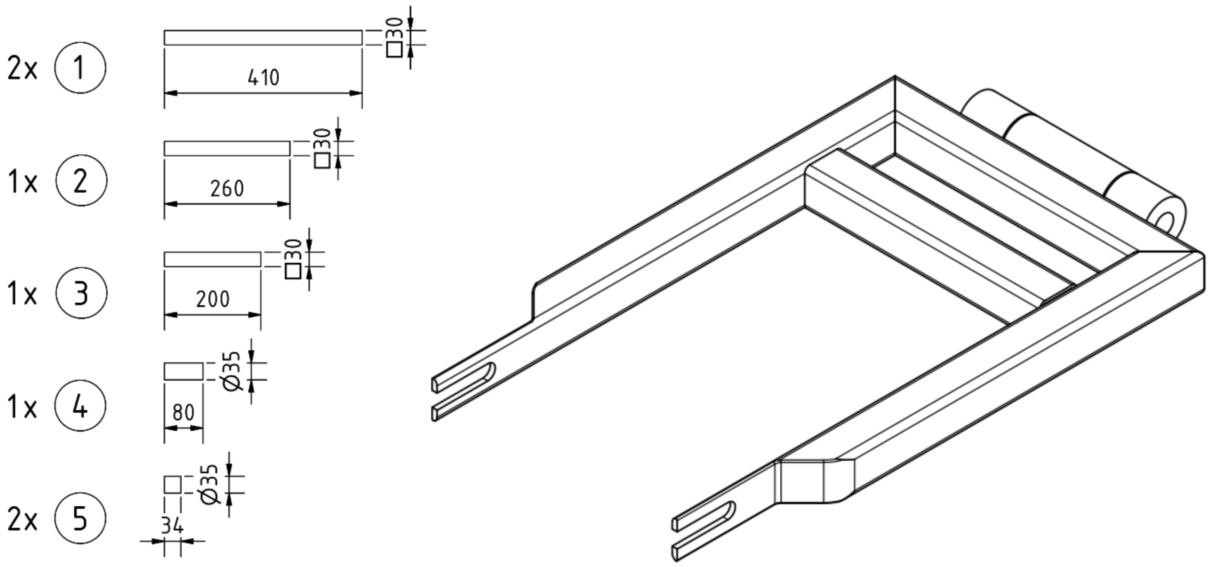
Funded by
the European Union

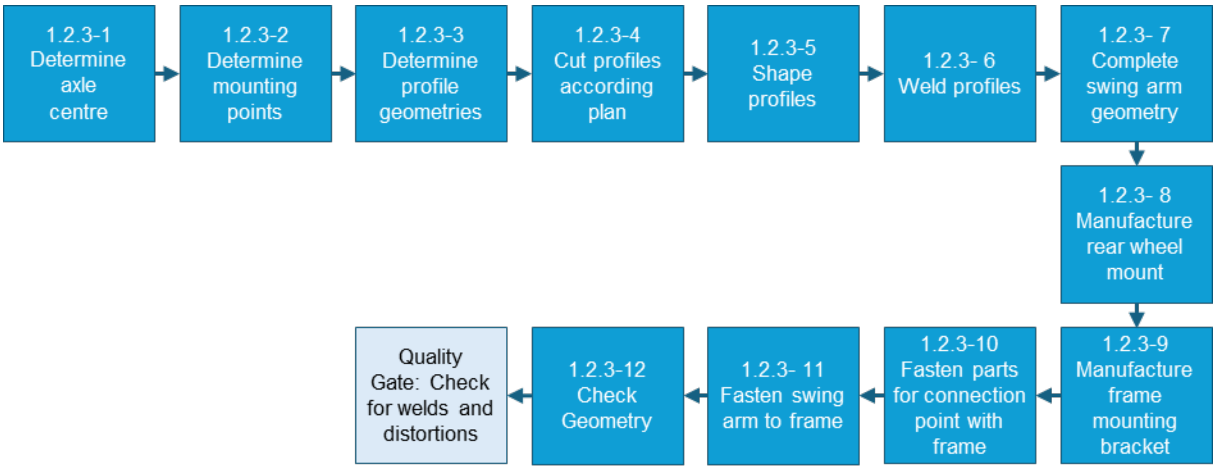
Step	Instructions	Visual Assistance
Step 1.2.2-7	Components: • Front wheel • Rear wheel Tools: • Wheel balancing machine Process: a) Balance the wheels according to the instructions on the balancing machine.	
Quality Gate	Check rims and tires for proper fit	

Funded by
the European Union

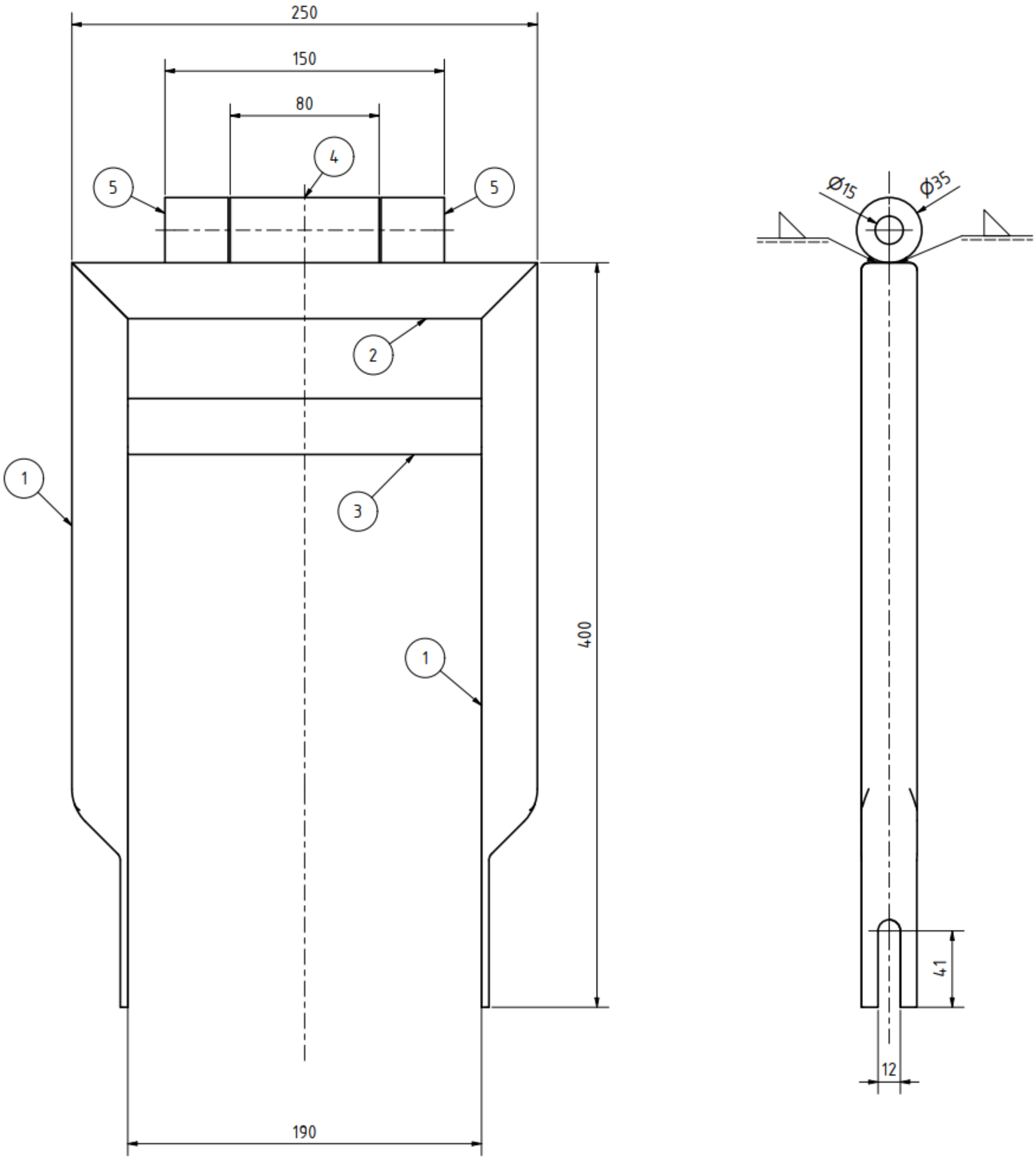
4.2.1.2.3 Rear Swing Arm

The rear swing arm is designed and manufactured below as a basic component of the rear suspension. The rear swing arm connects the rear wheel to the base frame via a bearing and 2 suspension struts.

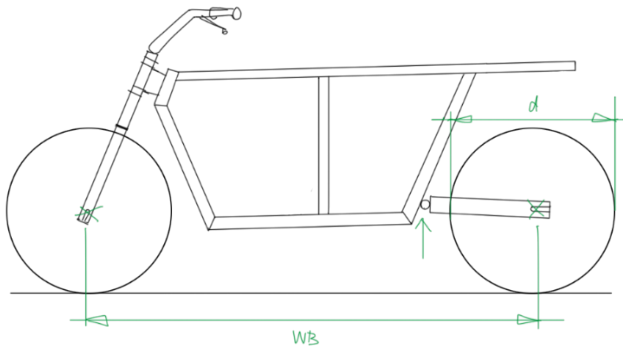




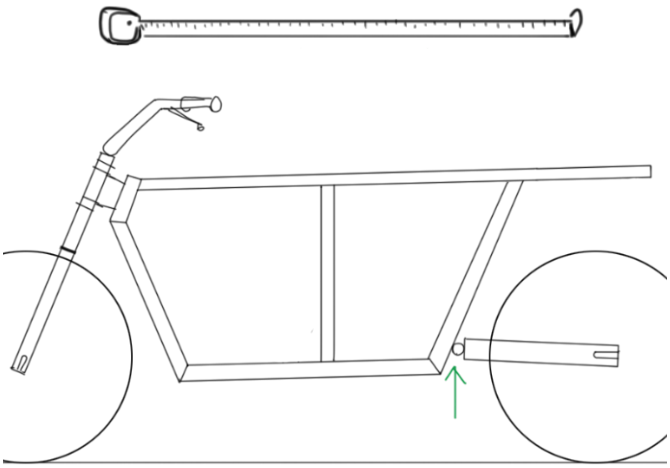
Funded by
the European Union



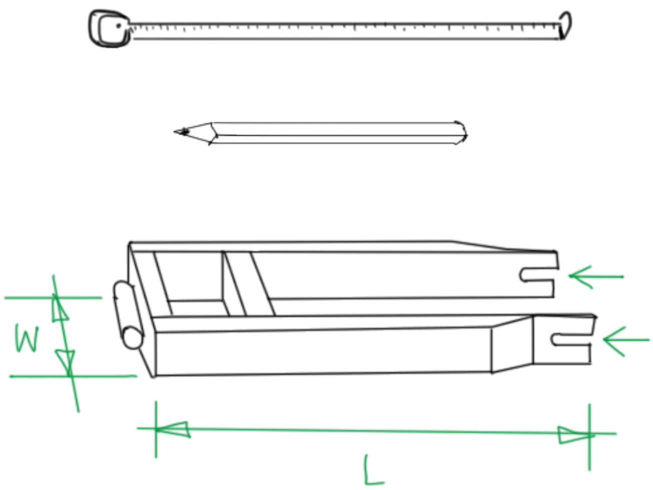
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.3-1	Components: • None Tools: • Tape Measure • Calculator Process: a) Use the wheelbase and the wheel diameter to determine the axle center of the rear wheel.	

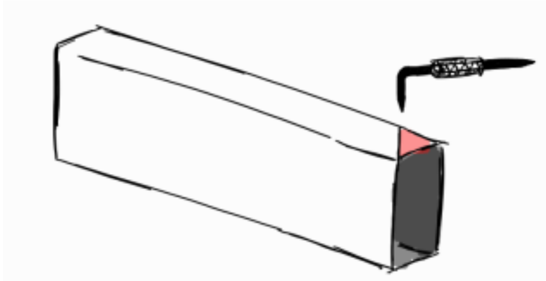
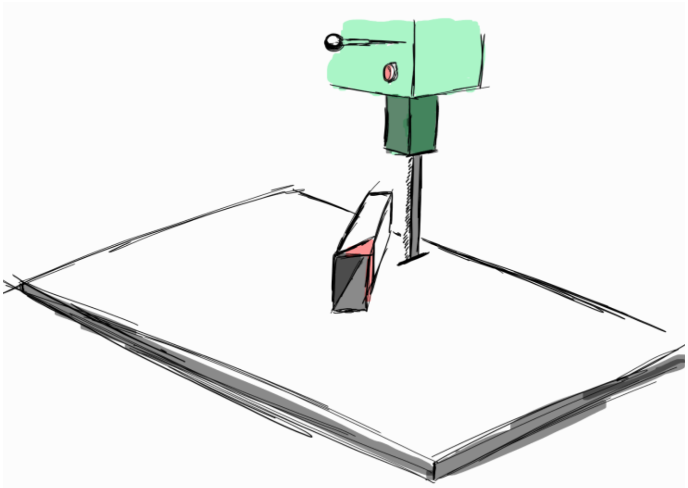
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.3-2	Components: • None Tools: • Tape measure • Calculator Process: a) Determine the attachment point of the rear swing arm on the frame. b) Ensure sufficient clearance during compression. The base frame should be aligned horizontally without load.	

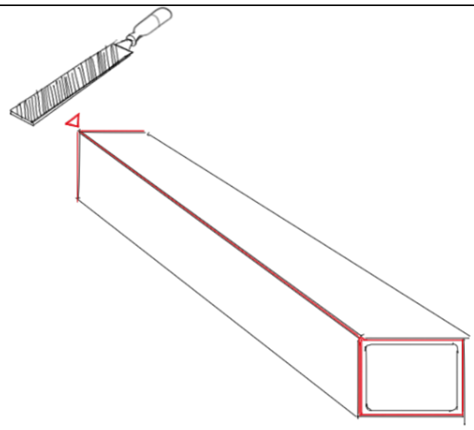
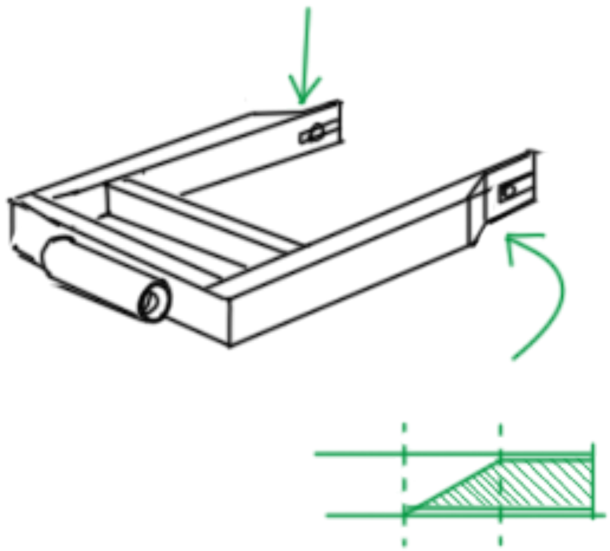
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.3-3	Components: • None Tools: • Calculator • Tape Measure • Scriber Process: a) Determine the geometry of the profiles and bearing for the rear swing arm for wheel mounting. This should be carried out as shown in the adjacent illustration.	

