



CHALMERS

Body design of electric three-wheeler

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Abstract

Electric three-wheeler manufacturer Omotion, located in Lund, Sweden, was in the process of improving the performance of their only existing vehicle model, the Omotion 2. A new vehicle model was desired in which the performance increase could be implemented. Omotion wanted to achieve a “modern” and “sporty” design which utilised the performance efficiently. Aerodynamics was therefore a concern. Included in the requirements was that the design had to have a roof over the occupants.

As a roof was a necessity, how individuals enter and exit the vehicle was considered in the work. Because the work was very aesthetics driven, aesthetic trends for motorcycles and sportscars in several Western European countries were studied. Naked and adventure motorcycles were determined to be trending and consisted of features such as exposed mechanics and small complex bodywork panels. Sports cars shared similarities such as low to the ground and slightly sloped hood. A function analysis was also done as part of the prestudy and guided the concept development. The function identified were kept vague to allow for a wide variety of solutions.

Concept development was done with the help of sketches, morphological matrices, CAD models, and a clay model. Concept generation was also attempted using artificial intelligence (AI) but was unsuccessful.

The work resulted in a satisfactory concept despite difficulties ascertaining the aerodynamic performance. Mechanical solutions to make the concept feasible would still be developed but the mechanisms were already in use on other vehicles. With continued development of the concept, Omotion should have the ability to realise the concept within ten years.

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Table of contents

- 1. Introduction1**
 - 1.1 The current vehicle1
 - 1.2 Aim3
 - 1.3 Sub-aims.....3
 - 1.4 Limitations.....4
- 2. Method and Execution4**
 - 2.1 Function analysis5
 - 2.2 Requirement specification.....8
 - 2.3 Trend analysis10
 - 2.4 Brainstorming.....11
 - 2.5 Morphological matrix.....14
 - 2.6 AI image generation.....18
 - 2.7 Sketching19
 - 2.8 Categorising and Simplifying20
 - 2.9 CAD modelling22
 - 2.10 Clay modelling29
 - 2.11 Requirement testing.....29
 - 2.12 Decision matrix31
- 3. Final concept34**
- 4. Sustainability35**
- 5. Discussion36**
 - 5.1 Reflection of methodology and results36
 - 5.2 Future development of concept36
- 6. Conclusion.....37**
- References.....38**
- Appendix.....i**
 - Trend Analysis ii
 - AI generations by Dalle 3..... viii
 - AI generations by Pixlr ix
 - AI generations by Microsoft Co-pilot x
 - AI generations by Adobe Firefly..... xii
 - AI generations by Photoshop Image Generative Fill..... xiv
 - Sketches by Mrs. Loren Romell xvi
 - Sketches by Mr. Tevis Romell xvii
 - Sketches by Mr. Joakim Romell..... xix

1. Introduction

This report describes the development of a three-wheeled motorcycle concept, conducted in partnership with the company Omotion.

The development of this concept comes at a time of major societal change from fossil fuel driven personal vehicles to electric vehicles. According to the International Energy Agency electric vehicle sales in Sweden alone rose from 40 000 units in 2019 to 171 000 units in 2023. (IEA, 2024). There are several possible reasons for this shift towards electric vehicles. Comparable sale prices, low charging costs, government incentives, and improving infrastructure could be attributed to the shift towards electric vehicles. Provided that electricity was generated through sustainable methods, emission of greenhouse gasses could be reduced. Emissions during manufacturing still exist and the benefits could be debated. However, the absence of any emissions by the vehicle while in operation provide an undeniable benefit to the immediate surroundings. This fact is especially favourable for a vehicle such as the one developed in this work. It is small and used for short commutes, which are common in densely populated areas. Additionally, owners would be able to go for joy rides with less concern about their environmental impact.

The concept is meant to be an improvement on their currently produced model and applicable in the distant future. Various requirements and desires for the concept are outlined throughout the report. Requirements and desires in fields such as aesthetics, ergonomics and aerodynamics are discussed, with emphasis placed on aesthetics. The report concludes with a final concept after a decisive evaluation and elimination process.

1.1 The current vehicle

Omotion has developed one electric three-wheeler, the Omotion 2. It has a top speed of 110 km/h and a range of 150 km. The Omotion 2 can be seen in Figure 1.



Figure 1: Omotion 2

The Omotion 2 has no doors and no roof. This allows users to easily step over the side, into the vehicle, and lower themselves into their seat, much like getting into a go-kart. Because there is no roof, occupants are required to wear a helmet. The vehicle does not include a dedicated storage space for personal belongings. Passengers have to either hold their belongings in their lap or at their feet. The charging system is user friendly, with a charging port mounted directly on one of the side panels. The charging port is a large black circle, easily identifiable. It does have an impact on the appearance of the vehicle, but it is not significant, especially as it fits well amongst all the other components like mirrors, ducts, and headrails.

The Omotion 2 maintains a low profile by only having the seats and seat posts higher than the bodywork. The silhouette of the vehicle has slight curves to the front and rear. The bodywork is curved but includes many straight-line features. The straight-line features give the vehicle an “edgy” style while the low profile maintains the sporty appearance. It is very short in length. The vehicle was not much longer than it was wide. When viewed from particular angles the width of the vehicle was more prominent than the low profile, hence the sporty appearance is diminished. Figure 2 shows this diminished effect.



Figure 2: Omotion 2 from perspective

Particular features, such as the circular, vertical headlights fitted into smoothly sculpted sockets, also diminished the “edgy” style. The low profile, slight curves, non-smooth surfaces, headlights, hood line, and projecting wheels all combined to give an appearance which resembled a toad. Figure 3 shows this resemblance.

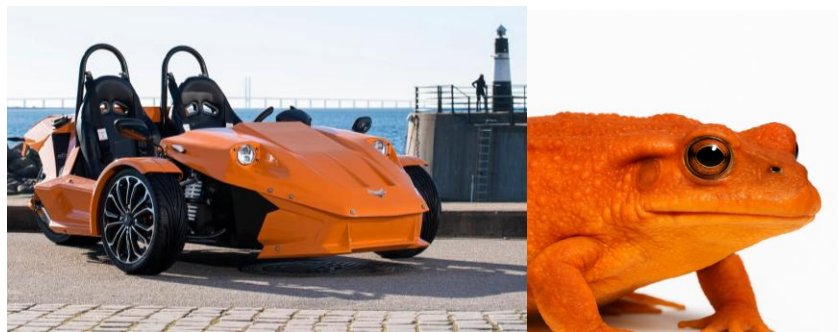


Figure 3: Omotion 2 beside a toad

The bodywork is constructed from composite materials which helps to keep the vehicle light weight and durable. Composite materials also allow for the fabrication of complex surfaces and shapes. Composite materials are not the most sustainable choice of material as they are difficult to recycle, and production is resource intensive.

1.2 Aim

The aim of this work is to:

Create concept bodywork for a practical and attractive 3-wheeler, meant for short commuting and includes a roof. The result of the work is to be a CAD model of the concept. The model is to have a roof above the occupants' heads and illustrations of the model are to be generated.

1.3 Sub-aims

To create a practical and attractive 3-wheeler concept many sub problems need to be addressed. Firstly, it needs to be determined what is practical and what is attractive. Other functions of the bodywork need to be identified and solved. For example, allow the occupants to get inside and keep the occupants cool. Sustainability is to be considered where possible.

Practicality of the vehicle includes aspects which are not directly linked to the bodywork, such as battery life. The right bodywork can improve battery life and indirect properties like this are not a major focus. Having a roof to protect occupants particularly from the weather is a definite improvement to practicality. Another aspect of practicality which is to be explored was the inclusion of storage space for light luggage. The following questions arise:

- How to enclose the vehicle with a roof?
- Is there sufficient room/ headspace inside?
- How much storage space is there?

Although Attractiveness is subjective, Omotion aims to sell to the masses, not a niche group. Therefore, a generalised understanding of the term attractive needs to be created. Omotion narrowed the generalisation down with the descriptors, “modern” and “sporty”. The following questions arise:

- What is attractive a.k.a. “modern” and “sporty”
- Is the concept bodywork attractive?

The functions of the bodywork need to be identified and addressed if significant in the concept stage. The following questions arise:

- What are the functions of the bodywork?
- Does the concept bodywork fulfil the functions?

With regard to sustainability, the following questions arise:

- Where can sustainability be implemented?
- How sustainable is the concept bodywork?

1.4 Limitations

The work conducted in this report was beyond scope of ongoing development within the company. That is to say, this work may not be applicable to the next model Omotion but for longer term development. Because the result of this work was not expected to be implemented in the near future, the level of detail was restricted to a digital low detailed concept level. The model generated did not need to be a finished product with every detail ready for production. A CAD model which could be easily adapted to unforeseen future changes was considered acceptable for this work. Sustainability was not a focus of the development; however minor considerations were to be made where possible.

2. Method and Execution

The development process conducted utilised many tools in succession. A summary of the process is seen in the paragraph below with references to the various tools.

The process began with understanding the functions of bodywork through the use of a function analysis¹. A requirement specification² was formulated from the demands and functions. Aesthetics was one of the functions, therefore a trend analysis³ was conducted and used to guide the idea generation. For each function, potential solutions were generated through brainstorming⁴. A morphological matrix⁵ was used to generate concepts by selecting unique combinations of potential solutions. The large quantity of sub-solutions resulted in an overwhelming number of possible concepts. The number of possible concepts had to be reduced, by eliminating potential solutions, thereby creating a reduced morphological matrix. In an attempt to quickly visualise the concepts, Artificial Intelligence (AI) image generation⁶ tools were used. The poor performance of the AI image generation resulted in the use of sketching⁷. Sketching was not as effective as anticipated with a low quantity of sketches produced with similarities between each other. The similarity of sketches allowed for categorising and simplifying⁸ of the sketches. For each group, one simple CAD model⁹ was made and evaluated. A clay model¹⁰ was created to evaluate proportions of the concepts. The concepts were checked¹¹ against the requirement specification. Desires from the specification were evaluated using decision matrices¹². The evaluation resulted in the selection of the final concept for further development. The following sub-chapters describe how each tool was used, why and the outcome.

2.1 Function analysis

A function analysis was done to create a list of functions which satisfy the customer's needs. Johannesson et.al (2013) provides examples of supportive and semantic functions; "Hold tools" and "give impression". In the case of the vehicle "protects against weather", "looks fancy" would be examples of this. Two flow charts were created to get a complete picture of the functions of a vehicle, beginning at origin and finishing at destination.

The flow chart in Figure 4 shows the stages a person needs to execute in order to get from origin to destination. Stages shown in green potentially require individuals to interact with the bodywork of the vehicle. The stages were kept quite vague to broaden the scope of solutions. For example, "interior is made accessible" can be achieved with more potential solutions than "Individual inserts key into bodywork and turns key to unlock vehicle".



Figure 4: Flow chart of stages during transport

The flow chart in Figure 5 shows the Interactions between the bodywork and its surroundings during a typical journey. Interactions occur all the time, even when the vehicle is standing unattended. Given that departure and arrival are essentially opposite, only half of the journey is detailed. Note that “accelerate” in the last stage shown means a further increase in speed.

