A New Generation of Roofed Electric Mopeds

Master of Science Thesis in Automotive Industrial Design Engineering

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ABSTRACT

As a green solution, designing new concept mopeds, primarily for park and ride which means parking a vehicle to ride public transport, is the aim of the thesis project. To set the practical guidelines for designing mopeds, people's needs and opinions on mopeds were identified through interviews and questionnaires. After that, research works regarding products & market, ergonomics, technologies and production were performed to realize new concepts. Then, the concepts were developed based on the previous research works and creative imaginations. For the final verification benchmarking and test driving were carried out. As a result of this project, two versions of 3D models were presented. Two concepts, 2-wheel version for young people and 3-wheel version for middle-aged people share the same platform. The application of platform design across two concepts is the most outstanding and innovative design solution. From this thesis project authors have found that: 1st, most people have noticed the benefits of electric mopeds but still prefer to use passenger cars; 2nd, people want more functions from mopeds even though the nature of mopeds is simplicity; 3rd, the style of mopeds is turned out as an important factor for purchasing mopeds, however some people do not notice that they prefer a stylish moped; 4th, the market for electric vehicles is growing along with the development of relevant technologies.

ACKNOWLEDGMENTS

It is a pleasure to thank those who made this thesis project possible. Firstly, we are heartily thankful to our supervisor and also the head of our department, Ralf Rosenberg, whose support and guidance from the initial to the final level enabled us to finish this project. He encouraged us to end up with better results than we would reach by providing critical advice in a wide and professional point of views. Secondly, we would like to thank Yngve Westerlund, the owner of Yngve Westerlund Konsult AB, also the project leader of the GPP-project. His great dedication led to the birth of the GPP-project also our thesis project as the part of it. He provided various support from arranging whole schedule and detail methodologies to financial matters. Thirdly, we would not forget the great help from all the participants who joined our interviews and discussions. Lastly, we offer our regards and blessings to all of those who supported us in any respect during the completion of the project.

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1 Introduction

1.1 Background

It is widely accepted that environment friendly solutions called as green solutions will become more and more important in the next several years. The reduction of carbon dioxides was magnified as the major conflicting issue in 2009 United Nations Framework Convention on Climate Change (UNFCC, 2009). Furthermore, it has been regarded as one of the main targets for sustainable industrial development in most areas both in developed and developing countries. The electric vehicle industry which can provide green solutions is developing fast in many countries. In Europe, following the governments demand for developing clean and efficient energy sources in the vehicle industry, many companies have started to speed up the research and development on new alternative modes of energy sources. In Asia some the development of electric motorcycles, mopeds and bicycles are progressing actively; for instance, People's Republic of China produced 16 to 19 million electric bikes in 2006 and over 21 million in 2007 (ADB, 2009).

At the same time, many people agree that increase using public transport instead of passenger cars is better for a sustainable society. To utilize public transport and reduce the travel distance by passenger cars as a combined solution, park-and-ride has been introduced. Park-and-ride means that people head for the public transport stations by personal vehicles including bicycles, moped or passenger cars from home and change to public transport to get the destination. It is useful for people who live in suburbs near main roads or railroads which are directly connected to a city where their working places are located. The distance between home and bus or train stations is often not very far, so it can be covered by small and light weight vehicles designed for short travel.

In the foreseeable future Sweden as a global leading country who focuses on sustainable and environmental friendly policies may need a new transportation system linked to a green solution. Park-and-ride can be an efficient and effective part of a new transportation system. Proper light weight vehicles and parking stations are essential for a new system based on park-and-ride. In most aspects described above, an electric moped is an appropriate vehicle for a new system. Therefore, it can be assumed that an attractive and innovative electric moped would lead a new system to success.

1.2 Project definition

This thesis project was carried out as a part of a larger project, Grön Pendelparkering (Green Plug & Ride, GPP in Short). It is coordinated by Yngve Westerlund Konsult AB and includes partners like Test Site Sweden at Lindholmen Science Park and Västtrafik AB, the regional public transport authority in West Sweden. The GPP project covers a range of issues around the new transportation system related with park-and-ride. The thesis project will mainly focus on designing a new electric vehicle which is suitable for park-and-ride.