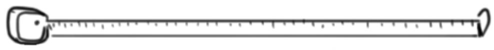
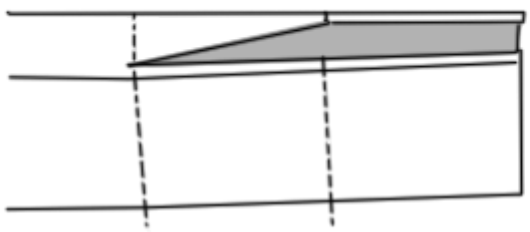
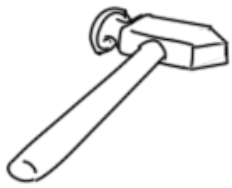
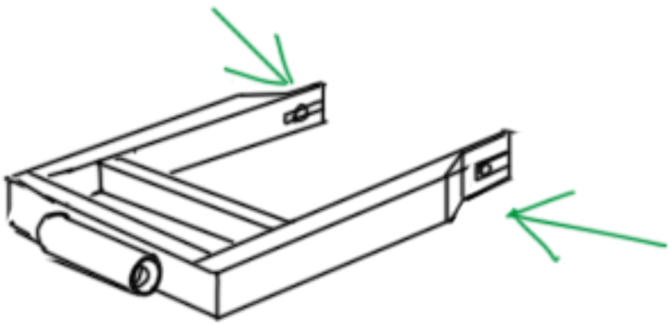
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.3-4	Components: • Rectangular profiles 30 mm x 30 mm; t = 2 mm Tools: • Angle grinder • File (used for deburring) Process: a) Cut out the marked areas from the profile using an angle grinder and deburr them. (Green is the top view. Repeat this mirrored for the other side)	 

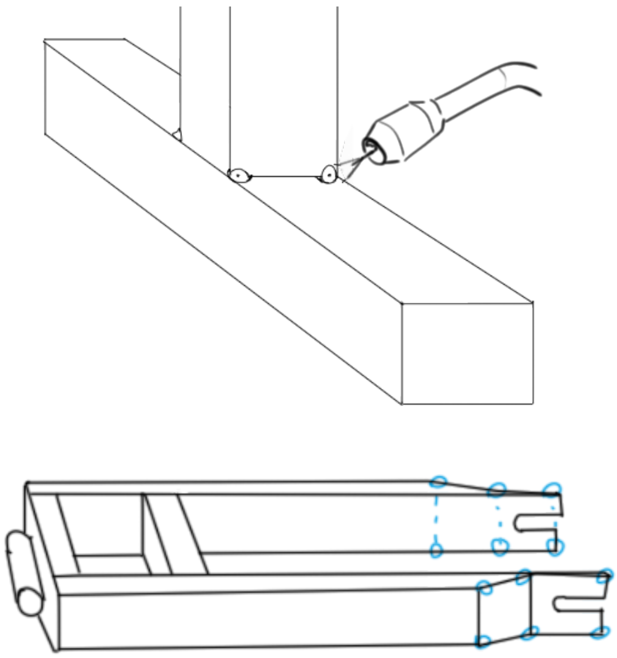
Funded by
the European Union

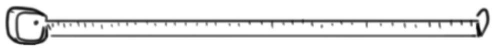
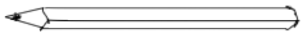
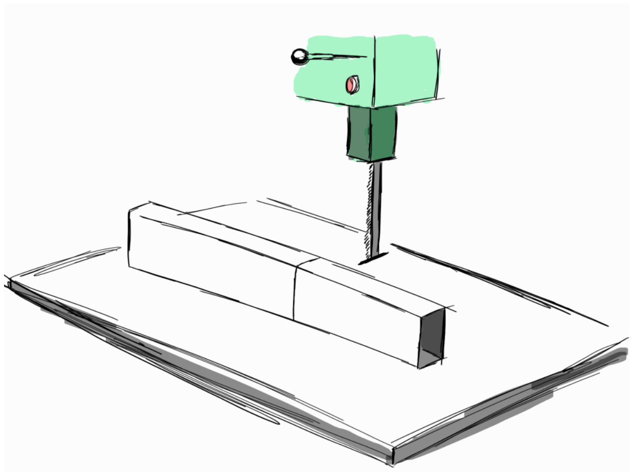
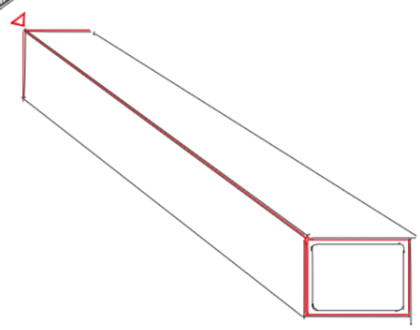
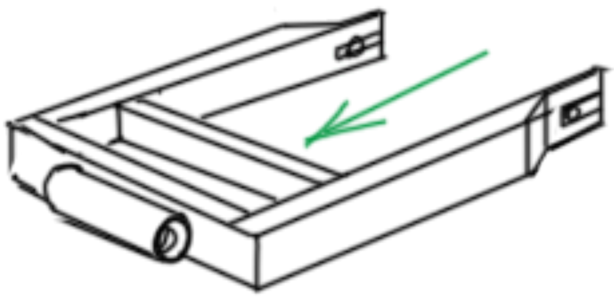
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.3-5	Components: • Rectangular profiles with cut out Tools: • Hammer • Screw clamp • Vice Process: a) Use a hammer, screw clamp or vice to shape the cut-out profiles as shown in the illustration. b) A superficial incision at the edges can simplify the shaping process.	    

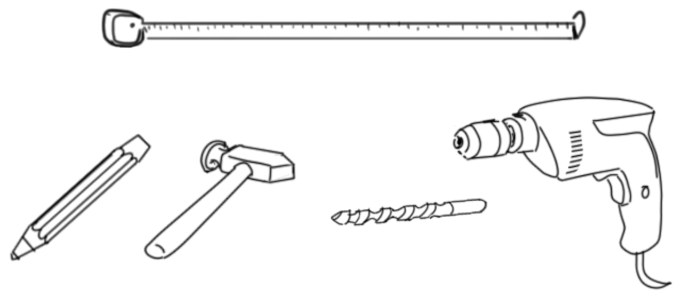
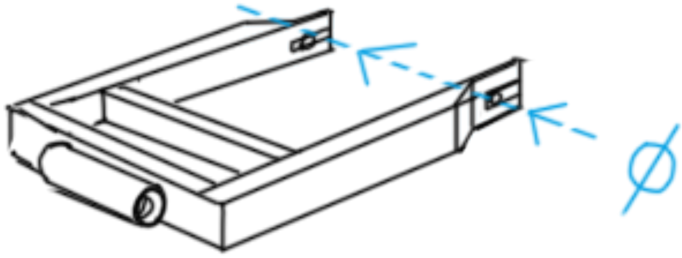
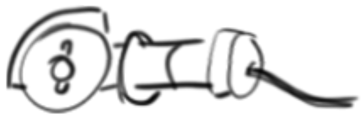
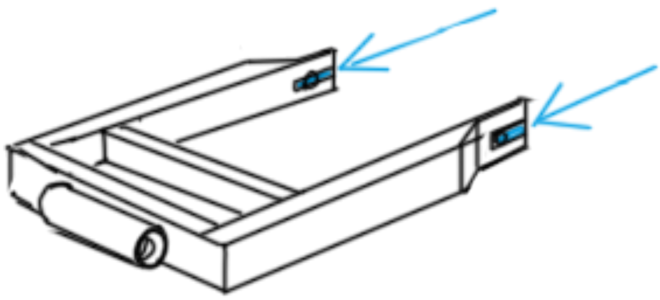
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.3-6	Components: • Cut profiles Tools: • MIG welding machine Process: a) Weld the profiles so that a closed contour is created at the interfaces.	

Funded by the European Union

Step	Instructions	Visual Assistance
Step 1.2.3-7	Components: • Welded swing arm profiles • Rectangular profiles 60 mm x 30 mm; t = 3 mm Tools: • Tape Measure • Scriber • Saw • File • Calculator Process: a) Fabricate struts from profiles according to the wheel hub width and the mount on the frame to complete the rear swing arm.	     

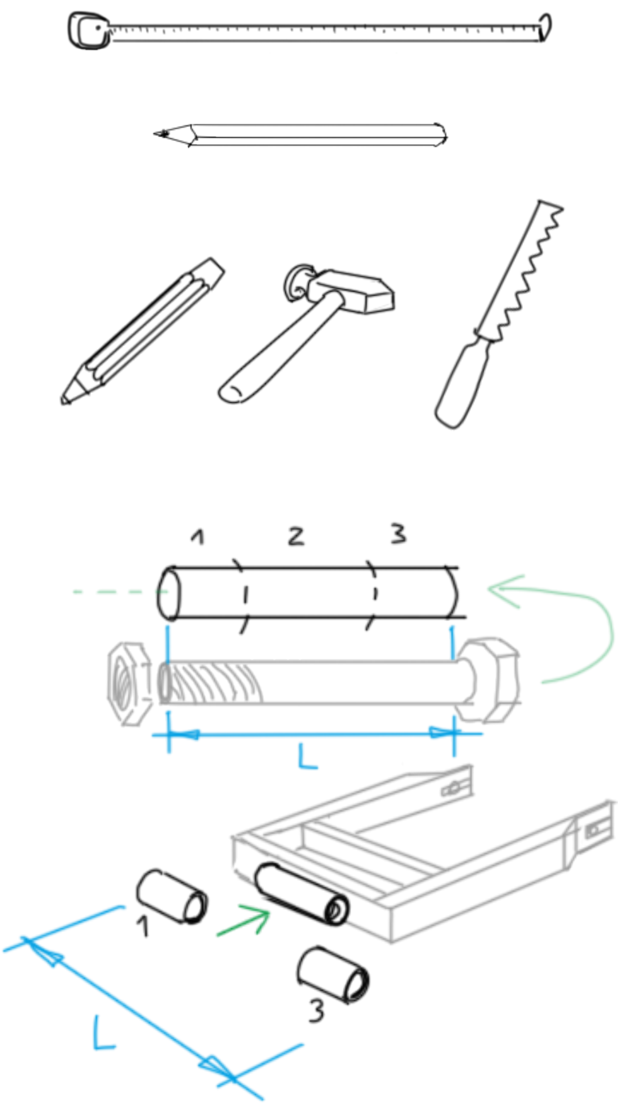
Funded by
the European Union

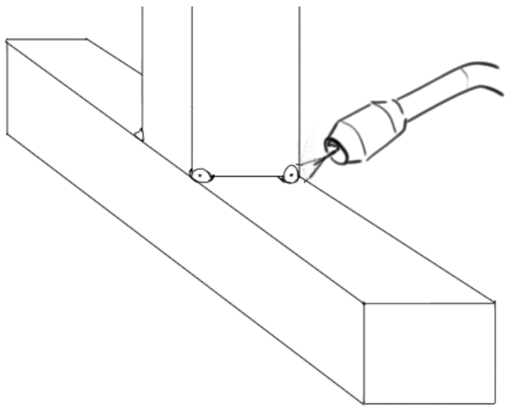
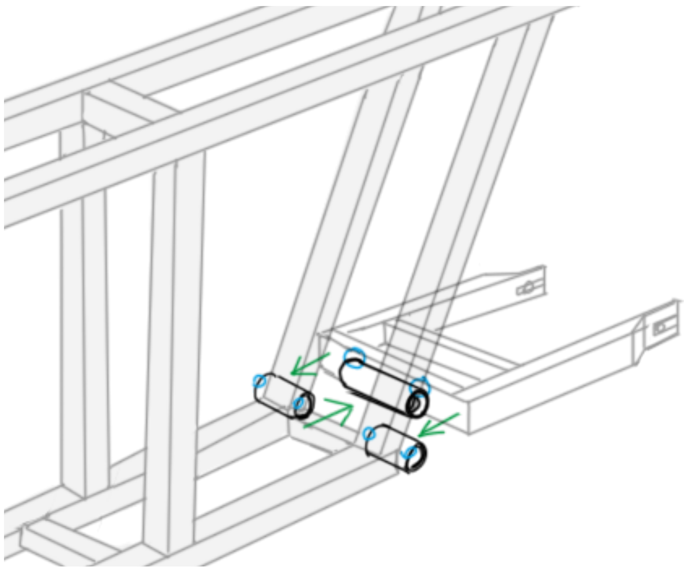
Step	Instructions	Visual Assistance
Step 1.2.3-8	Components: • Rear swing arm Tools: • Drilling machine • Center punch • Hammer • Tape Measure • Scriber • Saw Process: a) Mark the position of the axle center of the rear wheel on the rear swing arm. Pay attention to the previously greased dimensions. b) Use a hammer and center punch to mark the position. c) Drill concentrically through both halves of the rear swing arm so that the rear wheel axle can be fitted. d) Cut the bore horizontally by making 2 cuts per drilling so that the axle can be moved horizontally by the rear wheel to create a degree of freedom for	   

Funded by
the European Union

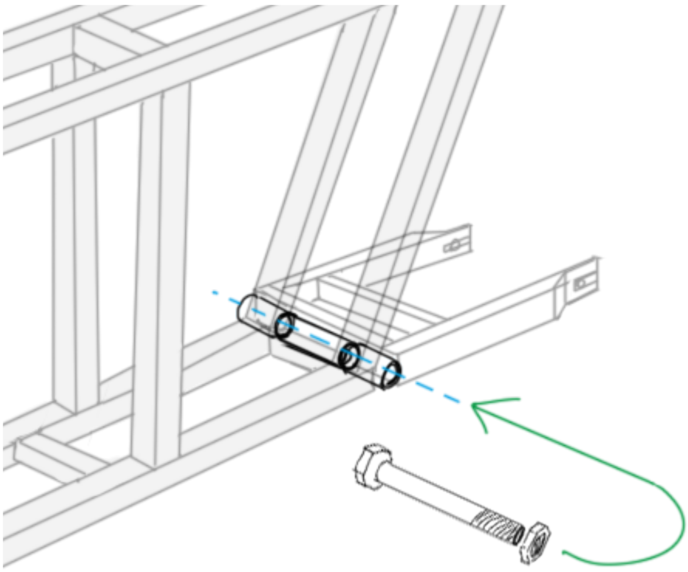
	tolerance compensation.	

Funded by
the European Union

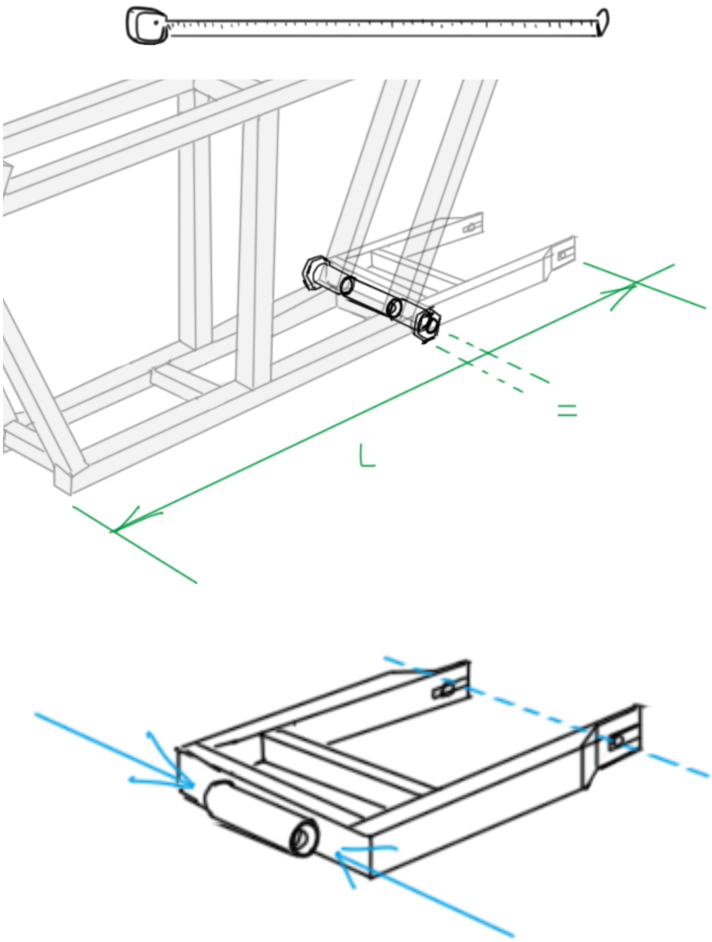
Step	Instructions	Visual Assistance
Step 1.2.3-9	Components: • Rear swing arm • Tube Tools: • Tape Measure • Center punch • Saw • Scriber • File Process: a) The inside diameter of the tube must correspond to the outside diameter of the axle / screw! b) Cut sleeves to a minimum width of 35mm for the outer sleeve and 80mm for the inner sleeve to be fitted to the frame and rear swingarm.	

Step	Instructions	Visual Assistance
Step 1.2.3-10	Components: • Rear swing arm • Tube • Axle / Screws Tools: • Tape Measure • Center punch • Saw • Scriber • MIG Welding Machine • File • Screwdriver/ Open-end spanner Process: a) Weld the center sleeve to the rear swingarm. b) Weld the outer sleeves to the base frame. c) Check the geometry.	   

Funded by
the European Union

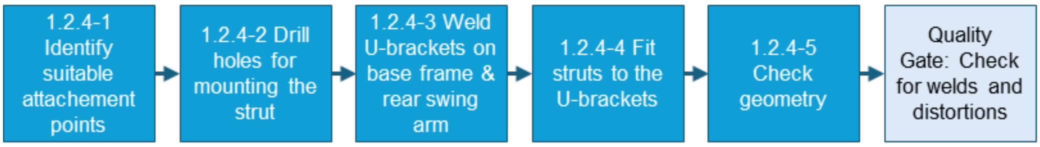
Step	Instructions	Visual Assistance
Step 1.2.3-11	Components: • Base frame • Rear swing arm • Axle / Screws Tools: • Screwdriver/ Open-end spanner Process: a) Screw rear swing arm to the frame. b) If necessary, add washers to reduce the bearing play.	 

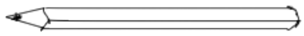
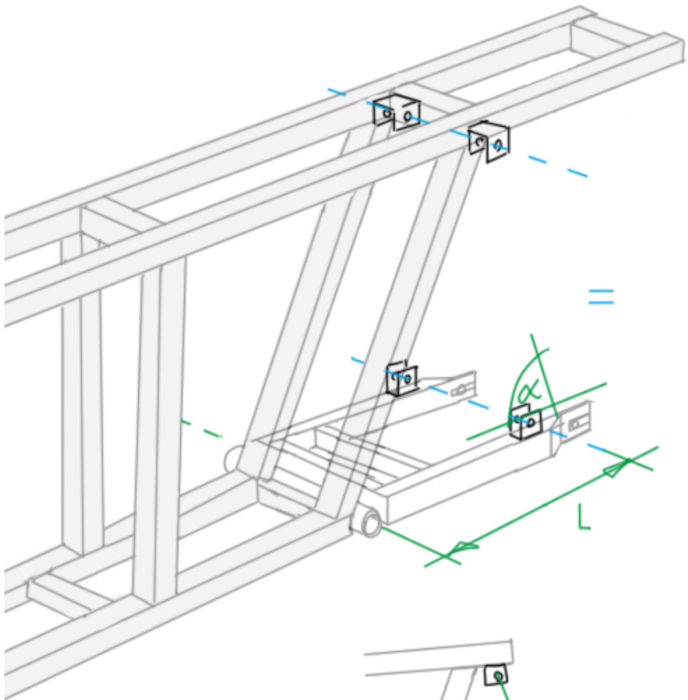
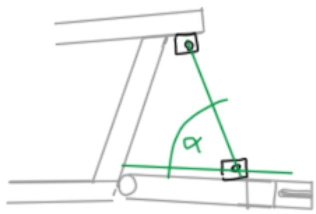
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.3-12	Components: • Base frame with rear swing arm Tools: • Tape Measure Process: a) Check the geometry of the rear swing arm for distortion and lack of parallelism / angularity with the base frame. b) If warped, loosen welded joints and realign.	
Quality Gate	Check for welds and distortions	

4.2.1.2.4 Rear Suspension

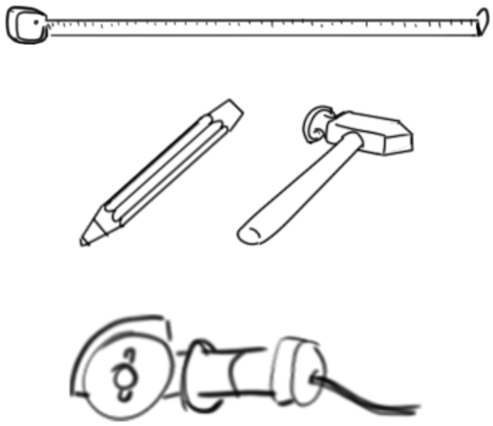
The rear struts are designed, selected and fitted below. They are installed at the rear of the base frame and improve driving stability and comfort by absorbing shocks and vibrations and keeping the vehicle level. In the overall vehicle manufacturing process, the rear springs and shock absorbers are installed after the steering system and suspension fork have been fitted.