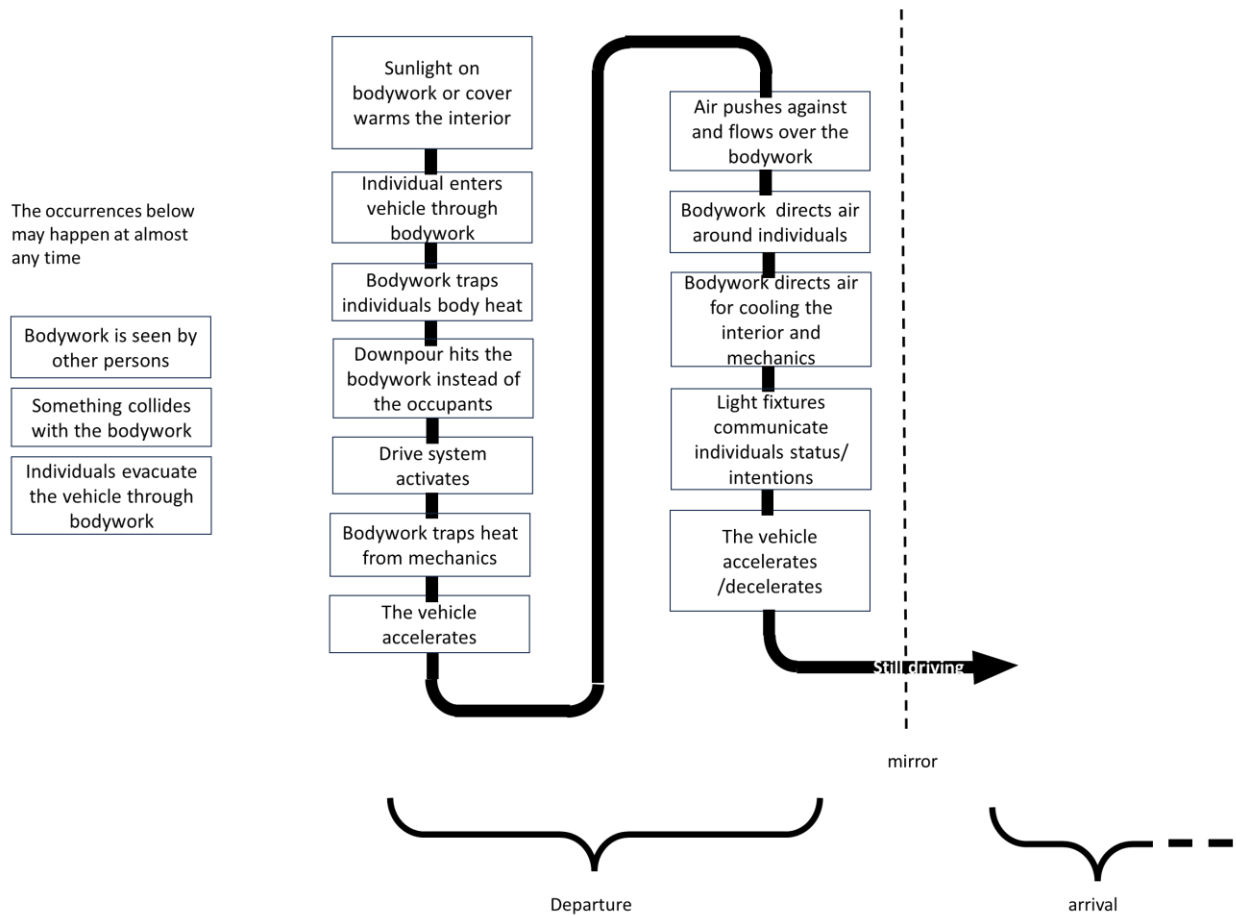


Figure 5: Flow chart of bodywork and surrounding interactions during a journey

The various sub-functions of the bodywork were identified so what needed to be accomplished during solution generation was known in detail. From the flow charts it was seen that the bodywork is involved in many operations and interactions. It can be stated that the body work has many functions which are related to several properties, for example protection, cooling, and aerodynamic drag. Table 1 shows all the functions identified for the bodywork, not including fixtures like lights

Body work Function
Secure interior
Provide baggage space
Poses electric charging connection
Provide entry
Control temperature for occupants
Control temperature for mechanisms
Protect occupants
Minimise aerodynamic drag
Create impression via aesthetics

Table 1: Functions of bodywork

The functions identified in the analysis were used to create a requirement specification.

2.2 Requirement specification

The requirement specification is a table that specifies any necessary or desired properties to the product being developed. Who set each particular property and how that property is to be evaluated is also included in the specification table. Measurable properties are given target measurements.

The specification follows that described by Pahl and Beitz (1995) and states if a property is a necessity or a desire by using a “must / want” column. Desired properties were given a weight on a scale of 1 to 3, representative of Omotion’s estimate on the importance of that property.

This tool was chosen because it acted as a very easy to follow checklist and compatible with several evaluation tools in the event of uncertainty.

Table 2 shows the requirement specification of the bodywork. The specifications are derived from the functions found in the function analysis and direct input from stakeholders such as Omotion, customers, and governing bodies. Explanations of the requirements and desires follow:

1. To maintain a small footprint, Omotion set a hard limit on the size of the vehicle based on a full-size vehicle. A desired limit was also set.
2. Storage space is desired. The volume of storage was set to 30L as it is a typical size of a small backpack. Omotion believes target customer want the vehicle to fit two adult persons.
3. Omotion would like to reduce the aerodynamic drag as it would improve the performance of the vehicle.
4. Omotion believes their target customer want a modern and sporty vehicle. Omotion did not have any specific definitions, themes, or features to describe modern and sporty. The customer ultimately decided if the vehicle is attractive or not, but Omotion was set to evaluate concepts.
5. Comfort was broken into three properties regarding protection and ergonomics. Protection is simple enough to guarantee but ergonomics is much more difficult to evaluate at a concept level. Hence only the sitting position is set as a requirement. Evaluation of entry motion would be estimated with help of a CAD model.
6. Safety is highly regulated by the EU.
7. Environmental impact is also very regulated by the EU.

Requirement list						
Omotion bodywork						
Conducted by Joakim Romell		Created: 01/09/2024		Modified 23/4/2025		
#	Requirement	Metric value	M = Must W= want	Weight	Requirement setter	Verification method
1	Size					
	Total space occupied by vehicle	Max: 2.5 m x 4.0 m x 2.0 m (W x L x H)	M		Customer	CAD model
	Total space occupied by vehicle	Max: 2 m x 3.4 m x 2.0 m (W x L x H)	W	2	Customer	CAD Model
2	Convenience					
	Space for baggage	Min: 30 L	W	1	Customer	CAD Model
	Seating for two adults	-	M		Customer	CAD Model
3	Performance					
	Less drag than Omotion 2	N/A	W	2	Omotion	-
4	Aesthetics					
	Sporty	-	M		Customer	Subjective review
	Modern	-	M		Customer	Subjective review
5	Comfort					
	Protects occupants from the elements	-	M		Customer	-
	Ergonomical sitting position	-	M		Customer	-
	Ergonomical entry method	-	W	3	Customer	
6	Safety					
	According to government / EU standards*	(EU) No 168/2013	M		Government	-
7	Environmental impact					
	According to government / EU standards*	(EU) No 168/2013	M		Government	-

Table 2: Requirements specification

The requirement specification is later used to check if concepts possess the necessary properties. Desired properties require a deeper analysis with the help of a decision matrix.

2.3 Trend analysis

The trend analysis conducted is a collection of observations of the styles of vehicles deemed relevant. The full Analysis can be found in the Appendices. Relevant vehicles such as sports cars and motorcycles recently registered in countries of target customers. This was done to determine the current preferences of target customers, and what was meant by Omotion’s requirement of modern and sporty appearance. These preferences were added to the requirement specification but additionally the analysis provided knowledge into how to create desired solutions.

For the trend analysis to be relevant, several limitations were set.

- Omotion’s customer base had not yet extended beyond Western Europe. Europe was therefore chosen as the boundary. To be more certain of an overall trend, trends within several European countries were studied.
- Newly registered vehicles were studied in the trend analysis. This ensured that the observations made were for modern vehicles.
- The different types of vehicles studied were limited to motorcycles and sports cars. These shared similar properties to Omotion’s such as they are personal vehicles, utility was not its main purpose, performance was important, and aesthetics was important.

Price was considered as an influencing factor on popularity. Since price does not determine what is modern or sporty, observations were not made solely on popularity. Sport bikes, which are more expensive, were included when studying motorcycles despite not being amongst the most popular types of motorcycles. This was done as it was expected for sport bikes to possess sporty features.

Popularity of a specific models of sports cars was not used to determine trends. Rather, randomly selected models from manufacturers with the largest sold variety of sports cars. The thought was that these manufacturers may be trendsetters.

The trend analysis found conflicting features between motorcycles and sports cars. However, all features observed could be considered “sporty”. If applied correctly, any selection of these features could result in a “sporty” concept. The results of the analysis can be seen in Table 3

"modern" & "sporty"	
Motorcycles	Sports cars
Built of small complex surfaces	Made of large panels with limited complexity
Leaves some mechanical/structural components visible	Does not contain a lot of accessories or display mechanical components
Multi-coloured, primarily two tones: colour + black	Is one predominant colour with black features
	Includes openings in front and behind the front wheels
	Leaves little space below the car
	The headlights are longer than they are wide
	The middle of the car is not as wide as the wheels
	The windshield is angled with a lot of slant
	The hood has a slight gradient down so that it is lower than the rear

Table 3: Trending features relevant to Omotion’s ongoing development

Additional to descriptors of terms modern and sporty, themes were observed in the trend analysis. These themes are defined as follows:

“sleek” – style composed by primarily larger simpler surfaces which cover the entire vehicle.

“edgy” – style which is composed by complicated surfaces and exposed mechanical features

2.4 Brainstorming

Brainstorming, collectively thinking of solutions to problems, was the first step towards creating a concept. Four participants took part in the brainstorming. When brainstorming solutions to the various functions identified were explored. Because solutions were generated independently, a solution for a particular function/requirement may cause failure of another function/requirement.

Brainstorming was chosen because it was simple to execute with rules conducive to generating large quantities of solutions. The rules applied are described by Johannesson et.al (2013)

The solutions generated are shown under paragraphs for function.

Secure interior

This refers to locking and unlocking the vehicle.

Potential Solutions:

- No lock
- Physical key to be inserted
- Remote control
 - Remote key
 - Key proximity detection
 - Mobile app
- Fingerprint / facial identification

Provide baggage space

Baggage solutions were expected to have minimal space. Omotion’s suggestion was to have space behind the occupants. This suggestion required volume within the vehicle and bodywork to be allocated for storage. It had potentially less visible impact than other solutions such as side bags.

Potential Solutions:

- No storage
- Storage mounted on outside of body
 - Rack on back/roof
 - Rack/s on sides
 - Pod on back/roof
 - Pod/s on sides

- Storage space within body
 - Behind occupants
 - Between occupants
 - Beside occupants
- Trailer

Poses electric charging connection.

The existing Omotion 2 was charged by manually plugging the vehicle into a power source. This was the most common form of charging though development towards robotic assistance and wireless charging was being explored by other companies.

Potential Solutions:

- Manual plug-in charging
- Automated plug-in charging
- Wireless charging

Provide entry

The method of entering the Omotion 2 was to step into the vehicle and then lower oneself into the seat. Given that the newly developed model had to have a roof, this method of entering the vehicle was not possible. Unless the roof was removed, individuals needed to duck below the roof when entering the vehicle. Ducking while climbing into a car is very common but the low height of Omotion 2 would make this very difficult.

Potential Solutions:

- No door to open
- Traditional hinged door
- Door is “virtual”
- Gull-wing-doors
- Roof incorporated into doors
- Roof slides out of way
- Seat slides into position

Control temperature for occupants

Creating an enclosed environment required thought towards the temperature within the enclosure. The vehicle was expected to be quite small, and it would be very quick to heat up. The low relative volume to surface ratio was beneficial for cooling the interior but the resulting temperature was difficult to assess in this work.

Potential Solutions:

- Alternative cooling, e.g., air conditioning
- Openable bodywork

Control temperature of mechanics

Temperature control of mechanical components was important for proper functioning of the vehicle. The current Omotion 2 used openings in the bodywork near radiators to allow for heat transfer away from the mechanical components. That is to say, the existing components are air

cooled. Exposure to air was therefore critical.

Potential Solutions:

- Openings in bodywork / air ducts
- Exposed mechanics
- Alternative cooling, e.g., water cooled

Protect occupants

The vehicle and its bodywork had to meet standards found in (EU) No 168/2013. From the function analysis it was seen that the bodywork protected individuals from weather conditions, wind, and foreign objects.

In 2018 Ferrari released the SP1, which featured a virtual windshield. This technology forces air upwards in front of occupants which creates a “virtual” windshield. A simplified illustration can be seen in Figure 6. The protective level of this type of windshield was uncertain but added to potential solutions. Note that a helmet was still required for this solution.

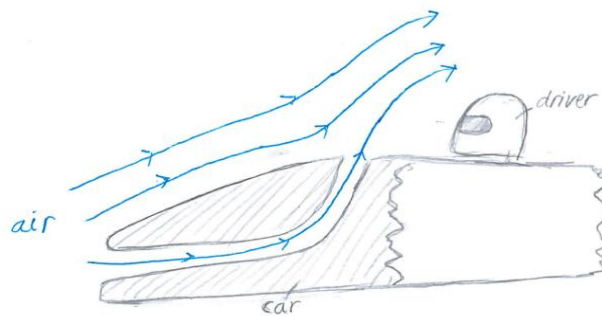


Figure 6: Simplified illustration of virtual windshield

Potential solutions:

- Roof + windshield
- Roof + virtual windshield

Create impression via aesthetics

From the trend analysis it was observed that motorcycles and sportscars had large differences between them despite both considered “modern” and “sporty”. Motorcycles had bodywork which used a lot of small, complicated surfaces and exposed mechanical features of the vehicle. This feature is referred to as “edgy”. The bodywork of sports cars used primarily larger simpler surfaces which covered the entire vehicle. These features are referred to as “sleek”.

“Sleek” and “edgy” encompassed only four of the thirteen features identified as “modern” and “sporty”. However, other features are not needed as potential solutions as their respective counterparts are not desired, as shown by the trends. For example, stretched headlights was a desired feature, shown by trends, so including stretched headlights and not stretched headlights

as potential solutions was not necessary. Not stretched headlights could already be eliminated. Therefore, only conflicting features are used as potential solutions.

Potential solutions:

- Sleek
- Edgy

Note that “sleek” and “edgy” were not binary properties. Complex curved surfaces could create a blend between “sleek and “edgy”. “Sleek” and “edgy” was however be treated as binary solutions for simplicity, even though blending may occur during solution development.

2.5 Morphological matrix

A morphological matrix, as described by Johannesson et al. (2013) is a table consisting of all the solutions to functions, used to create a “total solution” a.k.a. “concept”. A morphological matrix was chosen because it could provide all possible concepts.