As a precedent research work to assume and guide the direction of the moped design a survey and interviews were scheduled in cooperation with other partners of the GPP project. Based on the results of this research work user needs and opinions for new concept mopeds could be identified. In addition to user needs analysis, the implementation of research works regarding technologies also production were taken into consideration. The evaluation of derived concepts referring to manufacturability was planned after determining the final design of mopeds. In the very last stage of this project, physical prototypes were supposed to be presented for a practical test and completeness of design development in case there would be sufficient time and budget.

1.3 Aim

The aim of the thesis project is to develop an innovative and attractively priced vehicle which is optimized for relatively short distance travel to and from a commuter hub connected to public transport. As a promising vehicle for park-and-ride solution, an electric moped is strongly recommended and some preliminary design criteria are made as follows.

- **Acceptable comfort.**
- **Reasonable weather protection.**
- **Capacity for smaller luggage.**
- **Attractively priced and inexpensive to drive.**
- **Easy and safe to drive.**
- **Easy to build and maintain.**
- **Environmental friendly: electric propulsion or pedal-hybrid.**
- **Futuristic image.**
- **Potential for alternative use; for instance, mail delivery, pooling concepts.**
- **Realistic innovation level: possible to produce in 5 years.**

Including preliminary design criteria, regulatory requirements regarding the size and the maximum power & speed of a moped should be satisfied to be driven on a road. To verify and proof the achievement of all the requirements based on theories and methodologies is another aim of this project. Analyzing user needs is the first step to initiate and confirm the design of moped. For demonstration of the design implementation of various researches is the second step: product and market; technology and material; ergonomics; platform and modularity research. Benchmarking, test driving and production possibility analysis can be the final step for complete verification.

2 User Needs Analysis

2.1 Introduction

In Sweden electric mopeds are not as popular as they seem to be in Southern Europe like France, Spain and Italy. Harsh weather and terrain condition of Sweden may affect the low usage. Also more people usually prefer to use their bikes than mopeds as alternative commutes. People usually have driving experience of a moped after 15 years old. But most people who are over 15 years old use it for a short time only until they can drive a car. Thus, mopeds are considered as the temporary alternative vehicle to replace a car. It is therefore much more difficult to collect information about people's perception about a moped than a car. However, to identify people's potential need for a moped is the first step of research to design a moped.

To get more reasonable data, the underlying considerations is to ask right questions to right people. Potential and actual users of a moped are proper people and at least they have interest or experience about driving a moped. An interview and a survey are used widely to identify people's opinions. Hence, the selection of interviewees and a survey distribution area are underlying points for successful data collection.

For that reason, two methods were discussed for user need analysis. One was interviewees of deep discussion to get qualitative information. To interview as many as potential users from different age groups was focused. The other way was a survey for quantitative information. Finding a region where many potential users would live was a primary point.

2.2 Methods

To analyze user needs two main methods were prepared in the beginning of this project. But only one method, an interview was successfully executed during the initial phases of the thesis project. For practical reasons in the larger project a survey was distributed in Ale municipality where a new train line and train stations will be constructed. Unfortunately, the results from the survey were not available until the design of the moped was almost finished. The result of the survey did not affect any part of this thesis project. Therefore, the authors only picked two important questions in the survey and attached the result as appendix without explanation. It shows similar tendency with the result of the interviews.

2.2.1 Procedure

The procedure of interviews for qualitative information was divided into two sections. As the opening discussion, a few general questions were asked to interviewees in first section. Then, they were asked to describe their general impressions about electric mopeds also opinions concerning the functions of mopeds.

In the second section, interviewees were asked to express their opinions about the style of mopeds. The picture of five different mopeds was presented in front of each interviewee. 5 mopeds from sporty to futuristic, empirical to trendy, and mass production to prototype design were selected as examples. They were XY125zk from Xingyue, C1E from BMW, MP3 from Piaggio, C3-R from Honda and one prototype made by authors. Then, interviewees were asked to select the best and worst moped matching to 7 specific perceptional aspects. Next, they explained the reasons of selection. As the second last step, authors let them select their favorite moped among 5 and explain the reasons. Finally, extra discussion regarding any opinion or unclear points was taken.