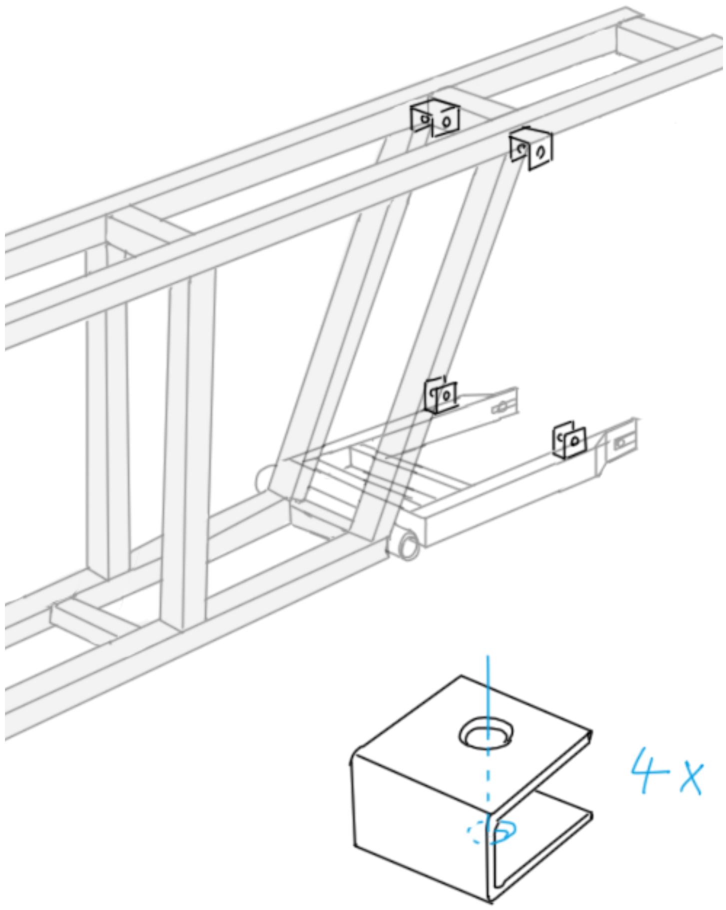
Step	Instructions	Visual Assistance
Step 1.2.4-1	Components: • Base frame and rear swing arm Tools: • Tape Measure • Calculator Process: a) Identify and mark suitable attachment points for the suspension struts. The typical installation angle of the suspension strut to the swingarm is between 20° and 45°. Angles outside this range can impair suspension efficiency and lead to undesirable effects such as insufficient damping or undesirable handling behavior. b) Furthermore, leverage laws	   

Funded by
the European Union

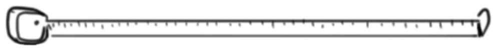
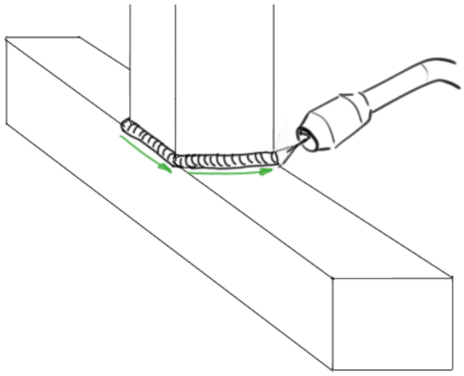
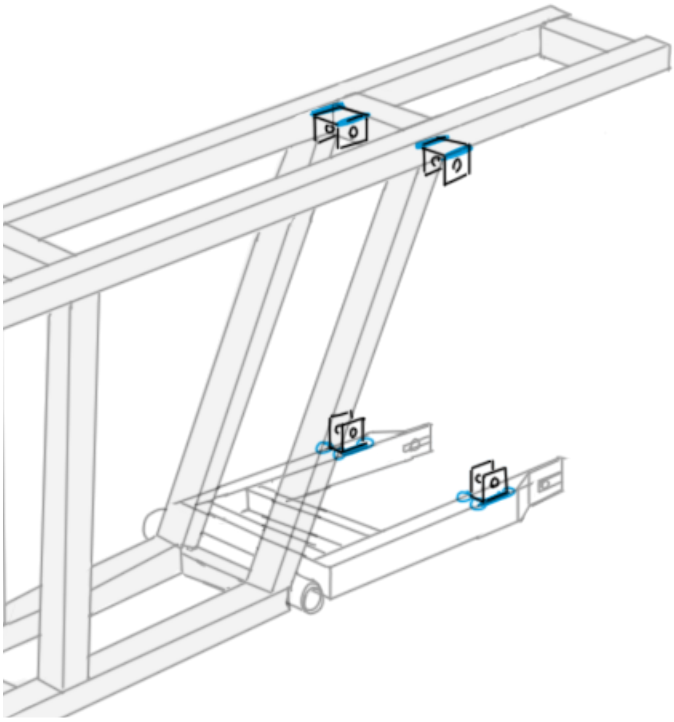
	regarding the mounting points of the suspension struts on the rear swing arm should be observed in order to achieve safe and comfortable riding behavior. The spring rate of the suspension struts is a decisive factor in calculating the position of the suspension strut mount on the rear swingarm. See 4.2.1.2.4.1 and 4.2.1.2.4.2.	

Step	Instructions	Visual Assistance
Step 1.2.4-2	Components: • Rear swing arm • Rectangular profiles 60mm x 30mm; t=3mm Tools: • Scriber • Center punch • Saw • Scriber • Tape Measure Process: a) Mark the holes for mounting the strut. b) Drill through both sides of the profile c) Cut away one surface to create an	

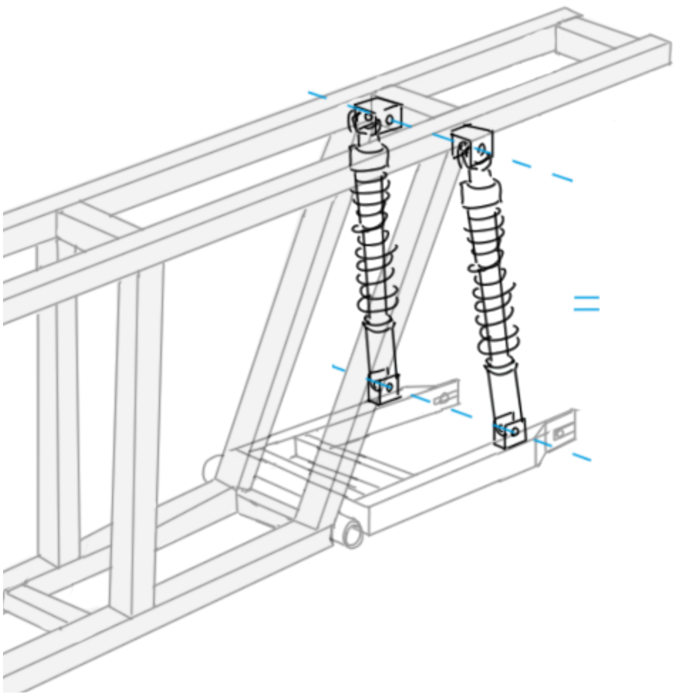
Funded by
the European Union

	open U-profile with a saw. Deburr the sharp edges and areas. d) Shorten the profile according to the available space for the strut mount. Deburr the sharp edges and areas.	

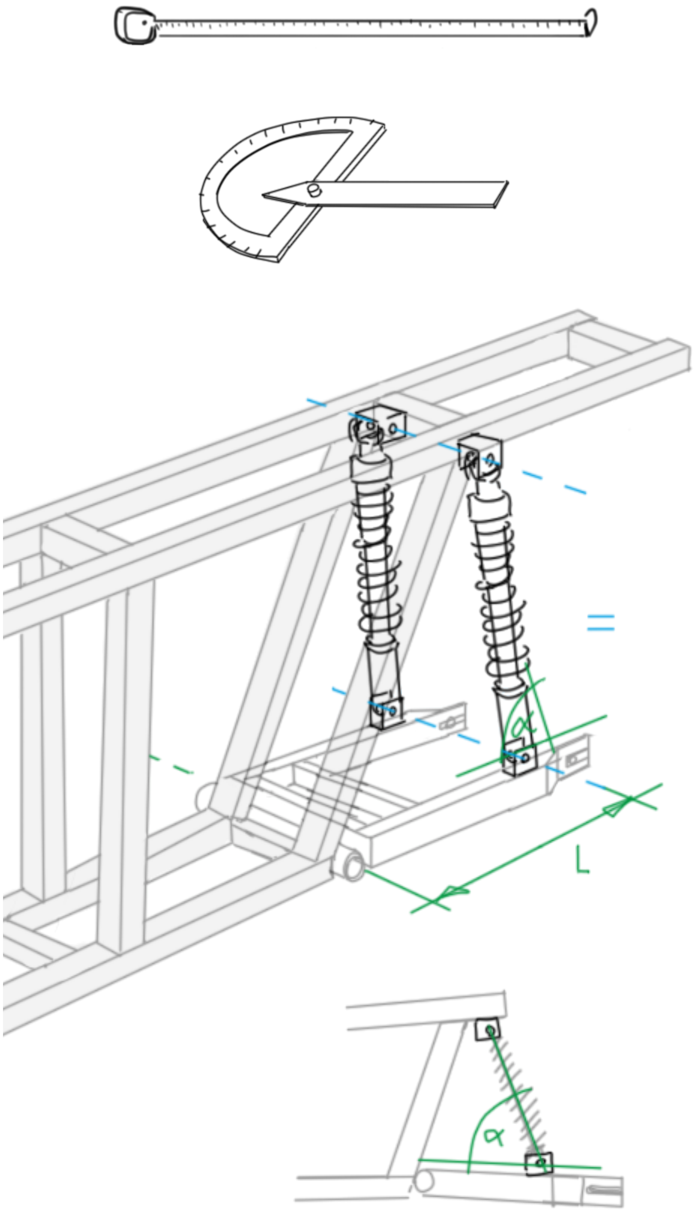
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.4-3	Components: • Base Frame with rear swing arm Tools: • MIG Welding Machine • Tape Measure Process: a) Tack weld the U-brackets at the previously determined points on the base frame and the rear swingarm b) Check the position. c) Weld the U-brackets completely on the base frame and rear swing arm.	  

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.4-4	Components: • Base Frame with rear swing arm • Struts • Screws • Nuts • Washers Tools: • Socket wrench • Open-End spanner Process: a) Fit the struts to the U-brackets using suitable screws. If necessary, use washers to compensate for play.	  

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 1.2.4-5	Components: • Base Frame with rear swing arm and struts Tools: • Tape Measure Process: a) Measure if the geometry is as planned. b) If the measurements are not correct, carry out the appropriate step from the previous steps again.	
Quality Gate	Check for welds and distortions	

Funded by
the European Union

4.2.1.2.4.1 Spring calculation

Combined suspension struts consisting of a spring and damper system are used for the vehicle's rear suspension. Two spring damper systems are used for this purpose, one for each side of the wheel suspension. The springs of the suspension struts must be designed and selected according to the following calculation. The deflection is also set at $80\ mm$ on the rear axle. It should be noted here that the suspension does not engage at the wheel center point. This means, that the deflection of the spring is different (smaller), which results from the ratio of the deflections to each other.

<u>Relevant parameters:</u>

n:	Number of springs (according to number of spring damper systems)
i:	Ratio of deflections
$m_{vehicle}$:	Total vehicle weight including payload
$m_{spring,rear}$:	Specific weight force acting on the individual spring (loaded vehicle taking into account the static axle load distribution)
s:	Deflection of the rear axis
s_{spring}:	Specific deflection for each spring

Force onto the spring: $F_{spring,rear} = m_{spring,rear} \cdot g$

Spring stiffness: $k = \frac{F_{spring,rear}}{s_{spring}}$

Specific weight force onto each spring: $m_{spring,rear} = \frac{m_{vehicle} \cdot i_{axleload,rear}}{n}$

Ration of deflections: $i = \frac{x_{distance,Pivotpoint-strut}}{x_{distance,Pivotpoint-axiscenter}}$

Specific deflection for each spring: $s_{spring} = s \cdot i = s \cdot \frac{x_{distance,Pivotpoint-strut}}{x_{distance,Pivotpoint-axiscenter}}$

The maximum deflection of the rear axle is set to $80\ mm$. This value is made up of the static preload of the spring, which acts as a force on the spring due to the weight of the vehicle when stationary, and the dynamic component, which is applied by driving over uneven surfaces. The dynamic component is referred to as dynamic wheel load fluctuation and can be ±50 % for uneven road conditions. To protect against suspension failure, a safety factor of 1.5 (corresponding to ±50 %) is therefore assumed for the forces applied.

Funded by the European Union

<u>Parameters for the static preload of the leaf spring:</u>

Static specific weight force onto each spring:

$$m_{spring,rear} = \frac{m_{vehicle} \cdot i_{axleload,rear}}{n} = \frac{280\ kg\ \cdot 0.74}{2} = 103.6\ kg$$

Maximum deflection of the rear axle:

$$s = 80\ mm = 0.08\ m$$

Maximum deflection for each spring:

$$s_{spring} = s \cdot \frac{x_{distance,Pivotpoint-strut}}{x_{distance,Pivotpoint-axiscenter}} = 0.08\ m\ \cdot \frac{280\ mm}{391\ mm} = 0.0573\ m$$

Safety factor for dynamic wheel load fluctuation:

$$S = 1.5$$

ATTENTION: The values specified above must be adapted to the individual concept for the design. The vehicle weight including payload may deviate from the concept presented here based on the materials selected, so that a calculation must be made at this point using the individual factors.

<u>Calculation:</u>

$$F = m_{spring,rear}\ \cdot\ g\ \cdot\ S\ =\ 103.6\ kg\ \cdot 9.81 \frac{m}{s^2} \cdot 1.5 =\ 1524.474\ N$$

$$k = \frac{m_{wheel,rear} \cdot g \cdot S}{s_{spring}} = \frac{103.6\ kg\ \cdot 9.81 \frac{m}{s^2} \cdot 1.5}{0.0573\ m} =\ 26605.13 \frac{N}{m}$$

The rider sag (the suspension sag under the weight of the rider, the payload and the vehicle itself) should be around 30-35% of the maximum deflection. For a maximum deflection of $57.3\ mm$:

$$x_{sag,min} = 0.3 \cdot 57.3\ mm = 17.19\ mm$$

$$x_{sag,max} = 0.35 \cdot 57.3\ mm = 20.06\ mm$$

The spring damper system must be selected according to the designed and calculated spring value $\boldsymbol{k}, \boldsymbol{x_{sag,min}}, \boldsymbol{x_{sag,max}}$.

4.2.1.2.4.2 Damper calculation

The damper constant c is calculated below for the design of the shock absorber. The damper constant c is designed primarily on the basis of the spring stiffness k and the relevant mass.

Funded by
the European Union

Relevant parameters:

Spring stiffness: $k = 26605.13 \frac{N}{m}$

Static mass onto each wheel of the rear axis: $m_{wheel,rear} = 103.6\ kg$

Critical damping:

$$c_{crit} = 2\sqrt{m_{wheel,rear} \cdot k} = 2\sqrt{103.6\ kg \cdot 26605.13 \frac{N}{m}} = 3320.42 \frac{kg}{s}$$

Actual damper constant:

In practice, a certain percentage of the critical damping is often used, depending on how "soft" or "hard" the ride feel should be. A common value is between 60% and 80% of the critical damping. A value of 70% of the critical damping is used here.

$$c = 0.7 \cdot c_{crit} = 0.7 \cdot 3320.42 \frac{kg}{s} = 2324.29 \frac{kg}{s}$$

ATTENTION: The calculated damper constant is based on the previously calculated leaf spring and the vehicle weight. Accordingly, the individual calculation must be adapted to the specific parameters of the individual concept.

4.2.2 Drivetrain

In the following chapter, the drive train of the vehicle is dimensioned. This includes information and calculations for the transmission as well as power requirement calculations for the motor.

ATTENTION: The following is the layout of the drive unit and the battery. Various calculations are given for this purpose, which must be recalculated and adapted with the parameters and framework factors of your own concept.

4.2.2.1 E-Motor

The vehicle described here is an electrically powered vehicle. In order to select an electric motor, calculations must be made with regard to the power requirements of the drivetrain. The following chapter presents the calculation principles for determining the necessary dimensions of the drivetrain.

ATTENTION: It is important to note that an AC/DC or DC/DC converter can be avoided under certain conditions.

Motor: DC

If the drive unit operates at the voltage level of the battery (e.g. 48 V), an additional DC/DC converter can also be dispensed with.

Funded by
the European Union

If the drive unit operates at a different voltage level than the battery (e.g. 60 V or 72 V), an additional DC/DC converter must be installed, which provides the operating voltage of the drive unit as the input voltage.

Motor: AC

An AC/DC converter must be provided regardless of the operating voltage of the drive unit, which provides the operating voltage of the drive unit as the input voltage.