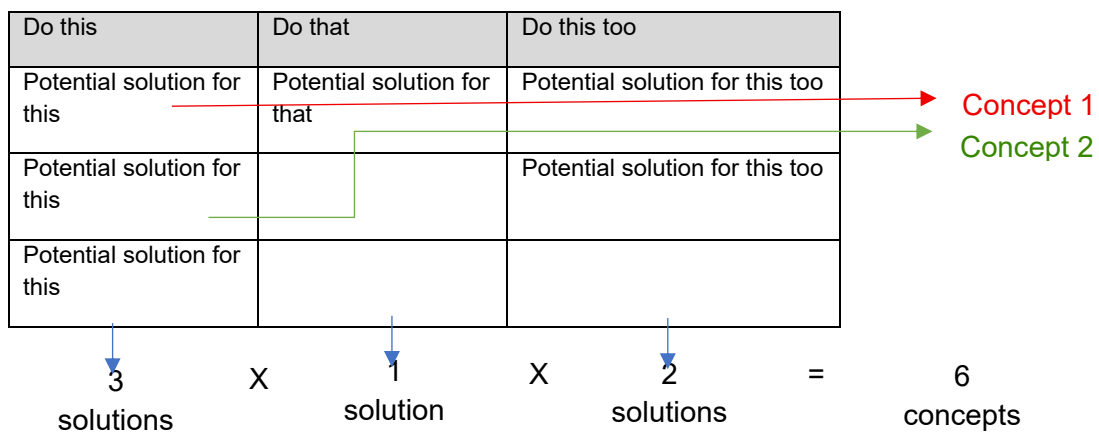


Figure 7: morphological matrix explanation

In the example, Figure 7, there are 3 solutions to the function “Do this”, 1 solution for the function “Do that” and 3 solutions for the function “Do this too”. To create a concept, one solution is chosen for each function. To create unique concepts a different combination of solutions is chosen as exemplified by Concept 1 and Concept 2.

Assuming all solutions are compatible with each other, the total number of possible concepts is found by multiplying together the number of solutions for each function. In the example there are $3 \times 1 \times 2 = 6$ ways to create a concept.

Table 4 shows the morphological matrix achieved for all the identified potential solutions for bodywork functions.

	Functions							
	Secure interior	Provide baggage space	Possess electric charging	Provide entry	Control temperature for occupants	Control temperature for mechanics	Protect occupants	Create impression via aesthetics
Potential solutions	No lock	No storage	Manual plug in charging	No doors	Alternative cooling of interior e.g. Air conditioning	Air ducts / openings in bodywork	Roof + windshield	Sleek
	Physical key	Storage within vehicle	Automated plug in charging	Traditional hinged doors	Openable bodywork e.g. windows, hatches	Exposed mechanics	Roof + virtual windshield	Edgy
	Remote control	Storage outside vehicle	Wireless charging	Virtual door		Self-cooling mechanics		
	Fingerprint / facial recognition	trailer		Gullwing doors				
				Roof incorporated into doors				
				Roof slides / lifts out of way				
				Seat slides into position				
				Removable door				

Table 4: Morphological matrix

This morphological matrix resulted in $4 \times 4 \times 3 \times 8 \times 2 \times 3 \times 2 \times 2 = 9216$ concepts. Not all solutions were compatible, but the difference would not have reduced the number of concepts significantly enough to be reasonable. Due to the large number of concepts, solutions were removed with varying reasoning. The solutions removed for each function and the reasonings are explained in Table 5.

Function	Removed solution	Reason
Provide entry	No doors	Protection provided by the roof would be reduced without encapsulating the occupants, which requires doors.
	Virtual doors	Unlike a virtual windshield, doors should be able to protect occupants from the environment even when the vehicle is stationary. Virtual doors would not provide this protection.
	Seat slides into position	Though this sub-solution is a viable one, too much development is necessary for the seat alone. Simpler sub-solutions are preferred.

	Removable door	Though this sub-solution has the potential to make entry very easy, having a loose piece is not desirable.
Protect occupants	Roof + virtual windshield	the technology is too new and too complicated to be set as a reliable sub-solution.
Control temperature of mechanics	Self-cooling mechanics	This sub-solution places less requirements on the bodywork but the features otherwise necessary were observed as common style features. Though it would be possible to create false cooling features in the bodywork, it is interpreted as unnecessary if the features can instead be made useful.
Control temperature for occupants	Alternative cooling of interior, e.g., air conditioning	The current Omotion 2 does not utilise air conditioning. Introducing air conditioning to the design would also require development with regards to space and electronics. This is determined to be too much work for the ongoing development.
Provide Electric charging connection	Wireless charging	The benefit of this sub-solution would be that the bodywork does not require any charging port, and that the user may not need to spend time connecting the charging cable. The technology is however not developed to a reliable point yet and would require more development from Omotion on how to incorporate it. Having a charging port impacts the bodywork the most, of the sub-solutions, but the impact is deemed insignificant.
	Automated plug in charging	Automated plug in charging may introduce additional requirements such as placement of the charging port, accessibility, the kind of port, etc. Since the automated technology is not yet developed, there are too many uncertainties to guarantee that automation would even be compatible.
Provide baggage space	Trailer	The impact on the aesthetics is considerable. Baggage should not be complicated to carry, and needing to connect and manoeuvre with a trailer is determined to be unnecessarily complicated

Table 5: Removed solutions and reasonings

Additionally, the function “Secure interior” was removed entirely because all the solutions provided had little significance to the bodywork of the vehicle.

After reducing the number of solutions for each sub-function, the reduced morphological matrix, shown in table 6 was created.

	Functions						
	Provide baggage space	Possess electric charging	Provide entry	Control temperature for occupants	Control temperature for mechanics	Protect occupants	Create impression via aesthetics
Potential solutions	No storage	Manual plug in charging	Traditional hinged doors	Openable bodywork e.g. windows, hatches	Air ducts / openings in bodywork	Roof + windshield	Sleek
	Storage within vehicle		Gullwing doors		Exposed mechanics		Edgy
	Storage outside vehicle		Roof incorporated into doors				
			Roof slides / lifts out of way				

Table 6: Reduced morphological matrix

None of the remaining sub-solutions appeared to be incompatible with each other. The total number of possible concepts was therefore found by $3 \times 1 \times 4 \times 1 \times 2 \times 1 \times 2 = 48$

48 concepts was estimated to be reasonable number of concepts for which to create simple visualisations of. The creation of these visualisations began with the use of AI image generation.

2.6 AI image generation

AI was used in an attempt to quickly generate all the concepts generated by the morphological matrix.

The following AI tools were used:

- Dalle 3
- Pixlr
- Microsoft Co-pilot
- Adobe Firefly
- Photoshop Image Generative Fill

Most AI tools worked such that the user held a conversation with the AI tool. In the conversation the user would ask the AI to generate an image based on the conversation, coaching, and any additional reference material provided.

A problem encountered when using most of the AI tools was that only a small number of generated images are allowed per day. Dalle 3 had a limit of 20 images per day. Microsoft Co-pilot, despite having a partnership with Chalmers University of Technology, had a similar limitation with tokens. Pixlr also worked in a similar way.

With all the AI tools mentioned above, there were not sufficiently many generations available to achieve useful results. Coaching the AI towards the desired results would use too many of the allowed generations. It was very difficult to achieve an image of a 3-wheeler with a windshield and a roof. More specific features like baggage and doors would only increase the difficulty.

Adobe Firefly did not have any limit of generations but could not generate new concepts. Adobe Firefly was not an AI with which a conversation can be held, unlike the previously mentioned AI tools. This makes it impossible to coach the AI towards the desired result. The AI was limited to what it has been trained on already. It was evident that the AI had no knowledge of 3-wheeled vehicles. An inspirational image could be uploaded but the AI would follow the inspiration too closely to generate new concepts.

Photoshop Image Generation Fill appeared to be trained on the same data as Adobe Firefly. It was therefore equally poor at generating new concepts. The AI could only be used to edit existing images or sketches, which severely limits the creativity and generation of a complete concept. The need to impose limits and attempting to achieve a successful edit was time consuming and not any faster than sketching by hand.

How one interacts with the AI tools can have major significance to the generated results. Therefore, a third-party person, was asked to attempt using the AI tools. Not much difference was achieved.

Due to the difficulties described, the 48 unique concepts were not generated. All generations can be found in Appendices. Despite this failure, the results were inspirational.

Some results inspired ways of thinking of solutions. Figure 8 appears to have a roof which operates like a latch. This is an example of the solution “roof slides/lifts out of the way” and introduced the idea of a canopy which lifts away like that of a fighter jet.



Figure 8: AI generated image of latch roof

AI generations also inspired styling choices. Figure 9 shows how a thinner, sleeker appearance can be accomplished with the use of a parting line and a differentiation of material.



Figure 9: AI generated image using CoPilot

2.7 Sketching

Due to the failure of AI concept generation, sketching was used to create the concepts generated by the morphological matrix. A concept to be sketched was randomly selected from the possible 48 combinations and sketched by one of three persons. Many sketches were made using a reference frame which was barely visible and could be easily ignored. The reference

contained the wheel outlines and the headspace reference of the Omotion 2. These references guided the sketches to a realistic proportion.

Not all 48 concepts were sketched. In the end, 24 concepts were sketched. It became apparent that concepts were similar to each other. Concepts with the potential solution “sleek” showed similarity to each other. Similarities for concepts with the potential solution “Edgy” were also noticed but to a lesser degree.

The similarity of the sketches was attributed to a lack of idea sources. Had more people been involved, a wider variety of ideas may have been achieved. Similarity between sketches was also a result of functions not having a significant impact on appearance. Figure 10 shows some of the sketches made.

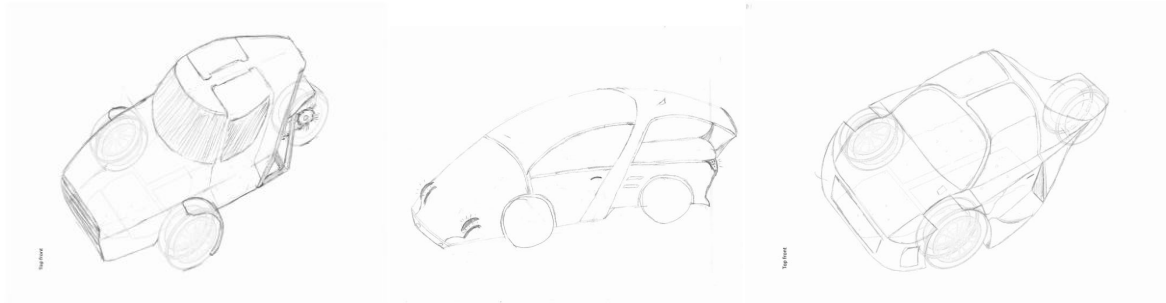


Figure 10: examples of sketches

2.8 Categorising and Simplifying

During a scheduled meeting with Omotion, the 24 sketched concepts were presented. It was suggested that the sketches be grouped into respective “sleek” and “edgy” categories because of the similarity of many sketches. Figure 11 illustrates the grouping of sketches

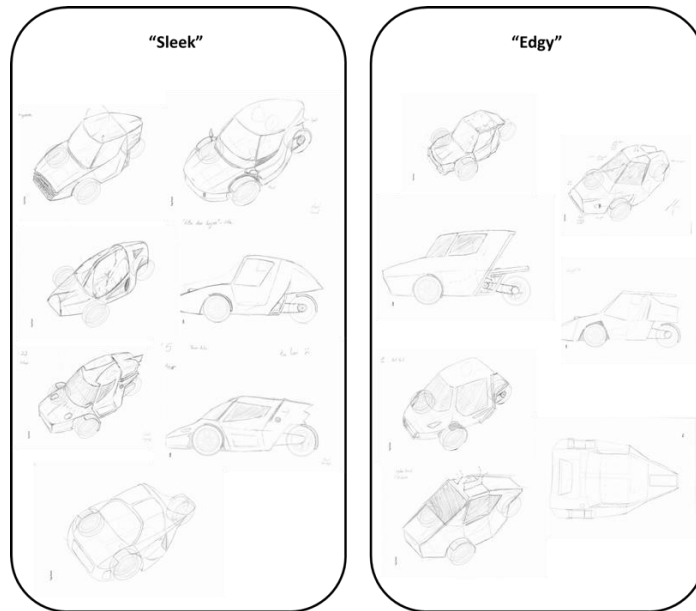


Figure 11: Grouping of sketches

Each group received one sketch as a representative concept for the group. The sketches chosen can be seen in Figure 12.

The “edgy” group was not appealing to Omotion except for one sketch. This sketch took inspiration from Tesla’s cyber truck. Instead of a collective representative for “edgy” group this singular sketch was used.

The sketch chosen as the basis for a “sleek” concept was chosen because it displayed the features described as “sleek”. It was comprised of larger simpler surfaces which cover the entire vehicle. The sketch also possessed features which were observed on sports cars, for example a low sloping hood.

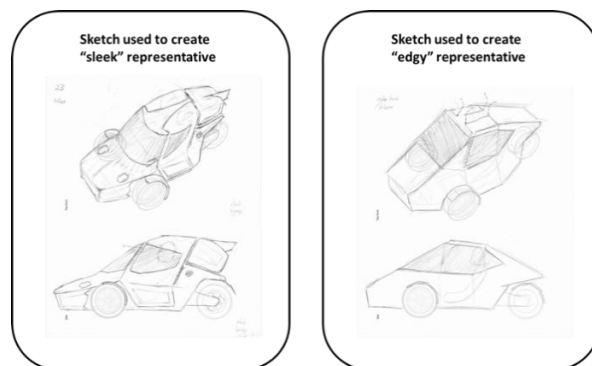


Figure 12: Sketches used to make representatives

Development of simple Computer Aided Design (CAD) models proceeded with these representative concepts.

2.9 CAD modelling

Based on the sketches selected during categorisation and simplification, simple CAD models were created. CAD was chosen as it was easy enough to create simple models which could be evaluated and to which details could be later added.

Aside from the “sleek” and “edgy” models a third model was introduced by Omotion. This third model was created by simultaneous work at Omotion. This model was modified in this work to be comparable with other models and is therefore called “modified”.

All models were created with a reference shape which represents the space needed for an occupants’ heads.

2.9.1 reference shape for headspace

The shape was created by placing two manikins into the frame of the Omotion 2. The frame serves no purpose but to ensure the seat is a realistic height above the ground. The manikins were given heights of 170 cm and 190 cm tall. The sitting posture was varied between laid back in the seat and pushed back in the seat. Figure 13 shows how the manikins were positioned. Figure 14 shows a cylinder for theoretical headspace and its position relative to the seat and frame.

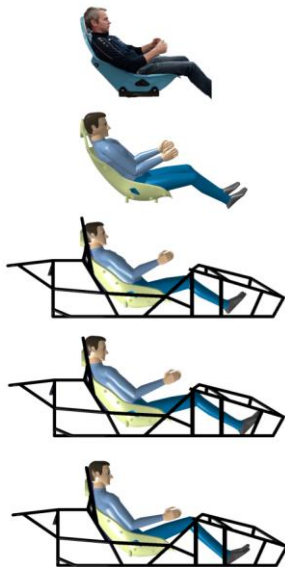


Figure 13: Digital manikins used to determine ergonomics

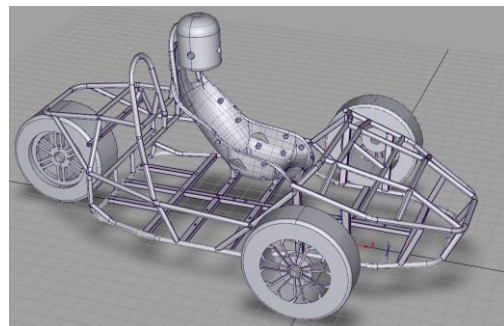


Figure 14: Theoretical Headspace

2.9.2 Edgy model

The simple CAD model created for the “edgy” concept can be seen in Figure 15.

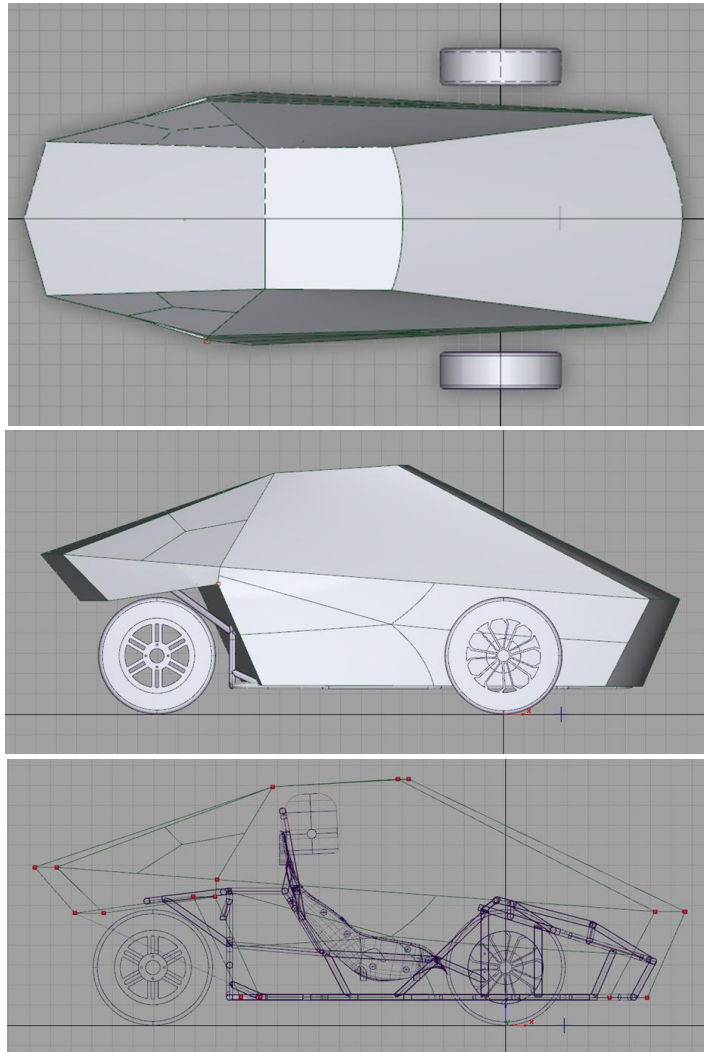


Figure 15: Simple “edgy” concept

The simple “edgy” concept was eliminated at this stage due to Omotion’s subjective review and prioritization of other models.

2.9.3 Sleek model

The simple CAD model created for “sleek” concept can be seen in Figure 16. The model was 3400mm long which was already the maximum desired length. Shortening the model was regarded as undesirable based on Omotion’s review.

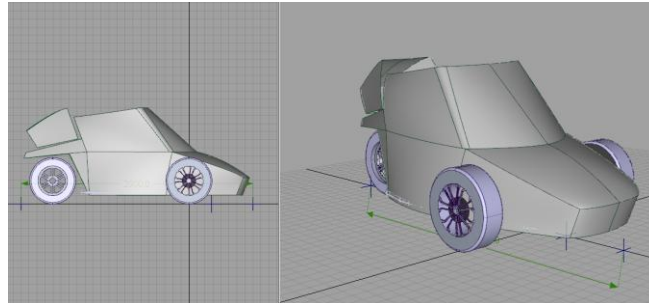


Figure 16: Simple “Sleek” concept

“Sleek” concept was developed further with the potential solution “gullwing doors”. The level of detail created on the “sleek” concept was made to be the same as the “modified” concept. This was done in an attempt to remove any bias based on level of detail. Figure 17 shows the concept rendered.



Figure 17: “Sleek” concept

Entering the vehicle is possible but it is likely not very ergonomic. The doors are opened by hinging upwards. The doors are held open by gas springs. The user would approach the opening in the bodywork headfirst, ducking to not to hit their head on the door. The user would lean into the vehicle, supporting themselves with the surrounding roof segments. The user would then lift each leg into the vehicle and lower themselves into the seat. Once seated the occupant would then reach up and pull down the door to shut it. The entry method was similar to that of other vehicles which use gullwing doors, but the challenges are increased due to the low height of the vehicle and the limited angle of the doors.

The concept was composed of surfaces which smoothly transitioned into each other. The hood was long and sloped slightly downwards and the front made to look like an opening duct. These features, aligned with sports car features, gave the concept a sleek appearance. However, tubes and two colours were used to balance the sports cars and motorcycle features without ruining the “sleek” appearance.

The baggage space was located behind the occupants. The space was measured to a volume of 155 litres. While the exact method of accessing the storage space was not decided, the rear window could potentially work well as an opening to the storage space. The space was not fully enclosed and access from the interior would also be possible. The storage space had a quite regular shape which would allow for a variety of items to be stored and efficient organization of smaller items. Figure 18 shows the volume allocated for storage.

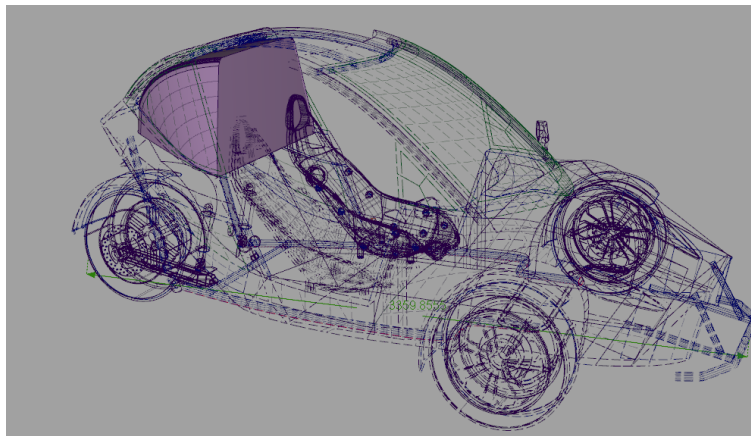


Figure 18: Storage volume for “Sleek” concept

The amount of headspace provided by the concept was sufficient to sit and look around. This was ensured by using the headspace reference during the development. Though the headspace meets the requirements, it can be described as confined.

The charging system was not defined in the concept as it was not expected to have a significant impact on the bodywork and its appearance. The charging port currently used on the Omotion 2 was included in the renderings of the “sleek” concept solely to provide a more complete visualisation. Replacing the charging port with another charging solution could be implemented

later without major difficulty. The included charging port does show however that the easily identifiable black circle does not diminish the vehicles appearance drastically.

The surface area of the bodywork panels, to be produced in composite material was measured at 4.4 m².

2.9.4 Modified model

During this development process Omotion had separately developed a CAD model which was of great interest to them. To be comparable within this process the model was to be modified. Th CAD model provided by Omotion can be seen in Figure 19.

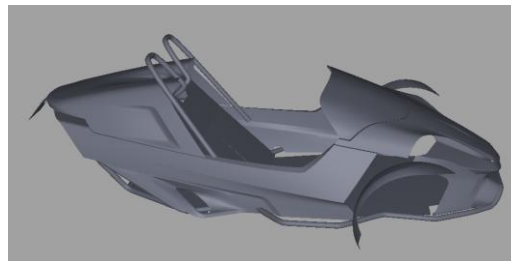


Figure 19: Modified concept in original state

The provided CAD model needed to be modified such that it possessed a roof and an entry method. The sub-solution “roof slides / lifts out of way” was selected as entry method. Only opening the canopy would make entry difficult. A suggestion of how to make the side panels movable was therefore also developed. Figure 20 shows the canopy and side panels in closed and open position respectively.

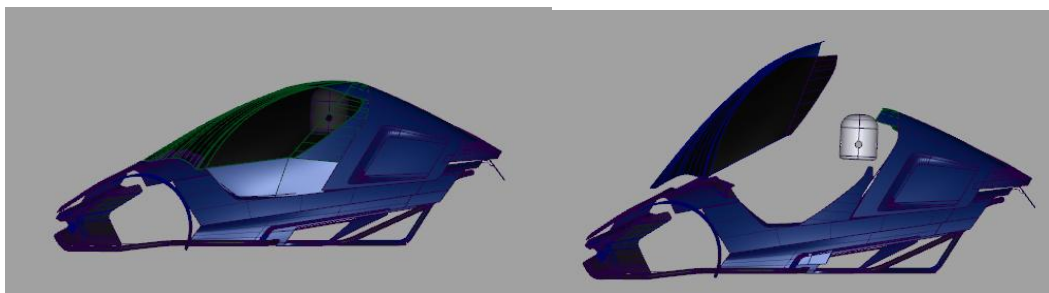


Figure 20: “Sleek” canopy in closed and open position

To enter the vehicle should be simple and intuitive. First the canopy would hinge forward creating ample head clearance. Next, the side panels would retract creating a lower hurdle to climb over. The user would then step over the side, into the vehicle, and lower themselves into the seat. Ergonomically it was quite similar to the existing model. When seated the occupant could then lift the side panels and pull down the canopy, enclosing them in the vehicle. One disadvantage of this entry method is that the temporary repositioning of the roof significantly exposes the interior of the vehicle. Downpour can therefore enter the vehicle during entry.

The amount of headspace provided by the concept was sufficient to sit and look around. This was ensured by using the headspace reference during the development. Though the headspace meets the requirements, it could be described as confined.

The modified concept was composed of very complex surfaces which gave it an “edgy” style. It was however mainly composed of smooth surfaces.

A spoiler and a splitter were added to the concept with consideration to potential aerodynamic benefits. These additions can be seen in Figure 21.



Figure 21: modified concept

The charging system was not defined in the concept as it was not expected to have a significant impact on the bodywork and its appearance. The charging port currently used on the Omotion 2 was included in the renderings solely to provide a more complete visualisation. Replacing the charging port with another charging solution could be implemented later without major difficulty. The included charging port, which is circular, does contrast the sharp edges and complex surfaces. It does stand out, especially on white panels. However, it does not ruin the overall appearance of the vehicle, as it matches with some of the other components and the bodywork is not a singular cohesive surface.