4.2.2.1.1 E-Motor selection

Several factors play a decisive role in selecting the right electric motor. The aim of the motor selection is to provide the motor power required for the designed vehicle concept. The factors influencing the determination of the motor power include the maximum vehicle weight, consisting of the vehicle's own weight and the maximum payload, the vehicle's intended climbing ability and the air resistance of the vehicle concept. The factors mentioned influence the driving resistance that occurs, which must be overcome by the engine power. Another important factor in the engine's design is the intended maximum speed of the vehicle. As it is an electric drive in any case, there is no need for a multi-stage gearbox. Since a wheel hub motor is recommended for the drive, additional integration of a reduction gearbox is not possible in this case. For this reason, it is important to consider the intended maximum speed as a selection criterion when choosing the drive unit. The power requirement calculation is generally based on the greatest demand from a number of different requirements. A first requirement may be to be able to achieve a certain speed in a certain time. This case is not relevant for the present case of the simplest possible vehicle concept. A second requirement may be to be able to reproduce certain dynamic driving characteristics (max. speed, max. gradient, etc.) with the vehicle performance. A third criterion may be to be able to overcome a certain curb height with the vehicle from a standstill, i.e. to have sufficient vehicle power to overcome a certain height of a step. The formulas for the last two design requirements are given below. The layout for the realization of certain driving characteristics is carried out as an example. The calculation of the necessary power to overcome steps and curbs must be carried out individually in relation to the local conditions. The required motor power is subsequently defined by the greater of the two power requirements.

Power Requirement Calculation

Required parameters:

Weight of the vehicle (incl. payload):	m (in kg)
Maximum speed:	v_{max} (in m/s)
Rolling resistance coefficient:	c_r
Coefficient of drag:	c_w

Funded by
the European Union

Frontal area of the vehicle: A (in m²)

Air density: $\rho \approx 1.225 \frac{kg}{m^3}$ (at sea level and 15°C)

Gradient of the road: θ (in degrees)

Efficiency of the electric motor: η

<u>Calculation formulas:</u>

The power P is made up of various components:

Rolling resistance force: $F_{roll} = c_r \cdot m \cdot g$

Air resistance force: $F_{air} = \frac{1}{2} \cdot c_d \cdot A \cdot \rho \cdot v^2$

Inclination resistance force: $F_{inclination} = m \cdot g \cdot sin(\theta)$

The total drag force: $F_{tot} = F_{roll} + F_{air} + F_{inclination}$

The required drive power: $P = F_{tot} \cdot v_{max}$

Since the e-machine has an efficiency, the electrical power actually required P_{electr} must be taken into account:

Electrical power (taking into account the efficiency): $P_{electr} = \frac{P}{\eta}$

<u>Relevant vehicle parameters:</u>

Total vehicle weight (including payload): $m = 280\ kg$

Maximum speed: $v_{max} = 16.5 \frac{m}{s} \approx 60 \frac{km}{h}$

Rolling resistance coefficient: $c_r = 0.01$

Drag coefficient (including driver): $c_d = 1.0$

Frontal area (including driver): $A = b \cdot h = 0.5\ m \cdot 1.4\ \mathrm{m} = 0.7\ m^2$

Gradient: $\theta = 7° \approx 12\%$

Efficiency of the electric motor: $\eta = 0.85$

Funded by
the European Union

<u>Calculation:</u>

Rolling resistance force:

$$F_{roll} = 0.01 \cdot 280\ kg \cdot 9.81 \frac{m}{s^2} = 27.468\ N$$

Air resistance force:

$$F_{air} = \frac{1}{2} \cdot 1.0 \cdot 0.7\ m^2 \cdot 1.225 \frac{kg}{m^3} \cdot \left(16.5 \frac{m}{s}\right)^2 = 116.727\ N$$

Inclination resistance force:

$$F_{inclination} = 280\ kg \cdot 9.81 \frac{m}{s^2} \cdot sin(7°) = 334.751\ N$$

The total resistance force:

$$F_{tot} = 27.468\ N + 116.727\ N + 334.751\ N = 478.946\ N$$

As described above, the required motor power depends on the driving speed and the total resistance forces. It should be noted that the vehicle should not be designed in such a way that the intended maximum speed can be reached at maximum inclination, as this would lead to a significant oversizing of the drive unit and thus to higher costs, weight and therefore also to a larger dimensioning of the battery, which in turn has an influence on costs and weight. Instead, the vehicle is designed in such a way that it can achieve the targeted maximum driving speed on level ground and still reach around 50% of the targeted maximum speed with maximum load and maximum inclination (edge case). The following two load cases must therefore be checked (ground level, inclination) and the dimensions of the drive unit determined accordingly.

The required drive power on ground level:

$$P_{ground} = F_{tot} \cdot v_{max} = \ (F_{roll} + \ F_{air}) \cdot v_{max}$$

$$P_{ground} = (27.468\ N + 116.727\ N) \cdot \ 16.5 \frac{m}{s} = 2379.2175\ W \ \approx 2.4\ kW$$

The required drive power for maximal inclination ($v_{inclination} = 0.5 \cdot v_{max} = 8.25 \frac{m}{s}$):

$$P_{inclination} = F'_{tot} \cdot v_{inclination} = \ (F_{roll} + \ F'_{air} + F_{inclination}) \cdot v_{inclination}$$

$$F'_{air} = \frac{1}{2} \cdot c_d \cdot A \cdot \rho \cdot v_{inclination}{}^2 = \frac{1}{2} \cdot 1.0 \cdot 0.7\ m^2 \cdot 1.225 \frac{kg}{m^3} \cdot \left(8.25 \frac{m}{s}\right)^2 = 29.182\ N$$

$$P_{inclination} = (27.468\ N + 29.182\ N + 334.751\ N) \cdot \ 8.25 \frac{\mathrm{m}}{\mathrm{s}} = 3229.057\ W \ \approx 3.2\ kW$$

Funded by
the European Union

The required motor power P_{req} is now determined using the larger of the required powers (P_{ground},$P_{inclination}$).

$$P_{req} = \max(P_{ground}, P_{inclination}) = P_{inclination} = 3.2\ kW$$

The electrical motor output P_{electr} now depends on the efficiency of the motor, which is assumed here to be $\eta = 0.85$.

$$P_{electr} = \frac{P_{inclination}}{\eta} = \frac{3.2\ kW}{0.85} = 3.76\ kW\ \approx 3.8\ kW$$

Power requirement for wheel curb climbing torque:

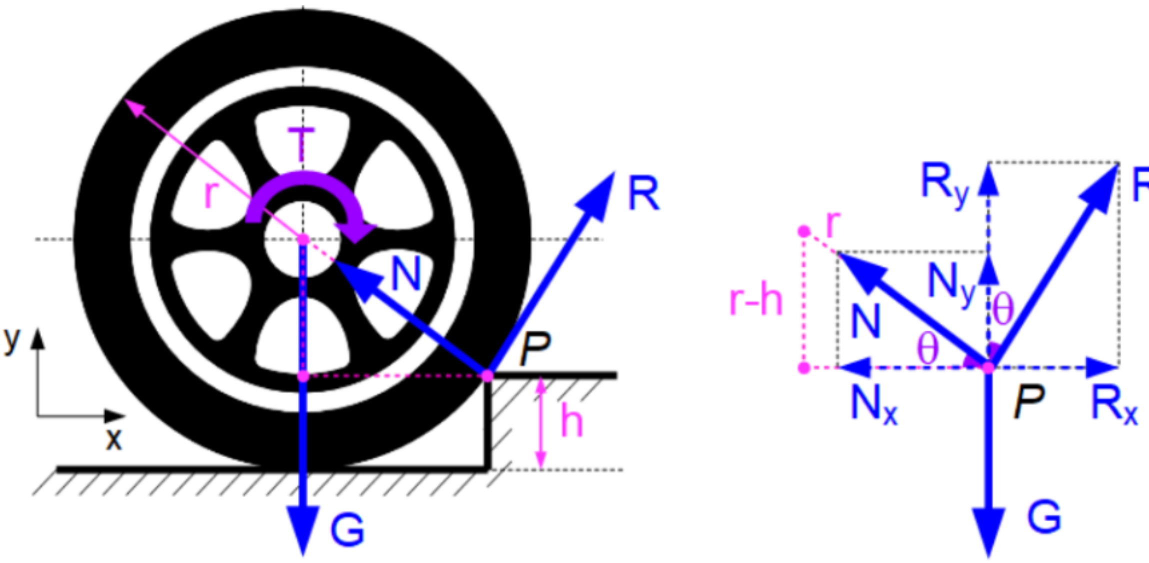


Figure 12: Wheel curb climbing torque

$$R = G\ \cdot \cos(\theta)$$

$$\theta = sin^{-1}\frac{r-h}{r}$$

$$T = R \cdot r$$

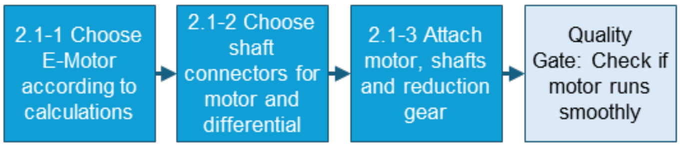
$$T_{mot} = \frac{T}{i_{tot}}$$

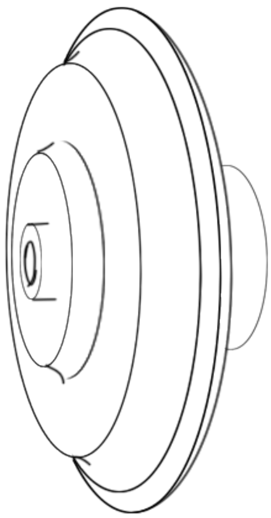
ATTENTION: The motor selection carried out should be adapted individually, taking into account the individual vehicle concept. The weight and climbing ability in particular have a major influence on the power requirement. In the event of deviations, an individual assessment should therefore be carried out.

Funded by
the European Union

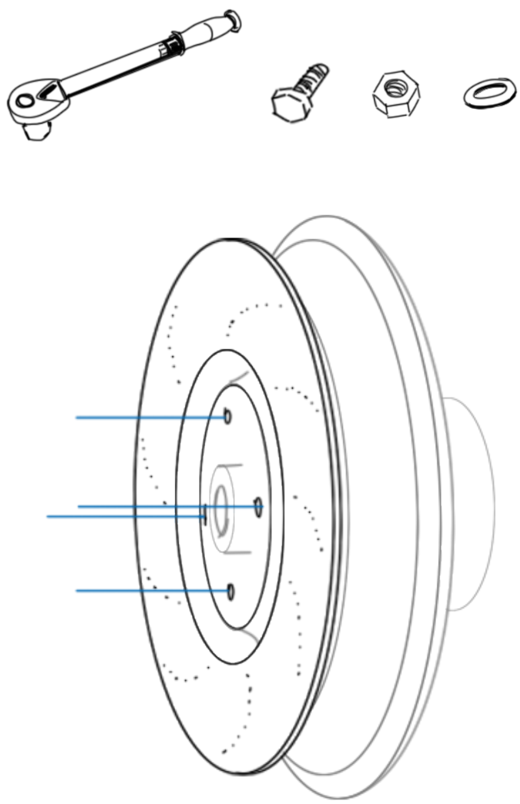
4.2.2.1.2 E-Motor installation

ATTENTION: Pay attention to the ground clearance of the vehicle during the following steps. When attaching the motor, make sure that the motor does not touch the frame or the road if the vehicle deflects.

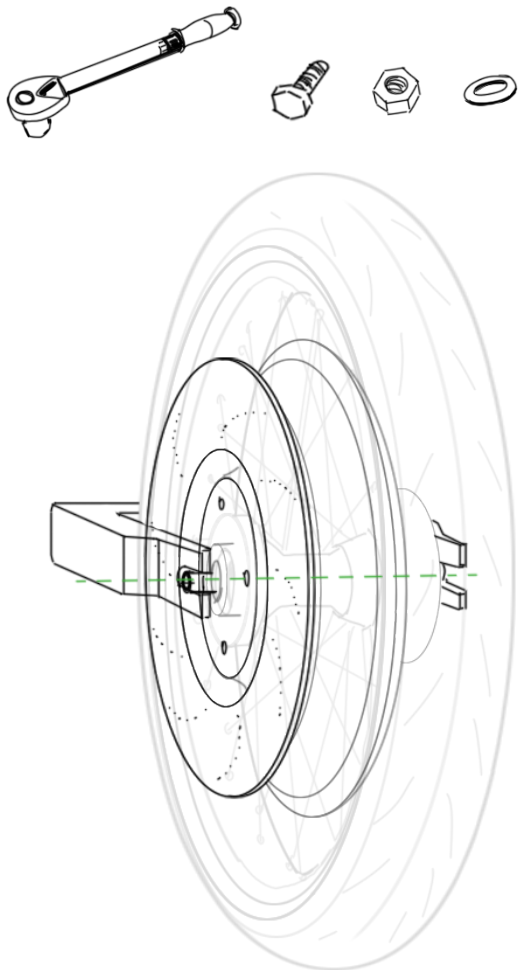


Step	Instructions	Visual Assistance
Step 2.1-1	Components: • None Tools: • Calculator Process: a) Calculate the required electric motor power output according to Chapter 4.2.2.1.1. b) Select a market available electric wheel hub motor according to calculation results of a)	

Funded by the European Union

Step	Instructions	Visual Assistance
Step 2.1-2	Components: • Wheel hub motor • Brake disc Tools: • Screws • Screwdriver Process: a) If not yet pre-assembled, attach the brake disk to the corresponding mount.	

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 2.1-3	Components: • Wheel hub motor • Assembled rear swing arm Tools: • Screws • Screwdriver Process: a) Insert the wheel hub motor into the rear swing arm and pre-assemble the screws (do not tighten them completely yet). b) Check the alignment of the wheel. Check that the brake disk runs flat in the brake shoes. If necessary, move the wheel hub motor in the mounting. c) Once the wheel and brake are running straight, tighten the screws.	
Quality Gate	Check that the wheel runs smoothly and straight ahead, no grinding noises	

Funded by
the European Union

4.2.3 Energy Storage

In the following section, the battery is designed for the developed vehicle. It is recommended that a battery including BMS be purchased and provided for the vehicle concept. A swappable battery concept has proven itself for comparable vehicles. The advantage here is that the battery can be dimensioned for a lower range, as longer charging stops can be dispensed with by replacing an empty battery with a full one. In the SOLUTIONSplus project, however, there were also cases during the test phases in which a swappable battery concept was replaced by a permanently installed battery concept with a larger range. It is therefore highly advisable to discuss the various concept approaches with potential users to explain the advantages and disadvantages and to tailor the concept to the future user. Due to the higher market penetration of swappable battery concepts in this vehicle segment, a swappable concept is described below. If a permanently installed concept is more advantageous, the following calculations must be adapted to suit the individual concept. When dimensioning a swappable battery concept, it should be ensured that two batteries can be provided in the concept, provided they are connected via an isolating relay. The cut-off relay switches the power supply of the drive between the batteries depending on the energy level.

4.2.3.1 Battery selection

For the design of the necessary battery size for the vehicle concept, some boundary conditions and assumptions must be made. The required battery capacity essentially depends on the intended range and the energy requirements of the vehicle. The target range is set at $60\ km$ per battery swap based on the experience gained from the SOLUTIONSplus project and on the fact that a longer charging stop can be dispensed with by replacing an empty battery with a full one. For the energy requirement, the formulas for the power requirement, which were already used in Chapter 4.1.2.1.1 for the calculation of the engine power, are applied below. An additional assumption must be made regarding the average speed and the altitude profile. At this point, the average speed is assumed to be $36\frac{km}{h}\ \left(10\frac{m}{s}\right)$ and the average gradient to be $2\%\ (\approx 1.1°)$. In the following, the power requirement is calculated and then converted into the energy requirement.

$$F''_{tot} = F_{roll} + F''_{air} + F''_{inclination}$$

$$F_{roll} = 27.468\ \ N$$

$$F''_{air} = \frac{1}{2} \cdot 1.0 \cdot 0.7\ m^2 \cdot 1.225\frac{kg}{m^3} \cdot \left(10\frac{m}{s}\right)^2 = 42.875\ N$$

$$F''_{inclination} = 280\ kg \cdot 9.81\frac{m}{s^2} \cdot sin(1.1°) = 52.732\ N$$

$$F''_{tot} = 27.468\ N + 42.875\ N + 52.732\ N = 123.075\ N$$

$$P''_{req} = F''_{tot} \cdot 10\frac{\mathrm{m}}{\mathrm{s}} = 1230.75\ W\ \ \approx 1.23\ kW$$

Funded by
the European Union

$$P''_{electr} = \frac{P''_{req}}{\eta} = \frac{1.23\ kW}{0.85} = 1.45\ kW$$

On average, an output of $1.45\ kW$ of the drive is therefore called up for the assumptions made. The energy requirement is now derived from the time required.

$$\Delta E = P''_{electr} \cdot \Delta t = P''_{electr} \cdot \frac{s}{v} = 1.45\ kW\ \cdot \frac{60\ km}{36\frac{km}{h}} = 2.42\ kWh$$

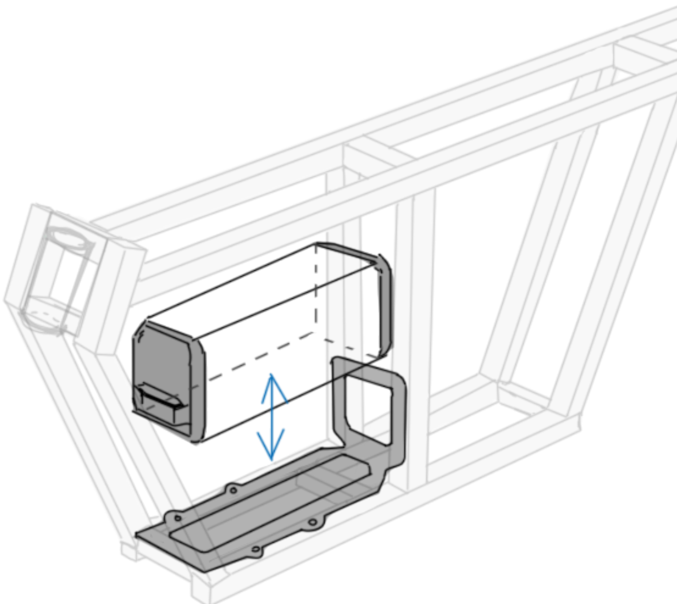
ATTENTION: The battery design carried out should be adapted individually, taking into account the individual vehicle concept as well as your own requirements for the vehicle and the driving cycle (made here by assuming). The weight and climbing ability, in particular, have a major influence on the power requirement. In the event of deviations, an individual assessment should therefore be carried out.