The dedicated storage space was located behind the occupants. With space left for framing, the storage space was measured to a volume of 173 litres. While the exact method of accessing the storage space was not decided, possibilities included a hatch on the outside, a hatch on the inside, or a movable rear panel. Because of where the storage space was located the users would need to lift their belongings off the ground to place them inside. The storage space had a quite regular shape which should allow for a variety of items to be stored and efficient organization of smaller items. Figure 22 shows the volume allocated for storage.

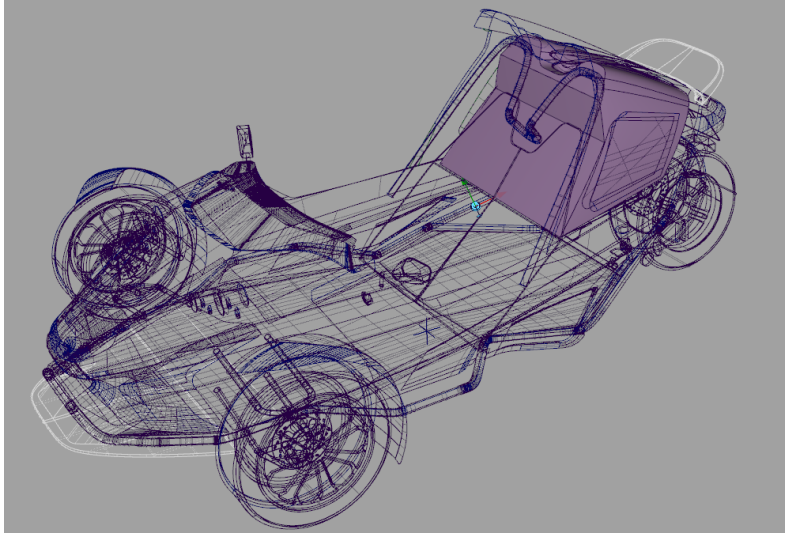


Figure 22: Storage volume for modified concept

The surface area of the bodywork panels, to be produced in composite material was measured at 5.7 m^2 , not including the spoiler and the splitter. The spoiler adds an additional 0.3 m^2 and the splitter 1.2 m^2 . Combined the total surface area would be 7.1 m^2 .

2.10 Clay modelling

A clay 1:5 model was created to get a better understanding of the proportions. The headspace required was a critical requirement which was believed to greatly impact the proportions. As the requirement was the same for all concepts only one clay model with simplified surfaces was created. Figure 23 shows images taken of the clay model.



Figure 23: Images of clay model

The clay model was presented to Omotion. This model had a length which would represent an actual length of 3200mm. Note this is under the 3400mm desired maximum by Omotion. Omotion approved the proportions and no changes to the length or proportions of models was requested.

2.11 Requirement testing

Requirement testing was a simple check to see if all requirements were filled by the concepts. This was to check if any solutions implemented have caused failures of other functions. Desires in the requirement specification were ignored at this stage. Several requirements could not be accurately assessed without further development to the concepts. These requirements were marked with *.

Requirement	Metric value	Verification method	Modified concept	Sleek concept
Size				
Total space occupied by vehicle	Max: 2.5 m x 4.0 m x 2.0 m (W x L x H)	CAD model	1.95 m x 3.2 m x 1,3 m	1.95 m x 3.4 m x 1.4 m
Convenience				
Seating for two adults	-	CAD model	TRUE	TRUE
Aesthetics				
Sporty	-	Subjective review	TRUE	TRUE
Modern	-	Subjective review	TRUE	TRUE
Comfort				
Protects occupants from the elements	-	-	TRUE	TRUE
Ergonomical sitting position	-	-	TRUE	TRUE
Safety				
According to government / EU standards*	(EU) No 168/2013	-	TRUE	TRUE
Environmental impact				
According to government / EU standards*	(EU) No 168/2013	-	TRUE	TRUE

Table 7: Checking fulfilment of requirements

The only known difference observed between the modified concept and the “sleek” concept was their sizes. As all requirements were fulfilled by both the modified concept and the “sleek” concept, determining which concept was inferior had to be done with consideration to desires. This was done using a decision matrix.

2.12 Decision matrix

A decision matrix, as described by Pahl and Beitz (1995), was used to compare concepts against a reference concept using desires and requirements of particular interest. The reference concept was thought of as a par. If a concept was better than the reference with respect to a desire, the concept was awarded value with a "+". Conversely, if the concept was worse, value was deducted with a "-". If there was no difference, a "0" was applied. The values awarded and deducted were determined by the respective weight for each desire. Once all the values had been assigned, the concepts were ranked from first to last, and another concept was chosen as the reference concept. The evaluation was conducted again. If the ranking remained the same regardless of the reference concept, then the evaluation was considered complete, and the lowest-ranked concepts were eliminated.

The desires used in the decision matrix, their respective weights and outcomes can be seen in Table 8. Several desires could not be accurately assessed without further development to the concepts. These desires were marked with *.

Desire	Metric value	Weight	Verification method	Modified concept	Sleek concept
Size					
Total space occupied by vehicle	Max: 2 m x 3.4 m x 2.0 m (W x L x H)	2	CAD model	1.95 m x 3.2 m x 1,3 m	1.95 m x 3.4 m x 1.4 m
Convenience					
Space for baggage	Min: 30 L	1	CAD model	173 litres	155 litres
Performance					
Less drag than Omotion 2	N/A	2		TRUE	TRUE
Comfort					
Ergonomical entry method	-	3	-	TRUE	FASLE

Table 8: Desires used in decision matrix

Table 9, Table 10, and Table 11 show the decision matrix with different concepts chosen as the reference concept.

Desire	Weight	Omotion 2	Modified concept	Sleek concept
Total space occupied by vehicle	2	reference	-	-
Space for baggage	1		+	+
Less drag than Omotion 2	2		+	+
Ergonomical entry method	3		-	-
$\Sigma+$				3
$\Sigma 0$				0
$\Sigma-$				5
Net		0		-2
Rank		1		3

Table 9: Decision matrix with Omotion 2 as reference concept

Desire	Weight	Omotion 2	Modified concept	Sleek concept
Total space occupied by vehicle	2	+	reference	-
Space for baggage	1	-		-
Less drag than Omotion 2	2	-		+
Ergonomical entry method	3	+		-
$\Sigma+$			5	2
$\Sigma 0$			0	0
$\Sigma-$			3	6
Net		2		-4
Rank		1		3

Table 10: Decision matrix with modified concept as reference concept

Desire	Weight	Omotion 2	Modified concept	Sleek concept
Total space occupied by vehicle	2	+	+	reference
Space for baggage	1	-	+	
Less drag than Omotion 2	2	-	-	
Ergonomical entry method	3	+	+	
$\Sigma+$			5	6
$\Sigma 0$			0	0
$\Sigma-$			3	2
Net		2		4
Rank		2		1

Table 11: Desire matrix with “sleek” concept as reference concept

From the perspective of the Omotion 2, seen in Table 9, the other two concepts had few improvements. The improvements noted was storage space and aerodynamic drag. Aside from this improvement, the other concepts were bigger and more difficult to enter. The inclusion of a roof increased the difficulty to enter and exit the vehicle. This was expected to negatively impact the ergonomics.

Though there appeared to be more negative impacts than positive, the negative impacts were regarded as unavoidable. It was left to Omotion to decide if the negative impacts were significant enough to stop or restart the ongoing development. With more development it may be possible to reduce the negative impacts.

Using the modified concept as the reference in Table 10, a difference was obtained between the

“sleek” and “modified” concepts. The “sleek” concept was shown to be inferior. In relation to the modified concept, the “sleek” concept was larger and had less baggage space. The gullwing doors were said to be poorly positioned relative to the seat. It would not be possible to stand straight up if standing in the seat. Standing in the seat is already not ideal. Persons would most likely need to hold onto the windshield and lower themselves. This negatively impacts ergonomics. The canopy of the modified concept was expected to provide an easier entry to the vehicle. Given that the canopy is opened to a sufficient angle, persons should at minimum be able to stand straight up in their seat. Though the “modified” concept used a canopy and a side door, the side door was used to make entry easier. For these reasons the “sleek” concept scored “-” for “ergonomic entry”. The “sleek” version did not use complex surfaces and was estimated to have a slightly lower drag coefficient than the modified concept. This was the only aspect for which the “sleek” concept was regarded as better.

Using the “sleek” concept as the reference concept, in Table 11, we expected and confirmed the results from Tables 9 and 10. The sleek concept was inferior. The modified concept was therefore selected as the final concept for which development can be continued.

3. Final concept

After elimination of inferior concepts, the modified concept was the remaining concept. Aside from minor fixes to the fit of the bodywork panels, the concept did not undergo any further development after its selection. The CAD model with better fitted panels can be seen in Figure 24.



Figure 24: New Omotion concept a.k.a. Modified concept

The concept was believed to fulfil the requirements, by all estimates.

- The vehicle's dimensions are 3.2 m x 1.8 m x 1.6 m.
- It seated two persons and covered them with a forward hinging canopy. Side panels slid open to allow for easier entry.
- Entry was not expected to be more difficult than entering a traditional car.
- Persons 195cm tall and shorter should be able to fit in the car.
- The bodywork was characterised as "edgy" but with "sleek" features indicative of a modern and sporty vehicle.
- There was storage space of 173 litres inside the vehicle behind the occupants.
- The charging solution was not specified but can be easily adapted to any chosen solution

The concept could be described as "edgy" because of the many complex surfaces which make up the bodywork. This aligns very well with trends in the motorcycle industry. The use of colour has not been explored in depth, but the singular predominant colour aligns with trends seen in sportscars.

Though the concept was not ready to be sent for manufacturing, Omotion regarded the provided concept as satisfactory. Continued development of the concept was left for Omotion.

4. Sustainability

Given that the bodywork panels and glass, were the main parts developed and that the material of the bodywork was already decided to be of composite material, considerations to sustainability were minimal.

Indirectly, a lowered aerodynamic drag could make battery usage more efficient. It was not possible to measure any improvements, but it was estimated to be small.

The bodywork panels are made of composite materials which are not easily recyclable, and production frequently involves the use harsh or toxic chemicals. The amount of material to be used was instead the primary focus with regards to sustainability. Because composite materials are layered sheet materials, the amount of material to be used is closely related to the surface area of the panels. Minimising the surface area would hopefully reduce the amount of material that had to be used. The final concept had 5.7 m² of composite materials for the bodywork panels and 1.4 m² for the addition of a splitter and a spoiler.

Bodywork panels are irregular shapes but the mats which the panels are made from are rectangles. Cutting out the irregular shapes results in waste pieces. Optimisation of cuts is strived for but waste pieces are expected. Bodywork with a larger surface area does not necessarily equate to more cut off waste. Larger area is an indication that more panels are used. More panels would likely area of the concept. The additional features are not necessary and can be excluded. The result in more cuts and more cut off waste pieces. The final concept has more surface area than the other concepts. There is potential to reduce the surface remaining bodywork can be altered to reduce the surface area. Such an alteration will impact the vehicles appearance. Attempting to balance aesthetics and surface area raises the question about using additional material to create something so valuable that the vehicle is maintained well and the life cycle is extended. That is to say, create more waste now and less later verses less now and more later.

Another way to improve the sustainability would be to use natural fibres in the composite material instead of fiberglass or carbon fibre. The generation of natural fibres is much less resource intensive than others. It would still be a composite material which required the use of epoxy or polyester, but it would not alter the manufacturing process of the bodywork panels. The downside is that it weighs more than the alternatives and would negatively impact the performance of the vehicle, thereby reducing sustainability in another way.

Though sustainability was not a primary focus during development, and the most sustainable option may not have been selected, Omotion is aware of its impact on sustainability. They were provided with the surface are data, which they could use to make improvements.

5. Discussion

This chapter is divided into a reflection on the methodology and the potential of future development.

5.1 Reflection of methodology and results

Many of the methods used during development encountered problems. AI image generation did not produce desired features and new concepts were difficult to obtain. Sketching failed in producing a wide variety of unique concepts. Aerodynamic simulation failed to obtain drag coefficients. Despite these problems, and all other problems encountered, the methods used suited the work well, were very cohesive and progressed the work in a logical manner.

The logical process was disturbed with the late introduction of concept derived from external development. However, the integrity of the process was maintained as the concept was fairly evaluated against other concepts derived from this work. In theory the concept could have been generated in the idea generation stage since it followed many of the sub solutions. Of course, it did need to be modified to fulfil all requirements and specific sub solutions like “roof slides/lifts out of way” had to be implemented.

It is noted that not all sub solutions were explored. It is a possibility that the other sub solutions would produce better results. Many of the sub solutions are non-critical to the bodywork’s conceptual appearance and a satisfactory result has already been reached.

It is also noted that an entire concept was eliminated during the development, for subjective reasons. The likelihood that this concept would survive elimination after evaluation was quite low based on the disapproval already shown by Omotion. Hence no work was done to the concept beyond a simple CAD model. The potential of this concept was not realised, to the level of the other concepts and this leaves room for further exploration.

5.2 Future development of concept

A lot of development is still needed before the concept can be made into reality. The development of the concept alone encountered some problems. Before attempting to realise the concept, asserting some of the problems is encouraged.

With the creation of a 1:5 clay model, simulation in a wind tunnel should be very possible. This was not done due to restrictions encountered with available wind tunnels. Such a simulation may not be necessary nor entirely accurate. Some sources of inaccuracy are, stationary wheels, inaccurate surface friction with the air, and inaccurate construction/components. Regardless, significant results from such a simulation would provide confidence in the concept.

Some mechanisms need to be created or modified in order for the concept to be feasible. Examples of these are hinges for the canopy, slides for the side door, and suspension components. The suspension has not been mentioned previously. The suspension arms of the concept are longer than that of the Omotion 2. Changes to the suspension forces are expected. Modifications to account for the change in forces is also expected. Calculations for these mechanisms should be possible while remaining at concept level. For example:

- The mass of the canopy can be estimated after decision on suitable materials and mounting methods.
- The slide for the side doors can be mocked up after applying appropriate thickness to the panels
- The suspension can be strain tested virtually.

Another area for development would be fixtures. Alternative fixtures were briefly examined during the development. A meeting with headlight producer J.W. Speaker was even held. However, the existing fixtures were determined to already be suitable to achieve the desired aesthetics. No alterations to the fixtures were made for this reason. The fixtures can still be altered to enhance aesthetics.

Ultimately, it is Omotion's decision how far development shall go. The concept was created with the intent that Omotion should be able to realise the concept within approximately 10 years. Development of this concept will take many years, but Omotion should have the ability to accomplish it.

6. Conclusion

After following the development process, as closely as allowed by Omotion, the aim of the development was achieved.

A concept bodywork of a 3-wheeler was created which was practical and attractive. It is suitable for short commuting and includes a roof.

The vehicle was made practical by its use of roof, entry points and storage. The roof provide protection to occupants. The entry points opens in such a way that makes entry easy. The roof and entry points were designed with consideration to how much space is needed to fit persons inside. This was done using digital mannequins to create a reference space which needed to be clear of anything.

Omotion considered the developed concept as attractive to themselves and believe it will also be attractive to target customers. A study into what the target customers would consider attractive was conducted and the developed concept possessed many of the features identified in the study.

Not all functions of the bodywork were solved because they were deemed to have little significance on the bodywork's appearance. The functions included how to secure the interior and how to provide an electric charging connection.

The other functions identified were fulfilled or estimated to be fulfilled.

Aside from the ones already mentioned;

- Baggage space was created but how to use it was not properly described.
- Temperature control for the occupants was narrowed down to windows or hatches
- Temperature control of mechanical components was set as openly exposed to the air.
- Minimize aerodynamic drag could not be measured but was estimated to be achieved with a more streamline silhouette.

Sustainability was considered with the consideration of the amount surface area, and thereby the amount of material, was needed to make the bodywork. Despite this consideration, other influencing factors led to the choice of a less sustainable option. Improvement in sustainability could be achieved in other ways than the shape of the bodywork.

There is additional room for improvement. Omotion was left to decide what needs should be further developed. The concept in its delivered state was satisfactory in many regards and realisation of the concept should yield a satisfactory product for many customers.

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Appendix

Trend Analysis

Motorcycles

According to statistics gathered by Statista (Sree-Kumar, 2023), during the year 2022, the countries with the most unit sales of motorcycles were Italy, Türkiye, Germany, France, Spain, and the United Kingdom. It is not stated if export sales are included. However, the sales are used as indicators for a thriving motorcycle industry, even within the country. Data for each of these countries regarding motorcycle brands and styles was collected.

The most precise data found was that for Germany. The German Motorcycle Industry Association, IVM, published a report in 2023 for all the makes and models of motorcycles registered in Germany in the year 2022. The ten most registered brands, in order were:

1. BMW
2. Honda
3. Kawasaki
4. Yamaha
5. KTM
6. Harley-Davidson
7. Ducati
8. Triumph
9. Suzuki
10. Royal Enfield

According to the data in IVM's 2023 report, the market shares in Germany, based on type of motorcycle, is shown in the pie chart in Figure 1.

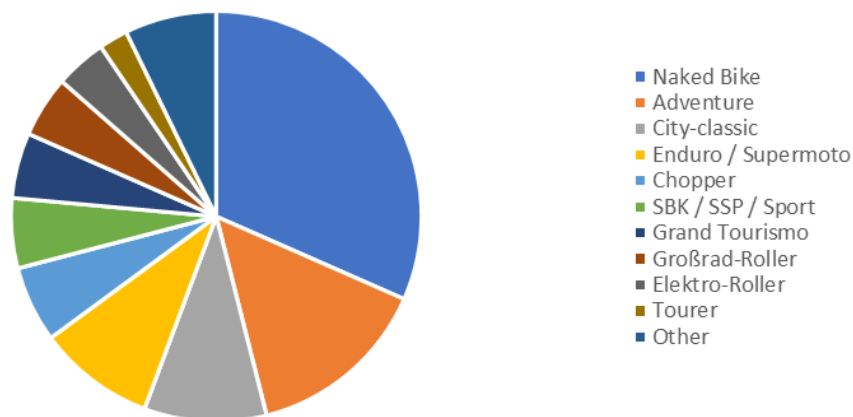


Figure 1: Motorcycle market share by type in Germany 2023

A list of the 50 most sold models can also be found in IVM's report (2023). Figure 2 shows interpretations of the first four motorcycles and their respective types.



BMW R 1250 GS (8530 registered)
Type: Adventure
Year: 2020

Kawasaki Z 900 (3599 registered)
Type: Naked
Year: 2020



Yamaha MT-07 (2529 registered)
Type: Naked
Year: 2023

Yamaha TENERE 700 (2079 registered)
Type: Adventure / Supernaked
Year: 2024

Figure 2: Popular motorcycles in Germany 2023

The least data found regarding motorcycles was that for Türkiye. It was however found that 58.5% of all motorcycles registered there during 2022 were less than 5 years old (Statista, 2023). 26% of the motorcycles registered are between 5 and 10 years old. This is a good indication that models 5 years and newer are of most interest and their styling should be noted.

Data obtained for Italy and Spain was not as detailed as for Germany, nor was it as recent. According to The National Association of Companies in the two-wheel sector (2024), also known as Anesdor, the most common brands in Spain as of April 2024 were:

1. Honda
2. Yamaha
3. KYMCO
4. BMW
5. Piaggio
6. Kawasaki
7. Zantes
8. Sym
9. Voge
10. KTM
11. Other brands

The top 5 brands in Italy during 2020 were the same as the top five brands in Spain during 2024, shown above (Statista, 2020)

Statista (2020) reported that in Italy 36.4% of motorbikes were of the type Naked. Enduro and Tourism followed with 34.32% and 10.82% respectively. Though the categorisation was not as specific as the data from Germany, it was clear that Naked and Adventure types dominate. No such data was found for Spain, but the domination of Naked and Adventure types in other countries suggested a similar trend throughout Europe.

Frequency of specific models in both Italy and Spain had also been obtained from the Italian National Union of Foreign Motor Vehicle Representatives (2018), UNRAE, and Anesdor (2024). However, what was considered a motorcycle varies such that the data includes what could otherwise be considered a moped. It can be noted however that the previously seen Yamaha MT-07 was one of the most frequent in Spain (Anesdor, 2024). The BMW R 1200 GS, similar to the BMW R 1250 GS, can be found in (UNRAE, 2018).

Naked, Adventure, and Enduro were determined to be trending in all countries studied. Major brands such as Honda, Yamaha, BMW, and Kawasaki were also trending in all these countries with the majority assumed to be less than 5 years old. Because the trends appeared to be very strong and very similar it was interpreted as the overall trend in Europe.

It should be noted that one property of Naked, Adventure and Enduro bikes was that, on average they cost less than the type Sport. Prices advertised on 8th May 2024, on [Hondamc.se](https://www.hondamc.se) and [Yamaha-motor/eu/se](https://www.yamaha-motor.eu/se) were used to determine this. On average, Honda Sport bikes cost SEK 106.000 compared to SEK 96.000 for street (Naked) bikes. Similarly for Yamaha, SEK 151.344 is the average price of a SuperSport and SEK 139.150 for a Hyper Naked. The popular Yamaha MT-07, mentioned previously, was listed for SEK 92.900.

The lower cost property introduced uncertainty within the trend analysis. The styles in Naked, Adventure and Enduro may not have possessed features which would be considered

most representative of “modern” or “sporty”, but rather a compromise for cost. Sport bikes may have provided a more accurate depiction. Sport bikes have additional features including bodywork meant to improve aerodynamics. An interpretation of a Sports bike can be seen in Figure 3.



price: SEK 113.900
Type: Sport
Year: 2024

Figure 3: Interpretation of Yamaha R7 Sports bike

The four motorcycles shown in Figure 2, and the sports bike in Figure 3, share a lot of the same features despite their price differences. Similarities observed are:

- The bodywork is multicoloured, primarily two tones: colour + black
- The bodywork is built of many small complex surfaces
- The bodywork leaves some mechanical/structural components visible

Sports cars

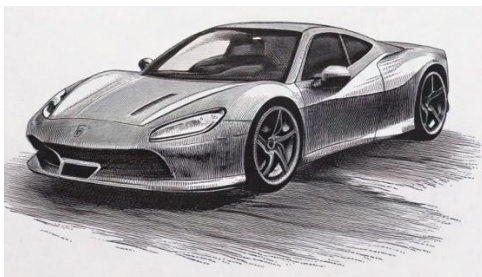
Vehicles categorised as sports cars by the Federal Motor Transport Authority of Germany, KBA, and registered during December 2023, were used to identify defining features of a sports car's bodywork. (KBA,2024).

The quantity of each model registered was not considered crucial due to the exclusivity of sports cars. Instead, which manufacturers produce the largest number unique models was of interest. Manufacturers with more than one unique model registered with KBA in December of 2023 can be seen in Table 1.

Manufacturer	Number of models registered
Ferrari	5
Mercedes	4
Porsche	3
Toyota	3
Aston Martin	2
Audi	2
BMW	2

Table 1: Number of registered unique models per sportscar manufacturer in Germany, December 2023

One model from each of the first four listed manufacturers in Table 1 has been chosen at random and can be seen in Figure 4.



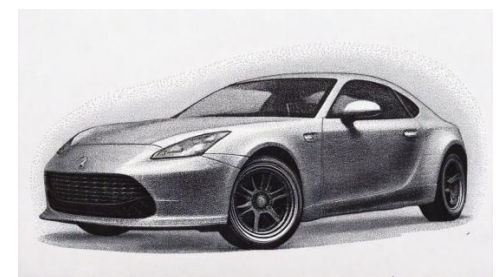
Ferrari F8
Production: 2019-2022



Mercedes AMG GT
Production: 2015-present



Porsche Boxster
Production: 1996-present



Toyota GR86
Production: 2012-present

Figure 4: Interpretations of random models of sport car manufacturers

From the four randomly chosen vehicles, a list of some similar defining features was compiled.

- The bodywork:
 - did not contain a lot of accessories or display mechanical components
 - was made of large panels with limited complexity
 - in the middle of the car was not as wide as the wheels
 - includes openings in front and behind the front wheels
 - left little space below the car
 - was one predominant colour with black features
- The headlights were longer than they are wide
- The total height of the vehicle was low to the ground
- The windshield was angled with a lot of slant
- The hood had a slight gradient down so that it was lower than the rear

Statista Market Insights (2024) confirmed the data obtained from the Federal Motor Transport Authority. The most sold brands within Germany were BMW, Porsche, and Mazda. These brands were also the most sold brands in other countries such as Italy, Türkiye and Sweden (Statista Market Insights, 2024). This was used as evidence of a shared trend across Europe. The defining features of a sportscar's bodywork were therefore assumed to be agreed upon throughout most of Europe.