BMS:

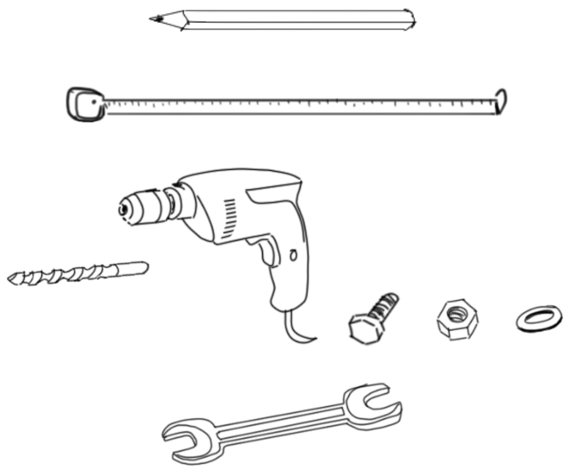
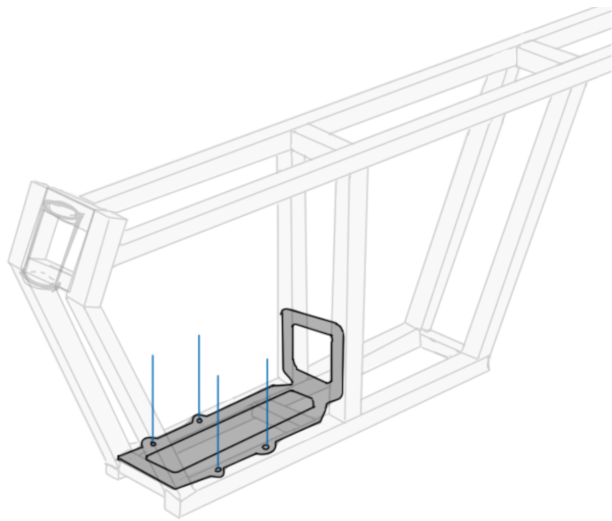
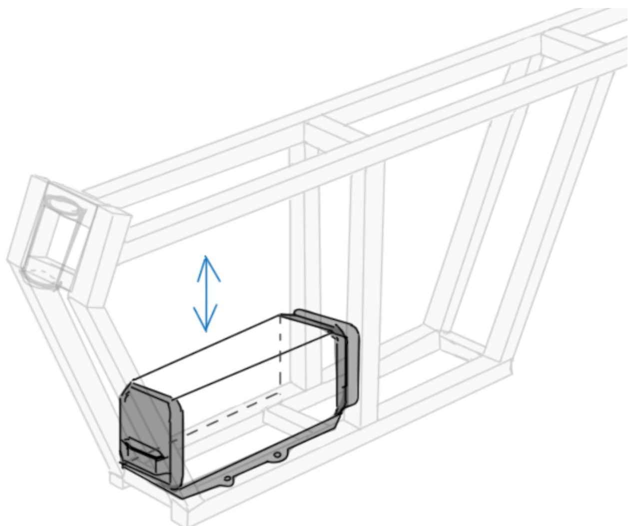
The battery management system is a central component of an electric drive. It is the control unit of the battery. It is recommended to select a battery that already contains a BMS in order to avoid time-consuming adaptations of a separate BMS to the battery.

Funded by
the European Union

4.2.3.2 Battery installation

Step	Instructions	Visual Assistance
Step 3.1-1	Components: • None Tools: • Calculator Process: a) Calculate the required capacity of the battery according to Chapter 4.2.3.1. b) Select an available, swappable battery (incl. BMS and housing) according to calculation results of a).	

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 3.1-2	Components: • Battery • Battery mounting • Base frame Tools: • Screws • Screwdriver • Tape Measure Process: a) Position the batteries as they are to be placed in the housing (see illustration). Note that the batteries can be pulled out of the holder and pushed back in again (only necessary for the recommended swappable battery concept). b) Measure the distances of the battery from the center axle of the vehicle to ensure even weight distribution. c) Attach the battery mounting to the base frame.	  

Funded by
the European Union

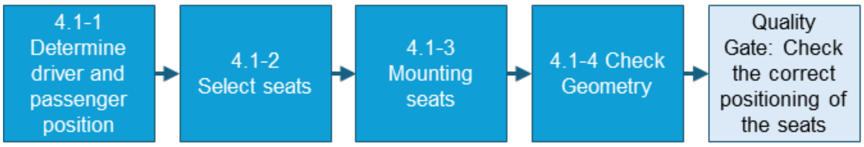
Quality Gate	• Check whether batteries can be inserted into the battery holder. • Check that the weight of the batteries is evenly distributed on the vehicle and that there is no imbalance around the longitudinal axis.	

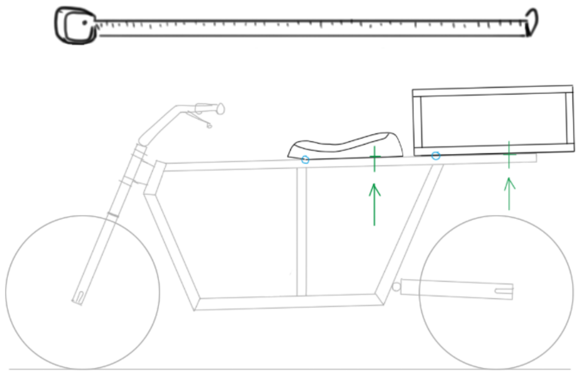
Funded by the European Union

4.2.4 Modular Carrier

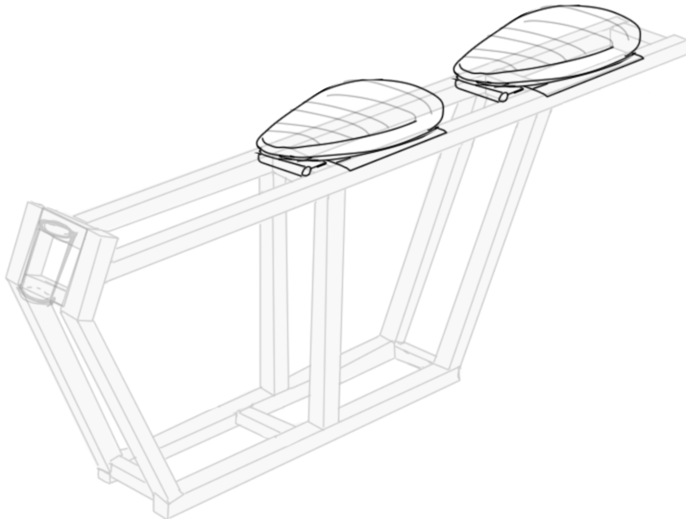
In order to design the eMotorbike as efficiently as possible to suit the different locations and associated requirements, the design of the eMotorbike is modular. It can be designed as a cargo or passenger version.

4.2.4.1 Seats

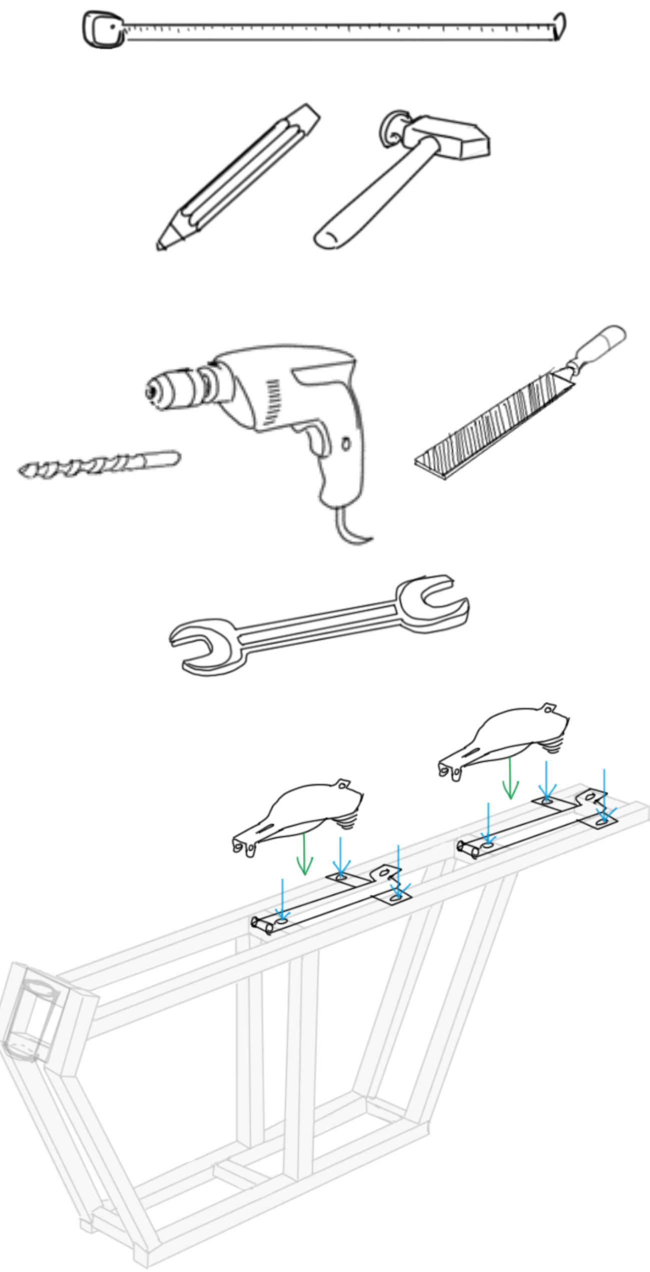


Step	Instructions	Visual Assistance
Step 4.1-1	Components: • None Tools: • Tape Measure Process: a) Determine the seating position according to personal preference. Ensure sufficient legroom for the passenger and a safe seating position for the driver. b) Mark the position of the driver's and passenger's hip point on the base frame.	

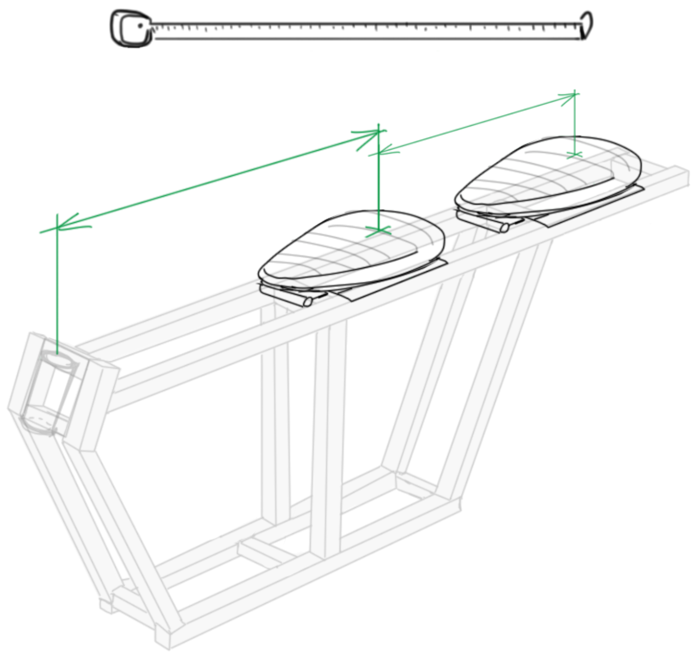
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.1-2	Components: • None Tools: • None Process: a) Select seats with seat frame according to your requirements and need regarding the driving environment and customer needs.	

Funded by the European Union

Step	Instructions	Visual Assistance
Step 4.1-3	Components: • Seat with seat frame Tools: • Drilling Machine • Punch • File • Screws • Nuts • Washers • Screwdriver Process: a) Position the seats so that the Hip Point of the driver and passenger is in the same plane as it is marked on the base frame (see Step 4.1-1). b) Mark the positions for bolting the seats to the base frame with a punch. c) Drill the holes for bolting the seat to the base frame. d) Debur the drilled holes. e) Attach the seat frame to the base frame with screws, washers and nuts. f) Mount the seat on the seat frame.	

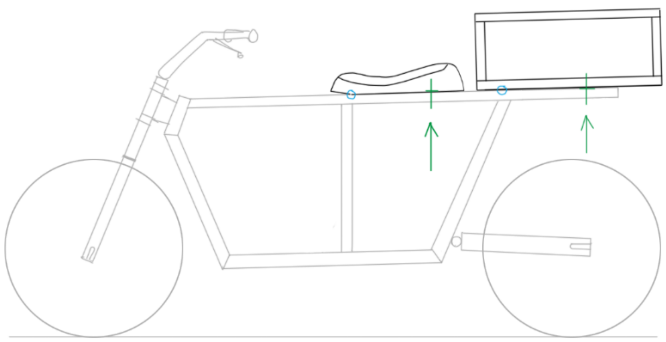
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.1-4	Components: • None Tools: • Tape measure Process: a) Check if the seats are in the right position so that the Hip Point of the driver and passenger are in the designated position.	
Quality Gate	Check the correct positioning of the seats	

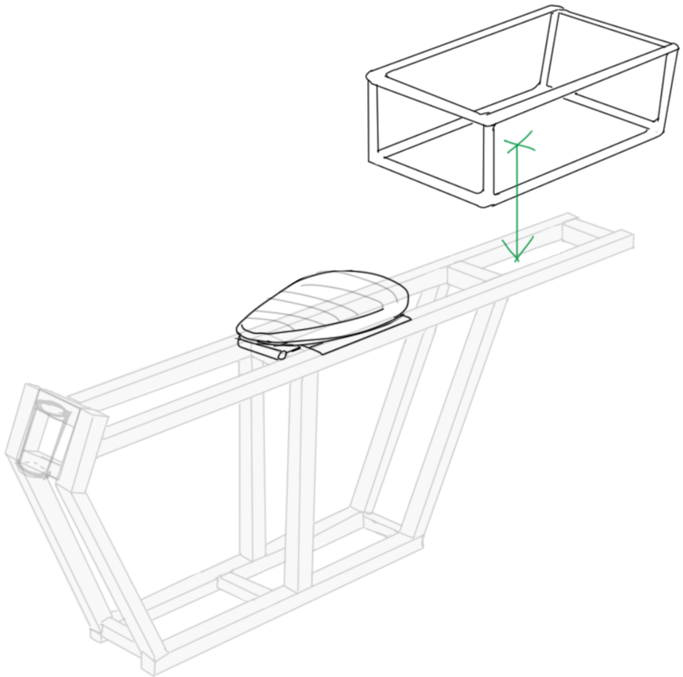
Funded by the European Union

4.2.4.2 Luggage Rack

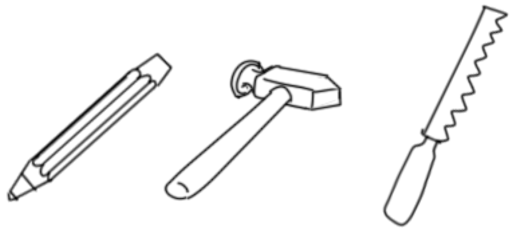
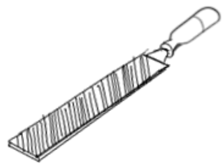
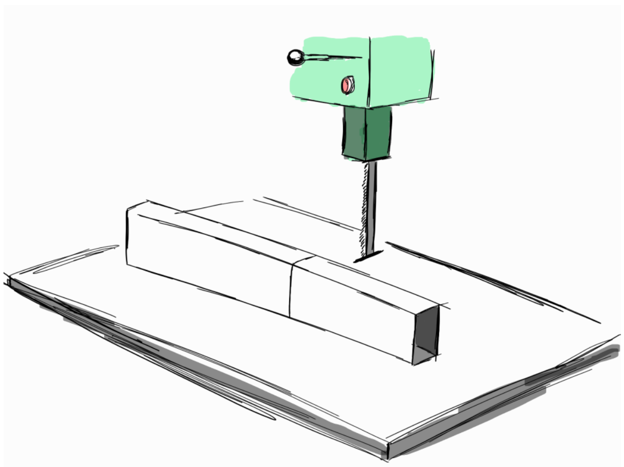
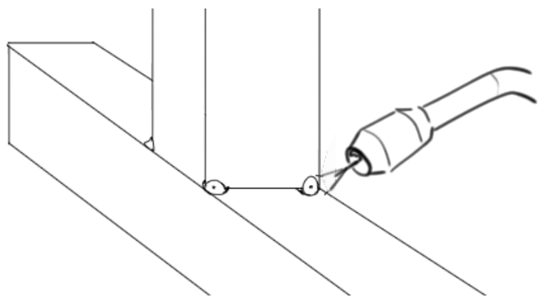
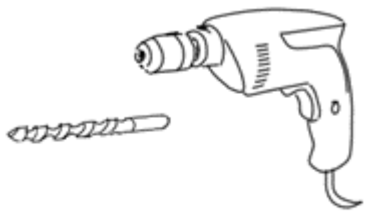
4.2-1 Determine Luggage Rack geometry → 4.2-2 Material selection → 4.2-3 Fabrication → 4.2-4 Determine fastening points → 4.2-5 Manufacture fixing points → 4.2-6 Fasten the Luggage Rack → Quality Gate: Check that the rack is firmly attached

Step	Instructions	Visual Assistance
Step 4.2-1	Components: • Base Frame Tools: • Tape Measure Process: a) Define the geometry of the luggage rack. Personal preferences can be taken into account. The luggage rack should be mounted symmetrically on the frame behind the driver's seat in the direction of travel.	 