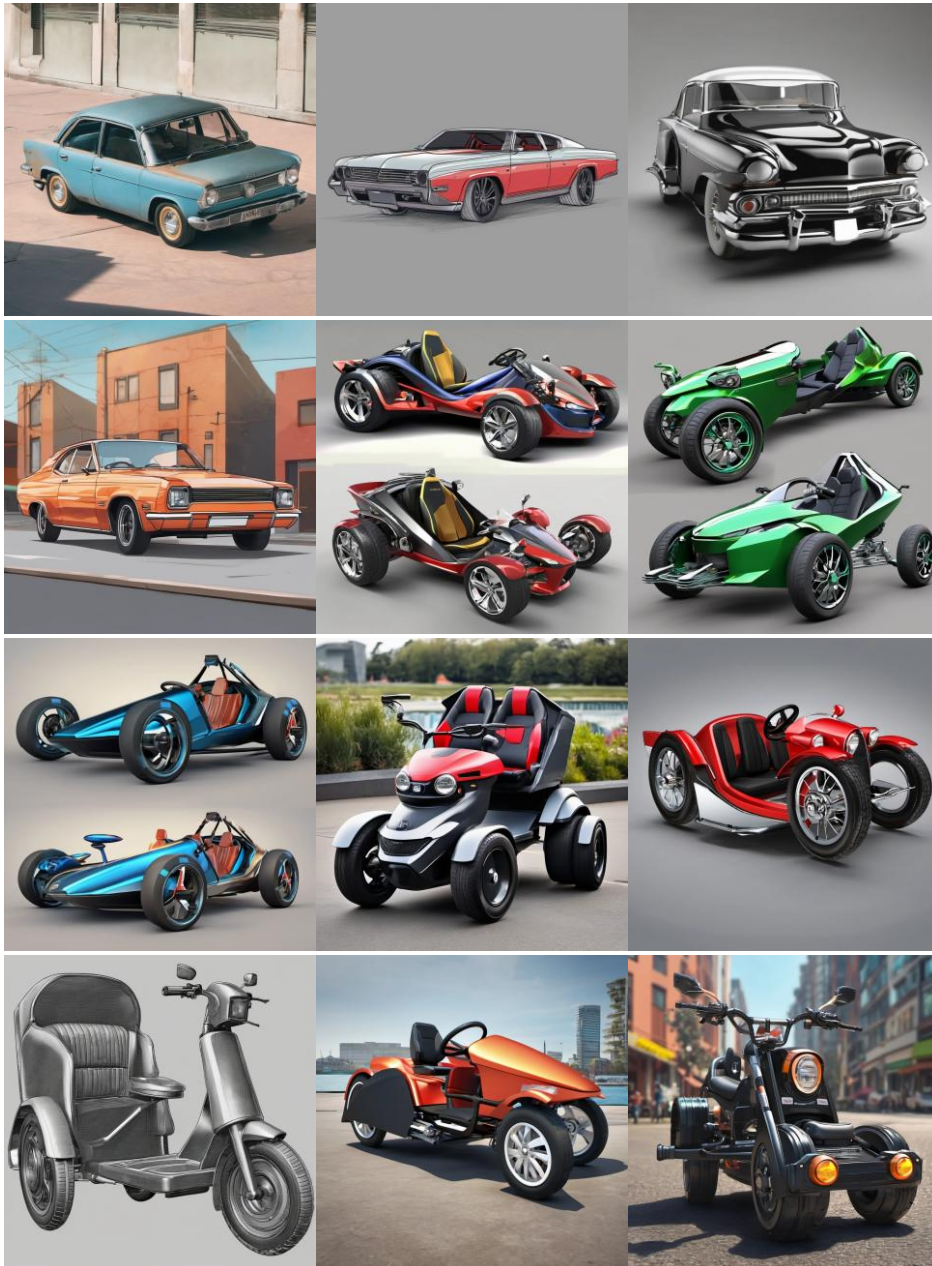
Conclusion

Some trending features of motorcycles and sportscars conflicted. The use of two colours is common between motorcycles and sportscars but the amount of each colour varies. Motorcycles often have many complex surfaces and show mechanical components. Sportscars have large panels with limited complexity and do not show mechanical components.

AI generations by Dalle 3



AI generations by Pixlr



AI generations by Microsoft Co-pilot





AI generations by Adobe Firefly



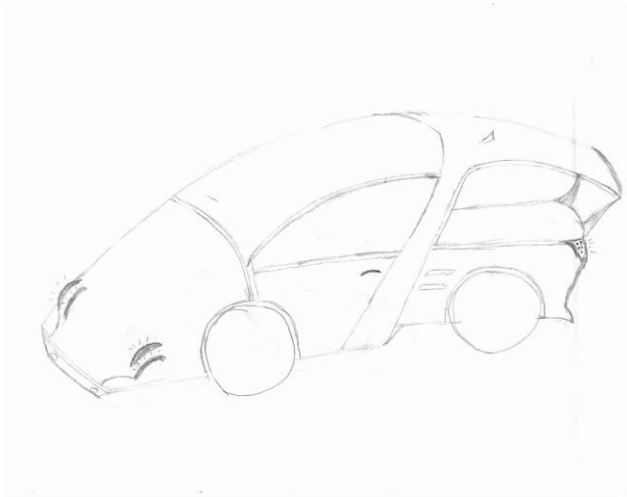
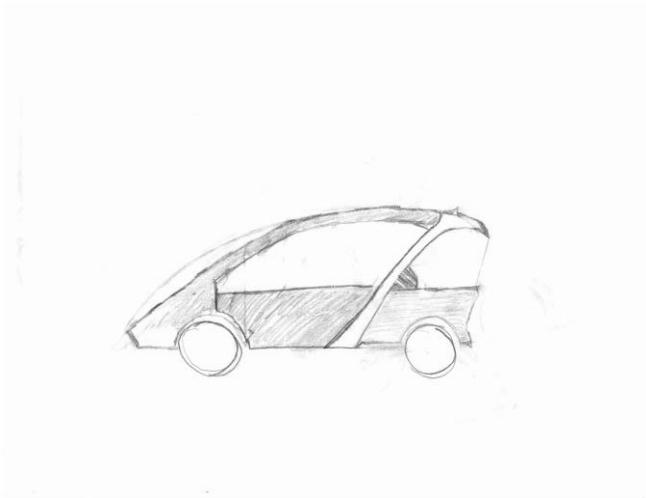


AI generations by Photoshop Image Generative Fill

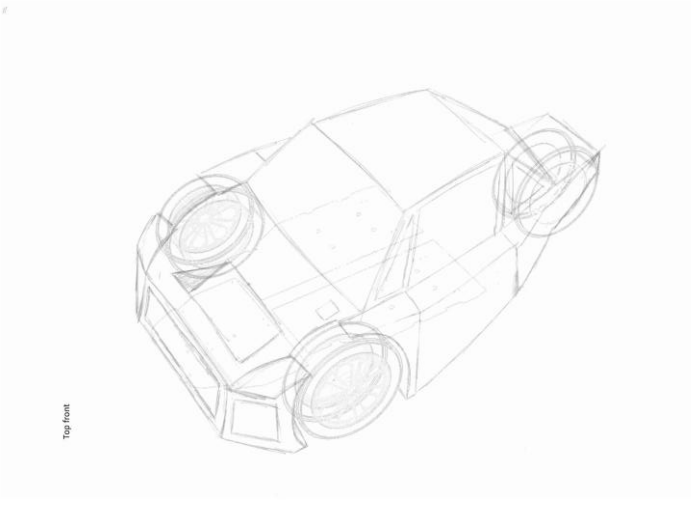
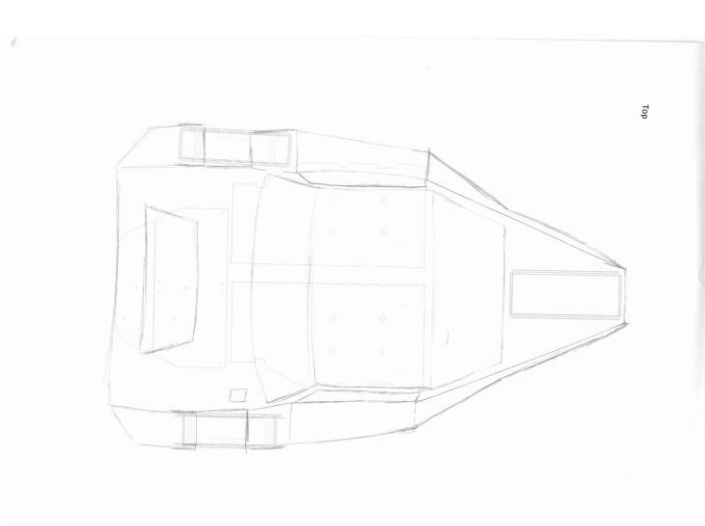
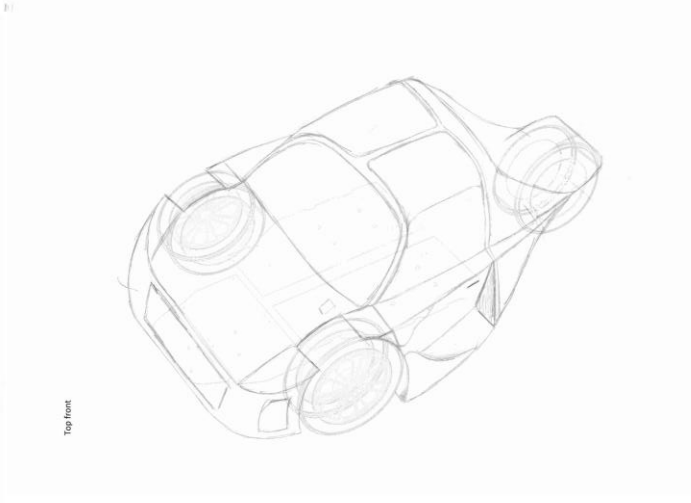
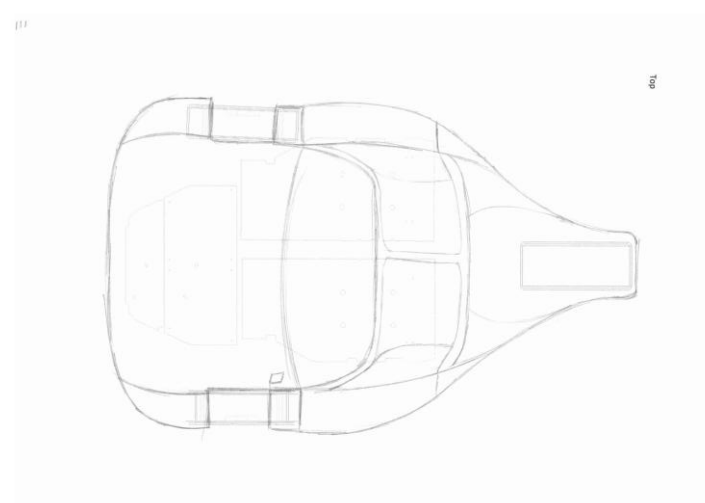
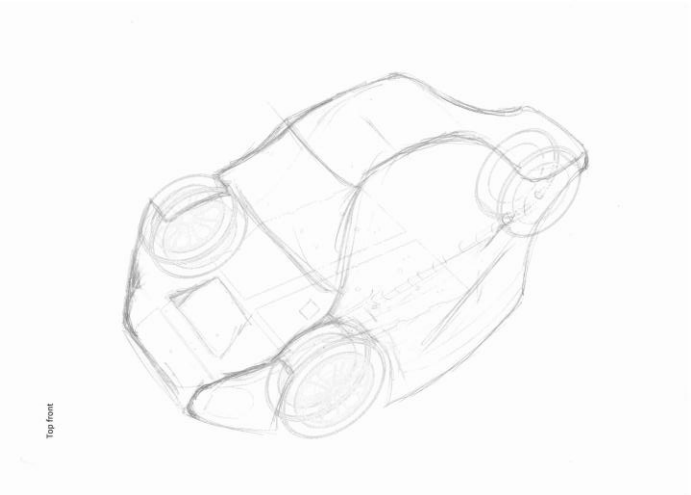
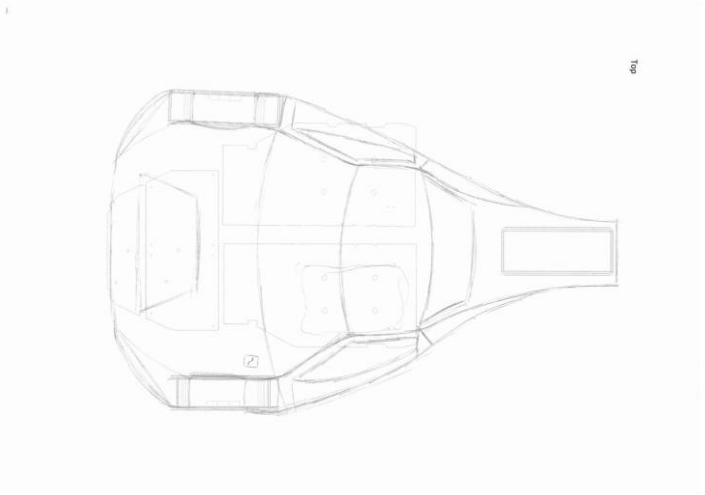


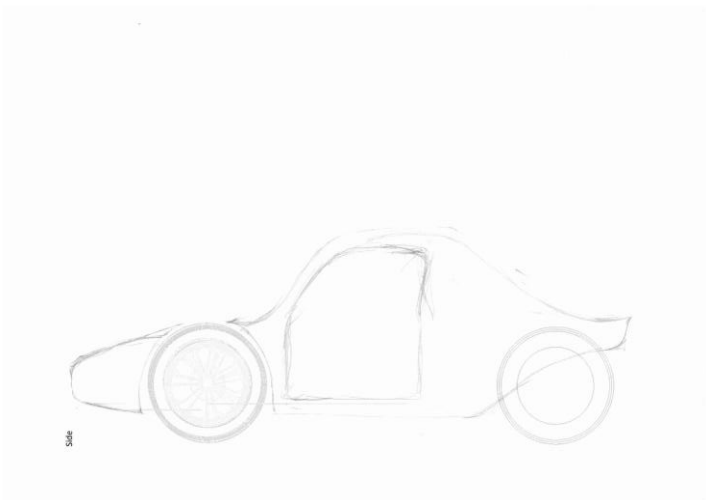
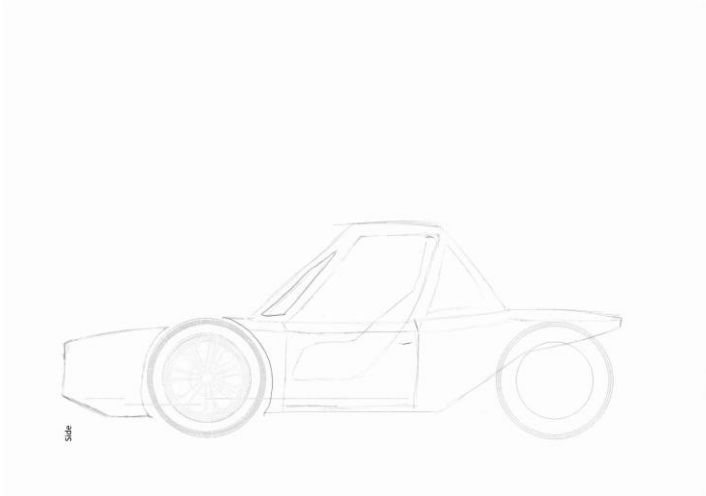
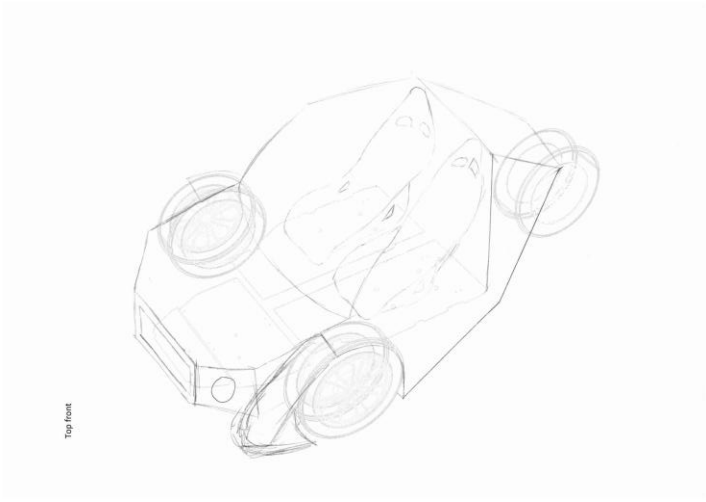


Sketches by Mrs. Loren Romell



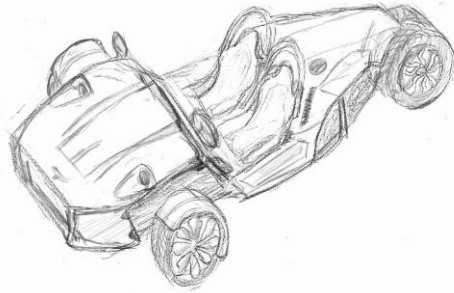
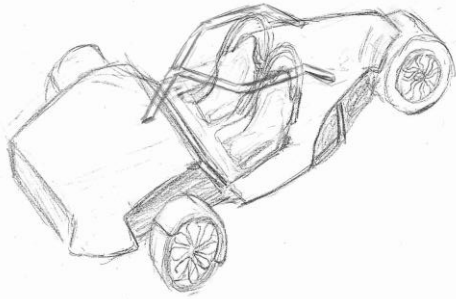
Sketches by Mr. Tevis Romell





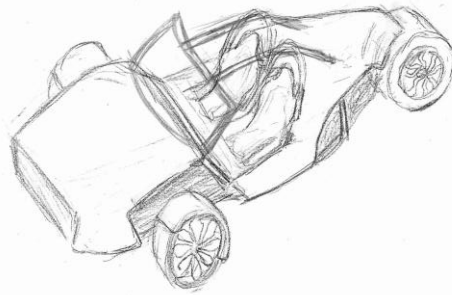
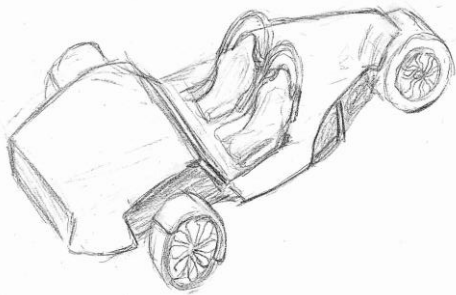
Sketches by Mr. Joakim Romell

hals

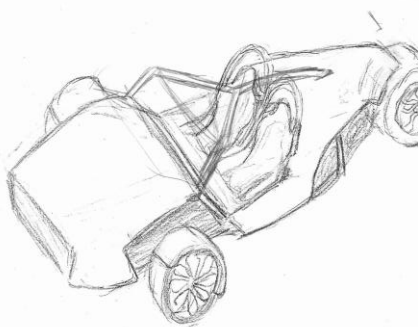


detailed

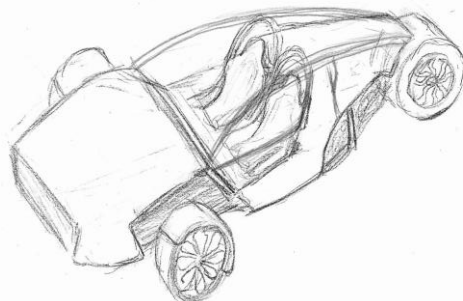
upper

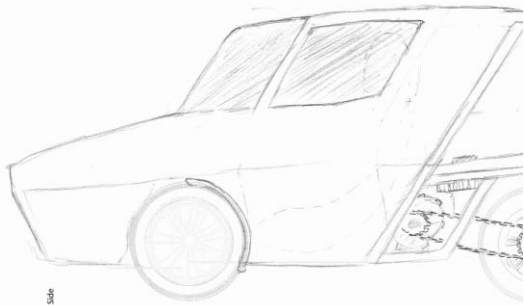


reverse hals



psd

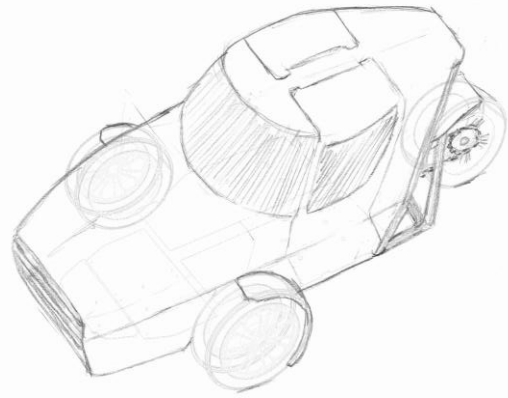




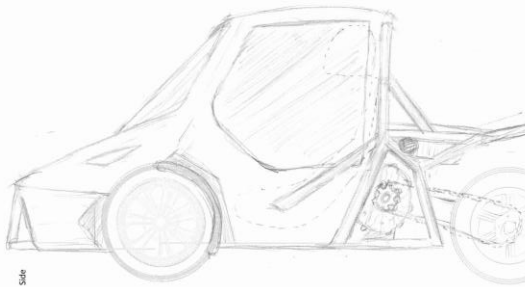
Side

1

tuk tuk



Top front



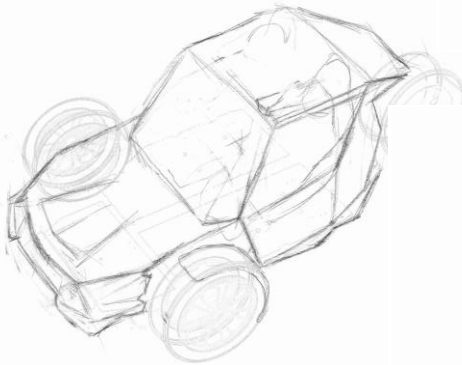
Side

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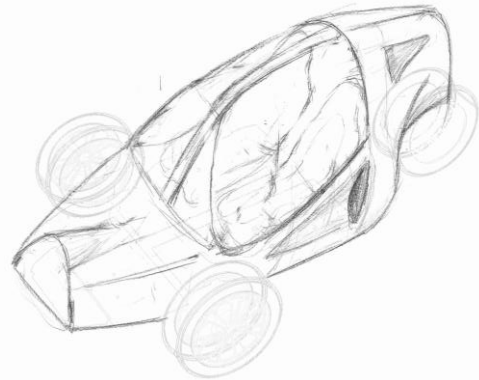
tuk tuk



Top front



Top front

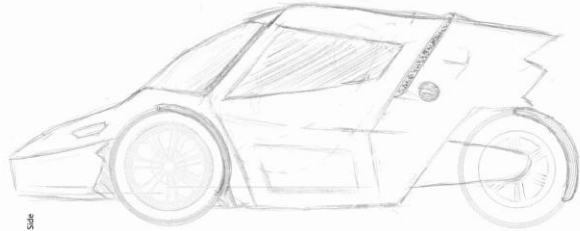


Top front

15 Tran bike

too low :-)

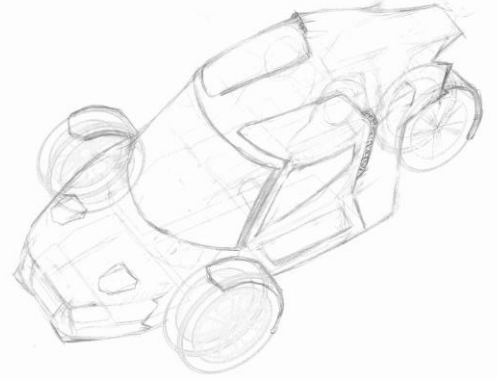
latres



Side

steak
warp

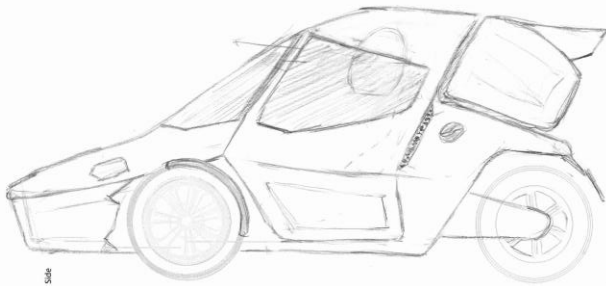
15 Tran bike



Top front

steak
warp
no. 1000

23

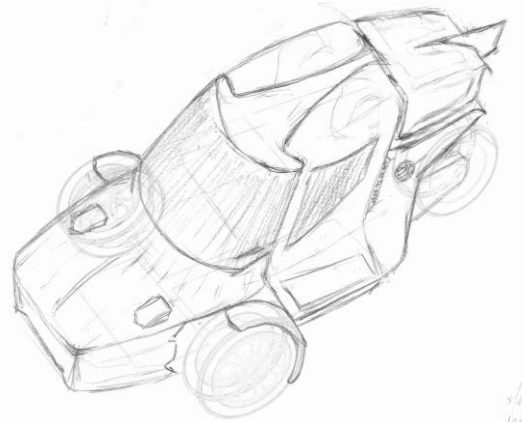


Side

steak
incap
no. 1000

23

latres



Top front

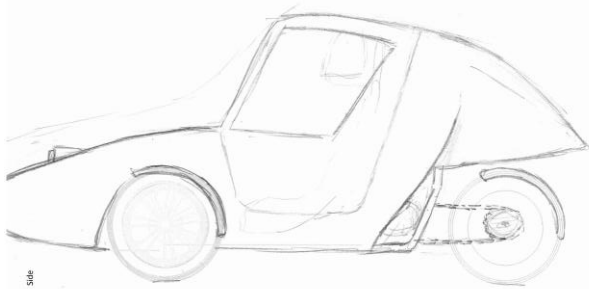
steak
warp



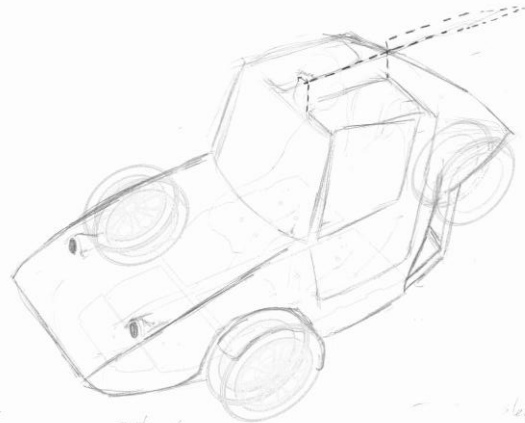
Top front

steak
hand

"kitta den linjen" - Ola



Side

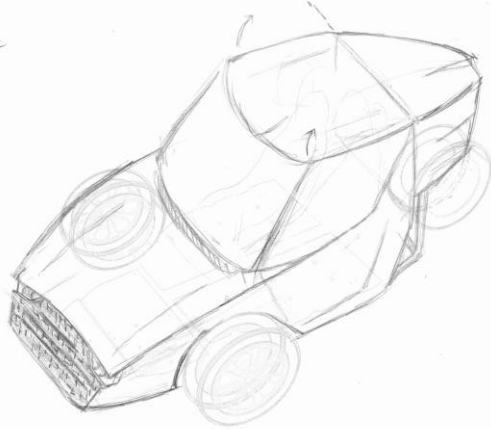


Top front

muskel / cocottes
... ad rubber

slad
gullare

ryra



Top front