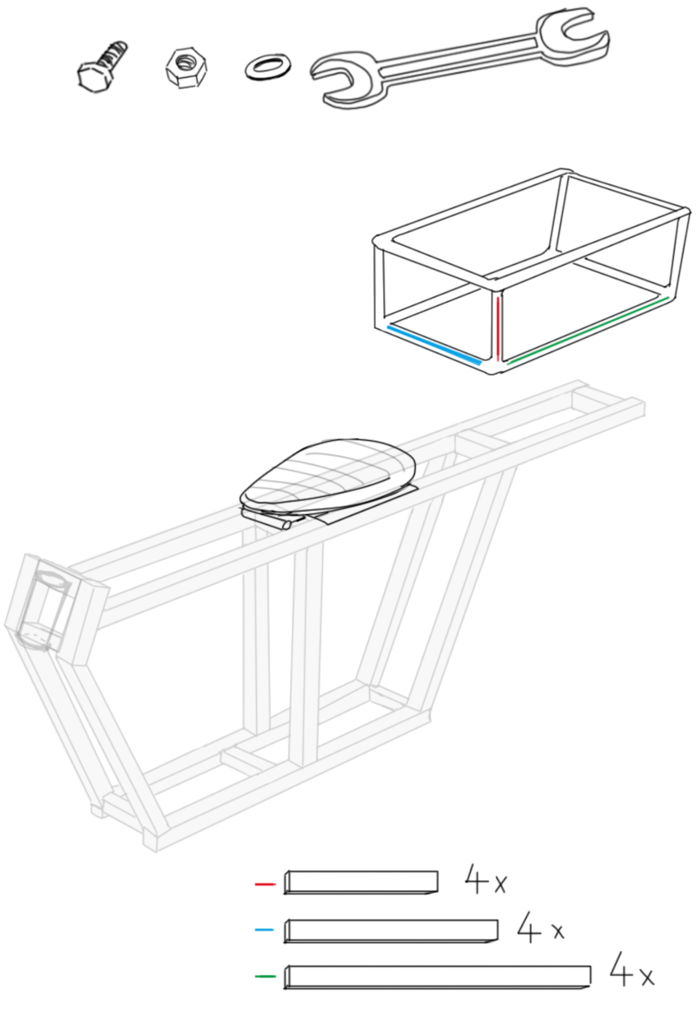
Funded by the European Union

Step	Instructions	Visual Assistance
Step 4.2-2	Components: • None Tools: • None Process: a) Identify the local requirements and availability of different materials for the manufacture of the luggage rack. It can be made of wood, plastic or metal. Depending on the material selected, note the processing characteristics. Deburr all sharp edges.	

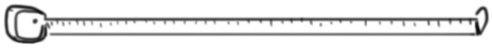
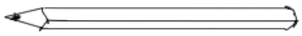
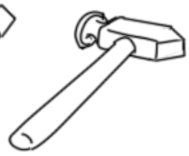
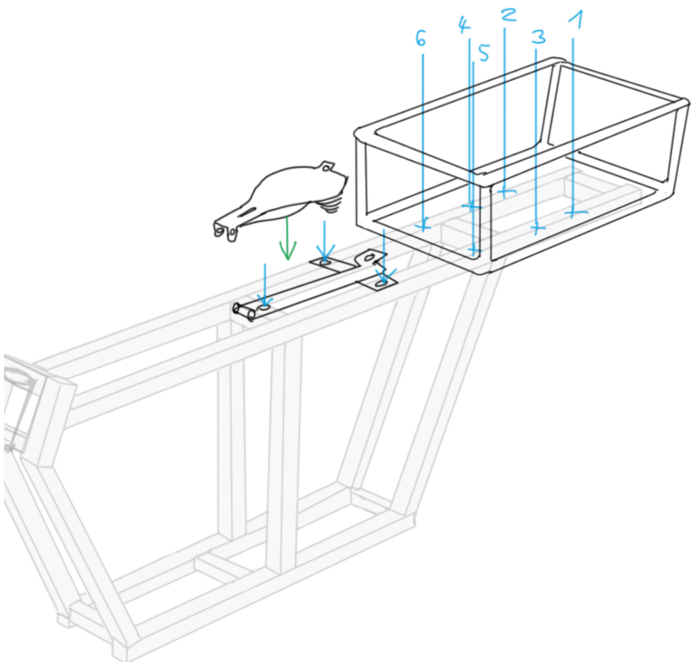
Funded by the European Union

Step	Instructions	Visual Assistance
Step 4.2-3	Components: • Raw material for Luggage Rack Tools: • Drilling Machine • Punch • File • Screws • Nuts • Washers • Screwdriver • MIG Welding Machine • Saw Process: a) Manufacture the luggage rack according to your personal preferences. Depending on the selected material, the joining technique, such as welding, screwing, ... should be chosen.	     

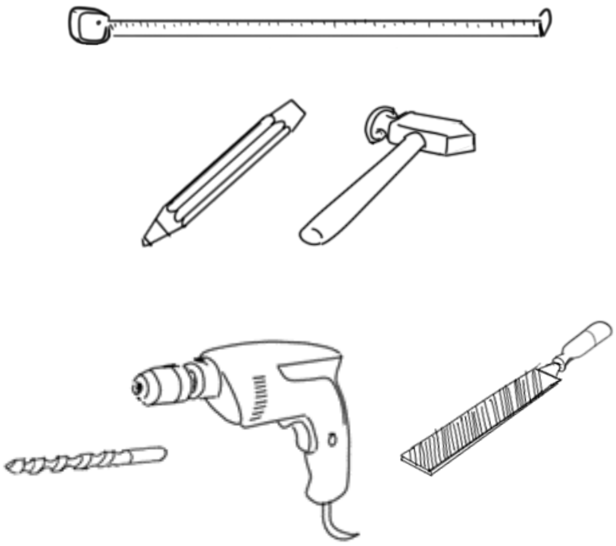
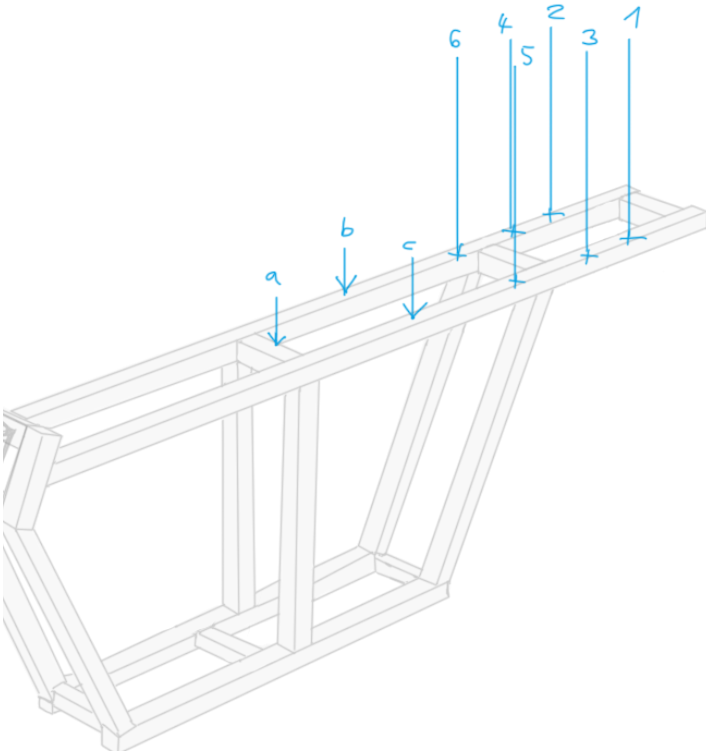
Funded by
the European Union

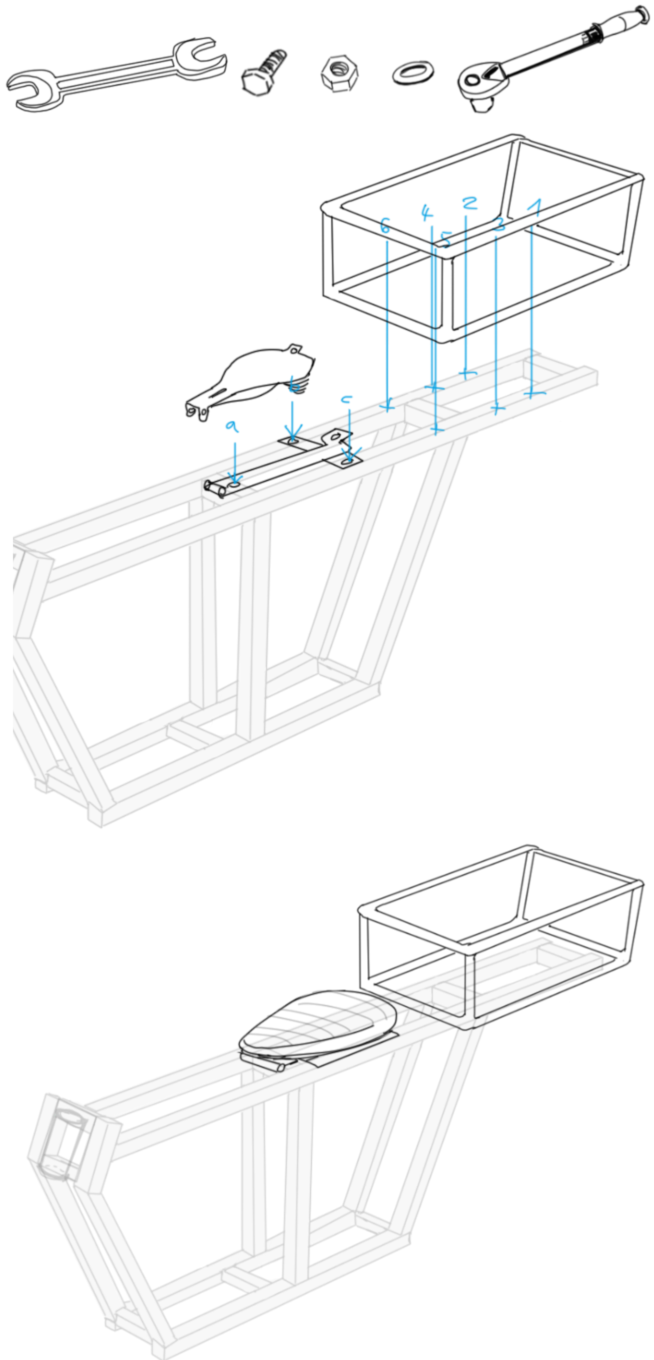
		

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.2-4	Components: • Base frame • Luggage Rack Tools: • Tape Measure Process: a) Determine the attachment points for the luggage rack on the base frame. Make sure that the rider is not restricted. Furthermore, the luggage rack should not protrude too far beyond the rear wheel, which could have a negative effect on weight distribution. Ideally, the luggage rack should be attached to the base frame at 6 points. The greater the distance between the attachment points on the frame, the stiffer the connection between the rack and the base frame. b) Mark the positions for bolting the seat to the subframe with a punch.	    

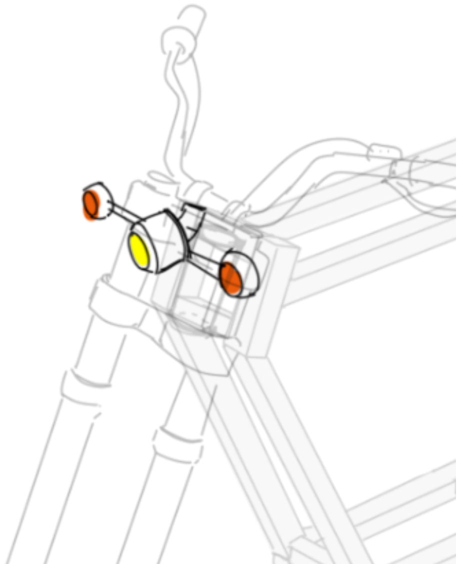
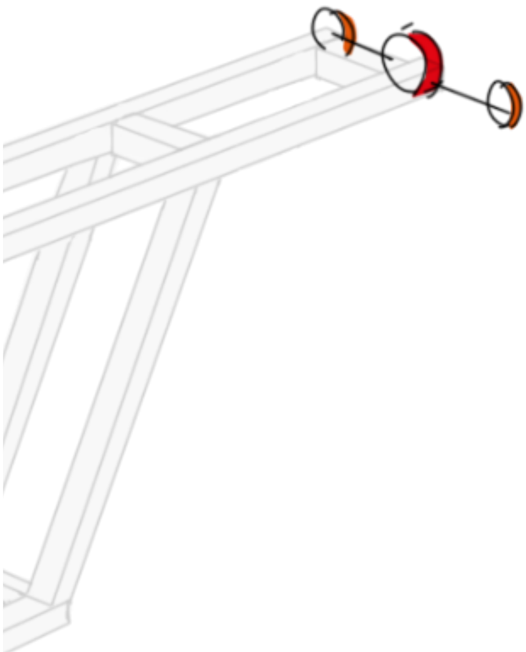
Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.2-5	Components: • Base frame • Luggage Rack Tools: • Drilling Machine • Punch • File Process: a) Mark the positions for bolting the seat to the subframe with a punch. b) Drill the holes for bolting the luggage rack to the base frame. c) Debur the drilled holes.	 

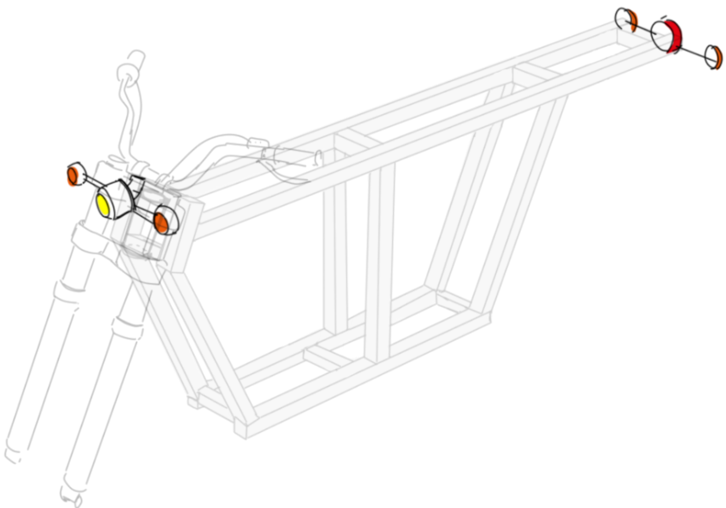
Step	Instructions	Visual Assistance
Step 4.2-6	Components: • Base frame • Luggage Rack • Screws • Nuts • Washers Tools: • Screwdriver • Open-end spanner Process: a) Attach the luggage rack to the base frame with screws, washers and nuts. b) Mount the luggage rack on the base frame.	
Quality Gate	Check whether the luggage rack is firmly attached	

Funded by
the European Union

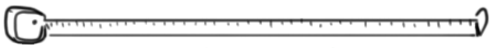
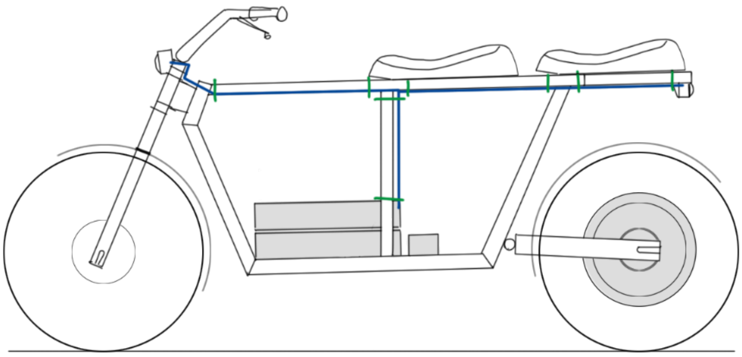
4.2.4.3 Lighting

Step	Instructions	Visual Assistance
Step 4.3-1	Components: • None Tools: • Calculator Process: a) Select suitable headlights, indicators, taillights and brake lights in accordance with the legal requirements at the place of use.	 

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.3-2	Components: • Headlight, indicators, taillights and brake lights Tools: • Tape measure • Calculator • Scriber needle • Drilling machine • Screws Process: a) Select suitable mounting points for the various lighting devices and install them by drilling and screwing. b) Fit switches for the headlight, brake lights and indicators on the handlebars. b) Make sure that the headlights provide sufficient illumination of the area in front of the vehicle and do not dazzle oncoming traffic.	 

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 4.3-3	Components: • Headlight, indicators, taillights and brake lights • Cables Tools: • Tape measure • Calculator • Zip ties • Soldering cobles • Solder Process: a) Plan suitable routes for laying the cables of the lighting equipment protected from environmental influences. b) Fasten the cables with the help of zip ties or alternative mounting options. c) Solder the cables or use connectors to connect the taillights, headlights and indicators to the power source	 

Funded by
the European Union

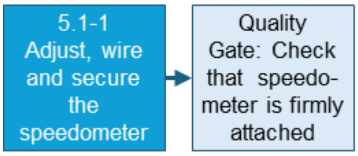
	and the signaling devices.	
Quality Gate	Check that headlights, indicators, taillights, brake lights and cables are firmly secured	

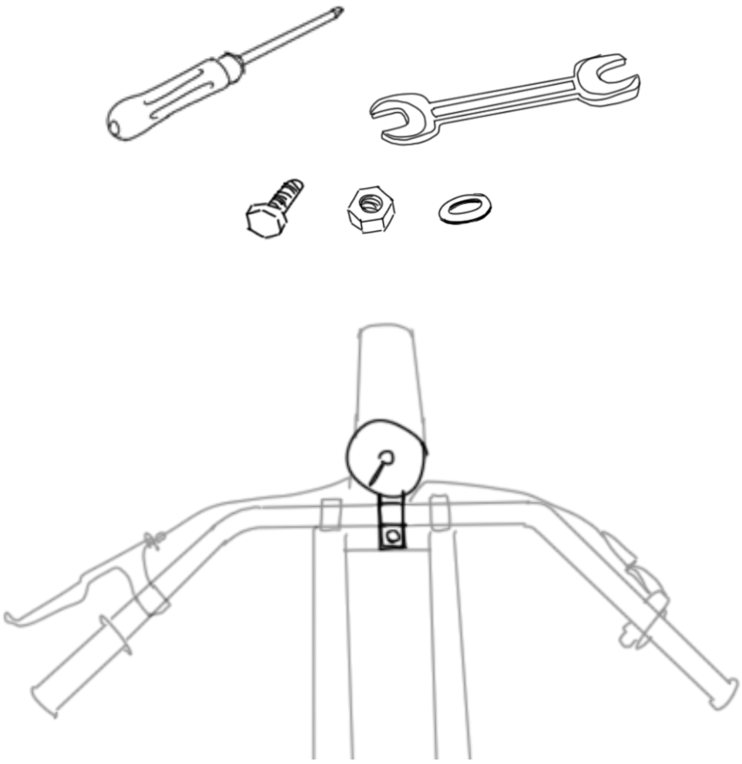
Funded by the European Union

4.2.5 Assembly

The various work packages required to complete the vehicle are described below. These include the speedometer, brakes, electrical wiring and further accessories.

4.2.5.1 Speedometer



Step	Instructions	Visual Assistance
Step 5.1-1	Components: • Speedometer • Clamp • Cable from Drive Train Unit Tools: • Screwdriver • Wrench • Bolts • Screw nut Process: a) Adjust the speedometer in the middle of the handling bar. b) Tighten the clamp with the Bolts and Screw nuts. c) Identify the Cable from the Drivetrain Unit. d) Connect the Cable from the Drivetrain Unit with the speedometer.	

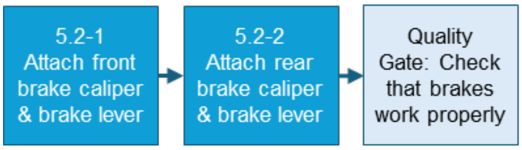
Funded by the European Union

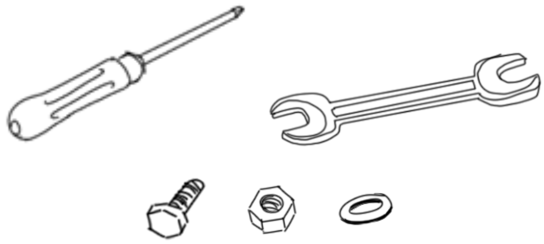
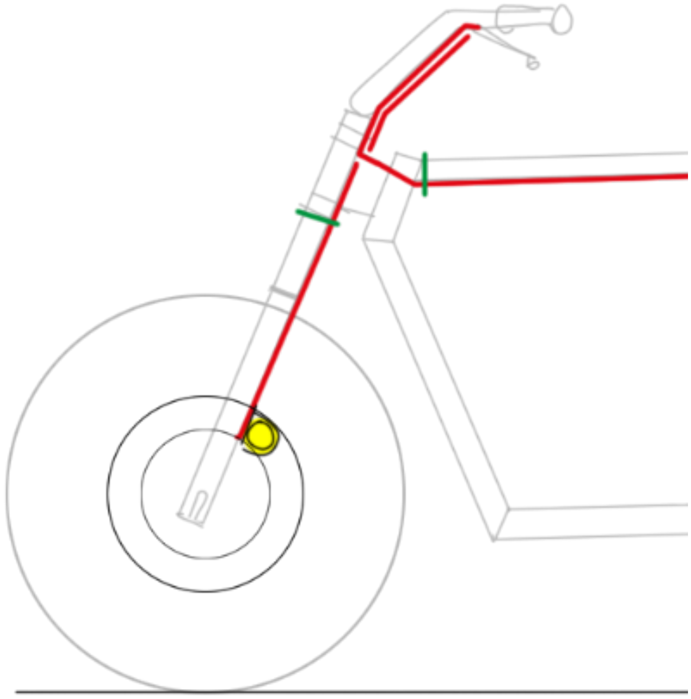
	e) Secure the cable with a suitable cable management system at regular intervals.	
Quality Gate	Check that speedometer is firmly attached	

Funded by
the European Union

4.2.5.2 Brakes

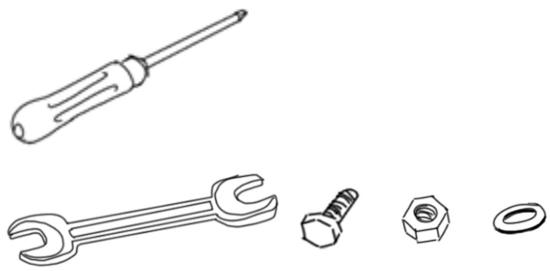
If available, **use screw adhesive** for each screw connection of the brake!



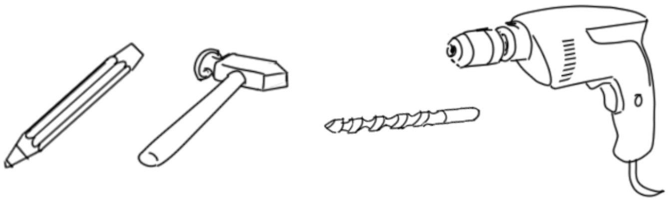
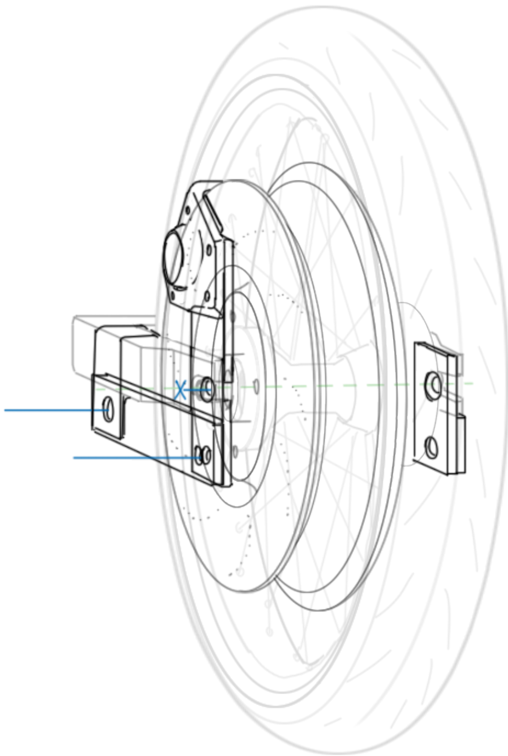
Step	Instructions	Visual Assistance
Step 5.2-1	Components: • Front brake • Base frame Tools: • Screwdriver • Wrench • Bolts • Screw nut • Screws • Open-end spanner Process: a) Attach the front brake caliper to the designated position on the suspension fork. b) In the next step, attach the brake lever to the handlebars. Make sure it is in a suitable position for comfortable and safe braking when you are sitting on the bike. c) Secure the brake line with cable ties, straps or	 

Funded by
the European Union

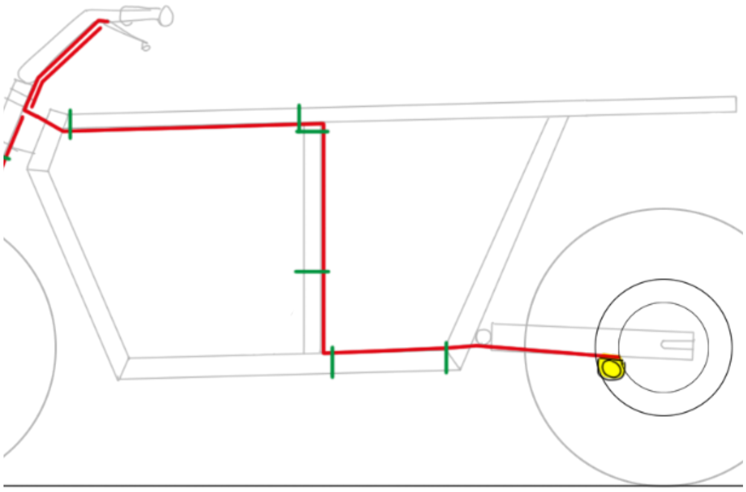
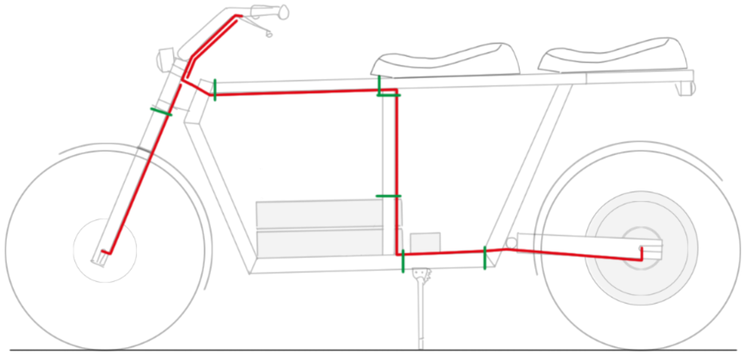
	similar to prevent it from slipping. Pay particular attention to the suspension travel of the suspension fork and the associated displacement of the brake hose.	

Step	Instructions	Visual Assistance
Step 5.2-2	Components: • Rear Brake • Base Frame Tools: • Screwdriver • Wrench • Bolts • Screw nut • Screws • Drilling machine • Center punch Process: a) First attach the brake caliper carrier between the rear wheel and the rear swing arm using the axle. Ensure that the carrier and the rear wheel are correctly aligned. The horizontal dropouts in the	

Funded by
the European Union

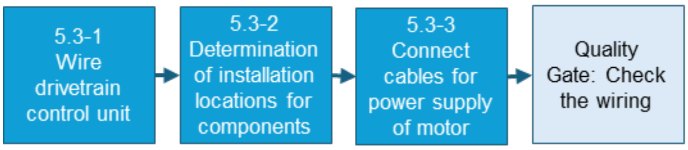
	rear swingarm allow for slight adjustments to be made. b) Use the supplied mounting material to realize a torque support of the brake caliper carrier via the rear swing arm. To attach the torque support, mark the holes at a suitable point, center punch them and drill through the rear wheel swingarm. c) Fit the torque support to the rear swingarm. d) Now fit the brake caliper to the brake caliper carrier and run the brake line via the pivot point of the rear swing arm over the base frame to the handlebars. Pay attention to moving parts that should not come into contact with the brake line. Furthermore, the brake hose should not be bent too much. e) Attach the brake lever to the	 

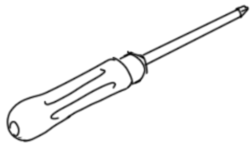
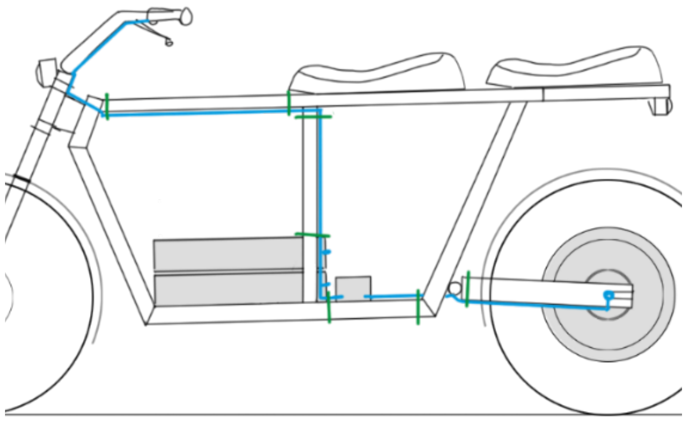
Funded by the European Union

	handlebars in an ergonomic and safe position for the driver.	 
Quality Gate	Check that the brakes are firmly attached and working properly.	

Funded by the European Union

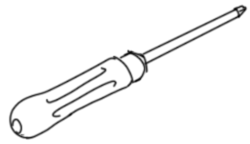
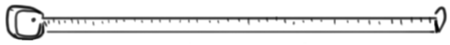
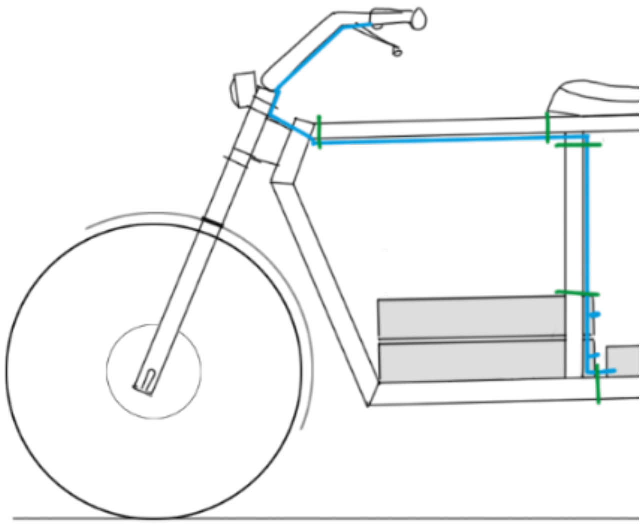
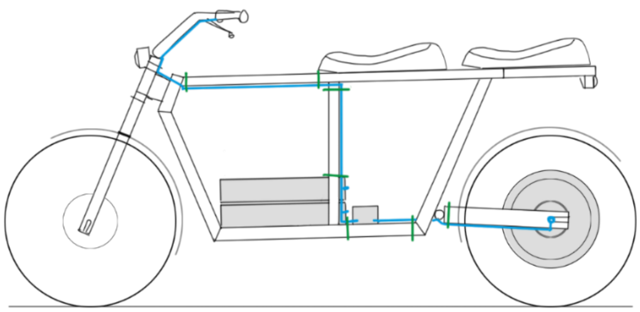
4.2.5.3 Electrical wiring



Step	Instructions	Visual Assistance
Step 5.3-1	Components: • Suitable cables for drivetrain – battery connection • Suitable cables for drivetrain control signals Tools: • Screwdriver • Cable ties/cable routing Process: a) Wiring of the Drivetrain control unit according to the manufacturer's information. b) Bundle the relevant cabling for the driver compartment (ignition key, power sensor, ignition), extend if necessary and route to the driver compartment. c) Bundle relevant cabling for power supply, extend if necessary and route to the battery. d) Secure the cables with a suitable cable	 

Funded by the European Union

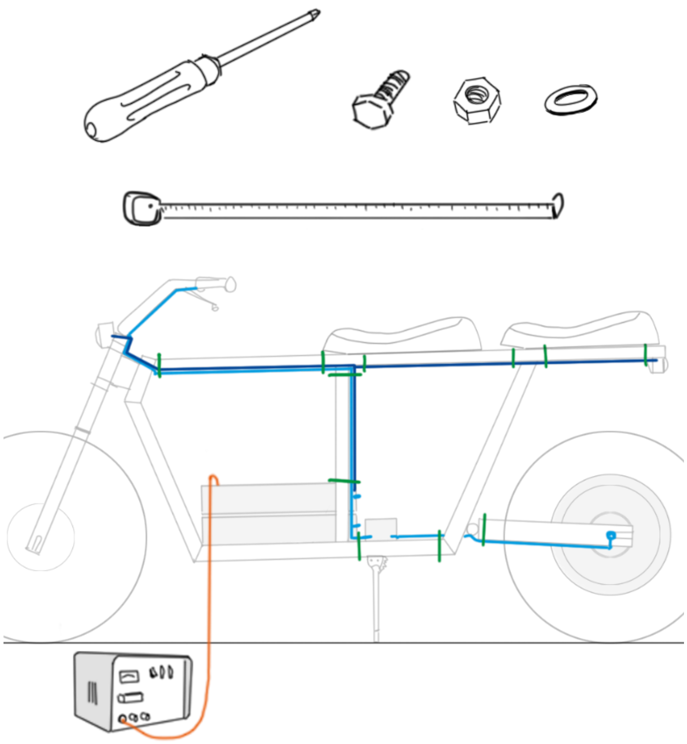
	management system at regular intervals. e) Make sure that the cables are routed as protected as possible from stone chips etc. Provide additional protection if necessary.	

Step	Instructions	Visual Assistance
Step 5.3-2	Components: • Driving relevant components (ignition key, power sensor, ignition) • Cables for driving relevant components (ignition key, power sensor, ignition) • Assembled handlebar Tools: • Screwdriver • Wrench • Screws • Bolts • Tape measure Process: a) Determination of the installation locations for the individual components (ignition key, power sensor, ignition) after ergonomic alignment. b) Route the corresponding cables for the relevant components to the specified installation locations. c) Secure the cables with a suitable cable management system at regular intervals. d) Connect cable and corresponding component.	   

Funded by
the European Union

	e) Attach component to corresponding installation location.	

Funded by
the European Union

Step	Instructions	Visual Assistance
Step 5.3-3	Components: • Battery • Battery charger • Cables for power supply Tools: • Screwdriver • Wrench • Screws • Bolts • Tape measure Process: **Be careful when working with high-voltage components** a) Identification of the cables for output power supply. b) Connect cables for the power supply of the motor and the battery.	
Quality Gate	• Check battery voltage and the correctness of the wiring. • Turn on the motor, the ignition and test if the motor is running with power supply. • If not: check the voltage at the motor input.	

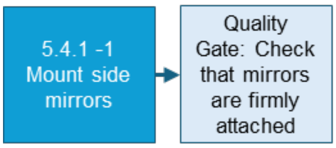
Funded by
the European Union

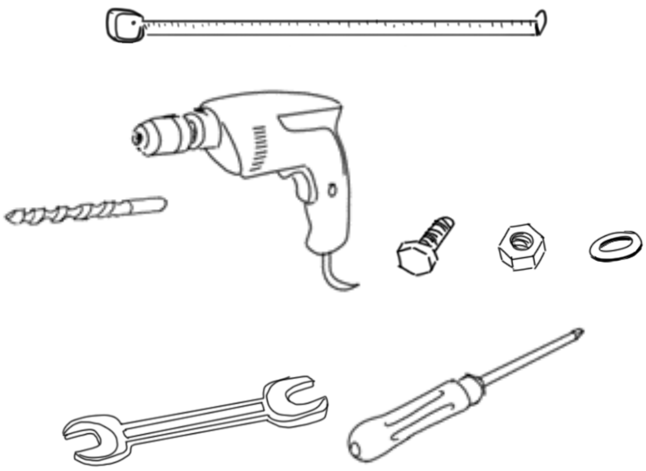
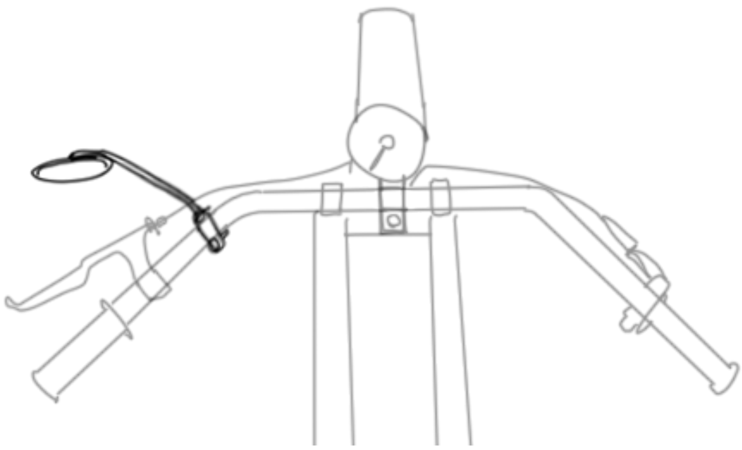
	• Check the motor wiring again according to manufacturer's information.	

Funded by
the European Union

4.2.5.4 Accessories

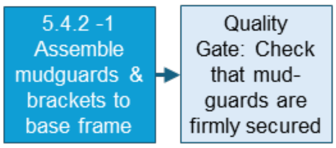
4.2.5.4.1 Side mirrors

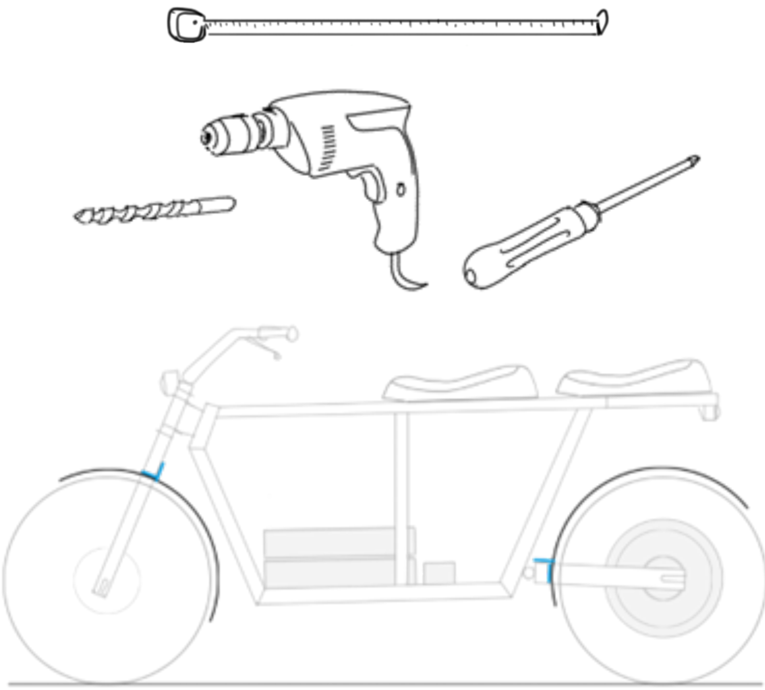


Step	Instructions	Visual Assistance
Step 5.4.1-1	Components: • Side mirrors Tools: • Screwdriver • Screw • Screw nut • Clamp Process: a) Mount the side mirrors on the handlebar, positioning them adjacent to the grips on either side. b) Secure the side mirrors using the clamps, bolts and nuts. Ensure a tight fit by properly tightening the fasteners. c) Check the viewing angle of the side mirrors and adjust them if necessary.	 
Quality Gate	Check that mirrors are firmly attached	

Funded by the European Union

4.2.5.4.2 Mudguards



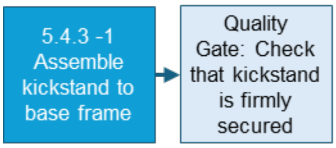
Step	Instructions	Visual Assistance
Step 5.4.2-1	Components: • Mudguards • Brackets Tools: • Screwdriver • Drilling machine Process: a) Screw one side of each bracket to one mudguard. b) Adjust the mudguards above the tire and in between fork. c) Assemble the other side of each bracket to the fork by drilling and screwing accordingly.	

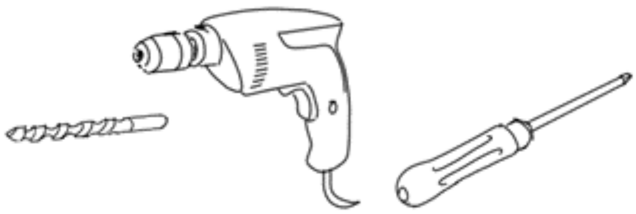
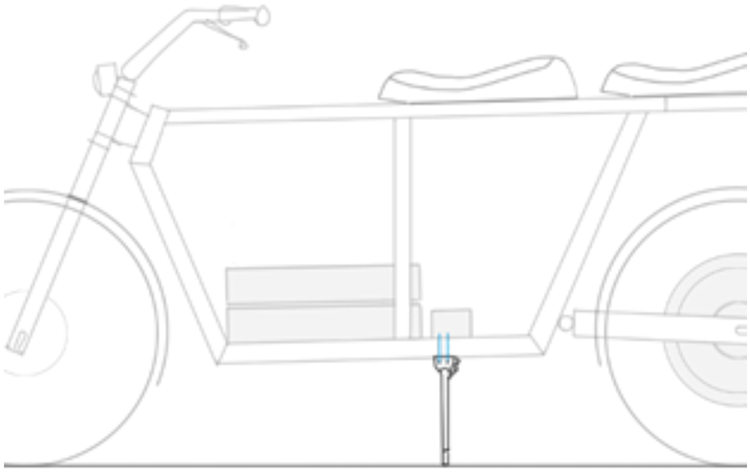
Funded by
the European Union

Quality Gate	Check whether mudguards are firmly secured	

Funded by
the European Union

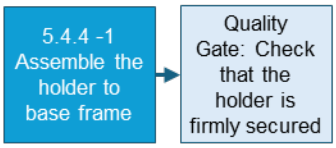
4.2.5.4.3 Kickstand

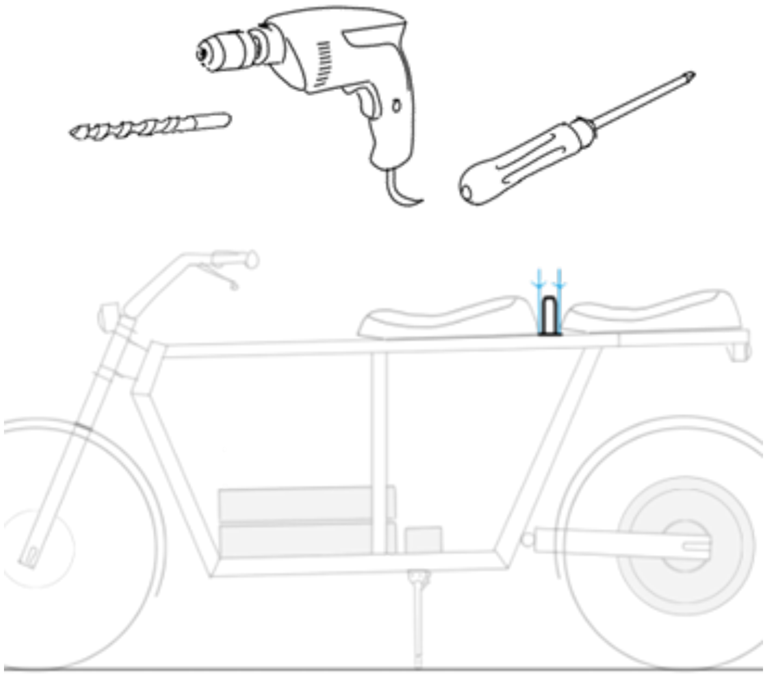


Step	Instructions	Visual Assistance
Step 5.4.3-1	Components: • Kickstand Tools: • Screwdriver • Drilling machine Process: a) Place the kickstand at the lowest profile of the base frame right behind the vertical profile in the middle of the eMotorbike. b) Assemble the kickstand to the frame by drilling and screwing accordingly.	 
Quality Gate	Check whether the kickstand is firmly attached	

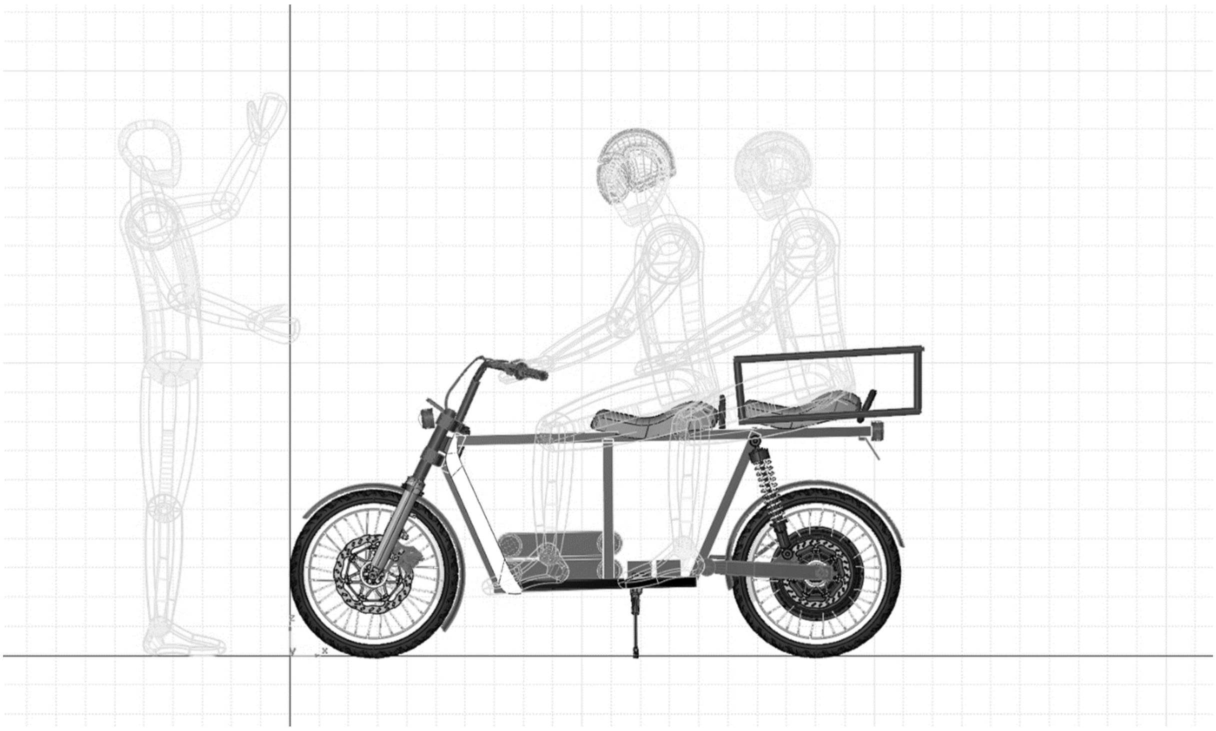
Funded by the European Union

4.2.5.4.4 Holder



Step	Instructions	Visual Assistance
Step 5.4.4-1	Components: • Holder Tools: • Screwdriver • Drilling machine Process: a) Place the holder in between the driver seat and the passenger seat. b) Assemble the holder to the frame by drilling and screwing accordingly.	
Quality Gate	Check whether the holder is firmly attached	

Funded by the European Union



In addition to assembly, a quality assurance checklist should be run through to ensure the safety and functionality of the eMotorbike.

General inspection

- Check the completeness of the vehicle (all parts and components present).
- Ensure all connections and fastenings are tight and secure.

Frame and structure

- Inspect the frame for cracks or damage.
- Ensure the base frame and support frame are correctly assembled, noting specified dimensions and angles.

Suspension and wheels

- Check the installation of the steering and front fork suspension.
- Ensure the wheels are securely mounted and spin freely.
- Inspect the rear springs and dampers for correct installation and functionality.

Drivetrain

- Ensure the drivetrain is properly assembled.
- Check the function of all moving parts and joints.

Energy storage

- Inspect the installation of energy storage components.
- Ensure all connections are secure.
- Test the function and charging capability of the battery/batteries.

Electrical wiring and lighting

- Check all cable connections for security and proper installation.

Funded by
the European Union

- Ensure the lighting systems (headlights, taillights, turn signals) are functioning correctly.

Braking system

- Inspect the brake components for correct installation.
- Test the brake function (including emergency braking).
- If a hydraulic brake is installed, ensure the brake fluid is at the correct level and the system is bled.

Steering and control

- Check the function of the steering.
- Ensure the steering operates smoothly and precisely.
- Test the alignment and adjustment of the front wheel.

Seats

- Ensure all seats are securely mounted.

Final Inspection and Test Drives

- Conduct a comprehensive test drive to check the functionality and safety of the vehicle.
- Inspect all systems during the test drive (brakes, steering, suspension, lighting, drivetrain).

Documentation and release

- Document all inspections and tests conducted.
- Ensure all user manuals and maintenance guides are provided.
- Release the vehicle for delivery if all tests are successfully passed.

Funded by
the European Union

5 Exploitation for production scale up mechanism

With regard to scale-up mechanisms, it is difficult to make a generic statement that is equally valid for all markets. Nevertheless, there are experiences and findings from the various model regions of the SOLUTIONSplus project that can help founders in their respective markets to successfully launch their companies on the market and establish themselves there. It is important to note that the following only summarizes the experiences from the respective regions that have arisen within the project and during the project period. No conclusions can be drawn about the success and continued success of the individual organizations in the model region beyond the duration of the project, as these were not known at the time this document was created.

Taking local tax guidelines into account, it can make sense to consider local cooperation partners and suppliers for the value chain of the own vehicle. Depending on local legislation, high taxes may otherwise be applicable to the import of EV components or HV batteries, for example. Long transportation routes for HV batteries are typically also associated with high transportation costs, irrespective of local tax conditions, as the transport of HV batteries is associated with high safety standards and risk surcharges. In addition to contractual agreements, the underlying company performance is also a decisive factor in the selection of local partners and suppliers. Previous quality assessments of the products and compliance with agreed delivery dates should also be taken into account. Consideration of local and national supply chains can also be useful in terms of delivery times. Various companies in the project have switched to local providers and suppliers over the course of the project, as external factors have led to enormous delays in international deliveries, which had a direct impact on the production of the companies themselves. Another advantage of a local and national supply chain is the availability and affordability of spare parts for the future end customers of the vehicles. This in turn is an important and central requirement of customers. When considering local suppliers, care should also be taken to prioritize locally available and therefore cost-effective materials. On the one hand, this can reduce production costs and, on the other, reduce the emissions caused by long transportation routes.

During development, the recycling of the vehicles should also be taken into account. On the one hand, this fulfils the requirement for a vehicle that is as sustainable and efficient as possible. On the other hand, the reuse of individual components of easily recyclable vehicles can also reduce production costs and thus increase sales potential.

For the companies that have developed vehicles within the SOLUTIONSplus project, the approach of using components that are available on the market and only developing or manufacturing the most necessary components themselves has proved worthwhile. This approach can also be seen in this guide, as it saves significant development costs and time, and therefore financial resources, especially in the initial phase of a young company and a new vehicle. For the companies in the SOLUTIONSplus project, quotas of 85% or more of purchased parts and components available on the market were common and target oriented.

Funded by
the European Union

Especially in markets and regions where electromobility is not yet widespread, the legal and authorization-relevant conditions as well as the funding conditions are often not tailored to electromobility and a sustainable mobility sector. For the companies involved in the project, it has therefore proved useful during the project period to proactively approach legislation and the government, to demonstrate the advantages of electromobility in terms of a more sustainable future and sustainable transport and thus to be able to influence the approval and funding conditions. In this way, it was possible to co-found individual national initiatives, influence strategic funding plans and create authorization requirements for light electric vehicles.

In the context of customer requirements for individual products, the enormous importance of direct feedback and detailed consideration of their own customers proved to be valuable for the companies involved in the project. There is no standardized solution that can be applied to all markets and all target customers. One example of this is the use of swappable batteries. Even if the principle of swappable batteries has become established and accepted in the majority of model regions and markets, in some regions, however, a further feedback loop has resulted in the use of permanently installed batteries with a larger capacity. In the examples mentioned, the concept adaptation resulted directly from the customer feedback and an adaptation of the customer requirements. An iterative development approach, that includes feedback from customers and transport operators, is therefore essential.

Furthermore, the experiences of the model regions have shown that it is not sufficient to consider the development of the company's own vehicle in isolation. Instead, the ecosystem as a whole must be considered, consisting of companies and digital platforms, workshops, charging infrastructure and the government, in order to reduce the pressure on individual companies and spread the risks. A major problem faced by the companies was the acquisition of well-trained personnel to support the development of the vehicles. The potential availability of well-trained personnel should therefore be considered when selecting the company's strategic locations. This can be achieved, for example, through local proximity or possibly even close cooperation with universities.

The above summary of the key findings and experiences of the companies in the SOLUTIONSplus project does not claim to be complete. Nevertheless, the findings show some ways of overcoming the initial hurdles of a young company and learning from the problems of the companies in the project. This document will therefore pave the way for entrepreneurial success.

Funded by
the European Union