All 15 interviews were written by both authors to prevent information missing. The average duration of interviews was 30 minutes. There were four interviews held at Donsö, one island just outside of Gothenburg. The survey was adjusted for them to match their living situation. Passenger cars are not permitted so most people use golf cars and mopeds. 5 mopeds plus one golf car were included in the picture to get various opinions.

2.2.2 Participants

As a result of whole procedure, totally 15 participants joined deep discussion. The range of age nearly covered the whole possible target customers. Participants were arranged from 18 year-old high school students to 62 year-old working ladies. They were2 high school students, 3 young adults, 5 middle aged men, 2 middle aged women, and 3 old people. The average age of the interviewees was 37.3 years old. Their careers were also different from each other. Meanwhile, deep discussion with one professor from KTH in Stockholm, who had invented electric mopeds, was hold through internet video conference. He was familiar with people's behaviors on purchasing and using mopeds. *Table 1* shows the interviewee's profiles briefly.

Participant	Age	Moped driving experience	Career
1	26	Yes	Master student
2	28	Yes	Master student
3	23	No	Worker
4	18	Yes	Student
5	22	Yes	Student
6	31	No	Officer
7	47	No	Healthy inspector
8	62	Yes	Journalist
9	59	Yes	Secretary
10	57	No	Ship operator
11	39	Yes	Fleet manager
12	47	Yes	Fireman
13	35	Yes	Ph. D Student
14	30	Yes	Builder
15	36	Yes	Sales man

Table 1 Interviewees' profiles.

2.3 Analysis

Analysis was conducted based on the collected data form interviewees. Analysis work was divided into 2 parts: functional perspective part which focuses what kind of functions people want from the electric mopeds; perceptional perspective part which focuses how they perceive from the style of mopeds to identify which style people prefer.

2.3.1 Functional Perspective

2.3.1.1 Data from Interviews

Questions

The questionnaire used for interviews consisted of 2 questions. The first one was to collect people's impression about electric mopeds and the second one was to collect people's the important factors for buying and using mopeds. All the data from two questions was collected as shown in *Table 2* and *Table 3*.

	Items	Score													Average
Impression about electric mopeds	Environmental friendly	5	5	5	5	2	4	5	5	4	5	5	3	5	4.5
	Moveable	4	3	5	4	1	4	5	5	5	5	4	5	4	4.2
	Easy to park	4	3	5	4	1	5	5	2	3	5	5	5	5	4.0
	Attractive, good image	3	4	4	5	4	3	5	3	4	4	5	2	4	3.8
	Safe	5	4	5	4	5	4	4	2	4	3	4	2	2	3.7
	Convenient	3	2	5	4	3	4	5	4	4	2	4	4	4	3.7
	Fast in traffic	2	3	2	2	3	3	5	4	4	3	4	4	5	3.4
	Affordable	2	2	4	1	2	4	4	5	3	3	4	3	2	3.0

Table 2 Question 1.

	Items	Score													Average
The important factor for buying and using mopeds	Charging time and battery run-time	5	5	3	5	5	5	5	5	5	4	5	4	5	4.7
	Cost of purchasing and operation	5	4	2	5	5	5	5	5	4	2	4	5	5	4.3
	Winter adaption	4	3	5	5	5	4	4	5	2	3	4	4	5	4.1
	Quick and easy to park & lock	4	3	1	5	5	4	5	5	3	4	3	5	5	4.0
	Speed	5	3	3	5	4	4	2	4	5	3	4	3	4	3.8
	Attractive design, image	4	5	4	5	4	3	2	4	4	1	2	5	3	3.5
	Extra seat for child or passenger	2	4	3	3	2	2	3	4	3	5	5	4	5	3.5
	Storage and luggage capacity	2	3	1	1	4	4	5	4	3	4	5	3	4	3.3
	Weather protective roof/cover	3	5	1	4	3	2	5	5	2	2	3	2	5	3.2

Table 3 Question 2.

Open discussion

Understanding people's behavior and experience can be useful to analyze how and why they have specific needs. After finishing first two questions, the interviews stepped into open discussion. The aim of open discussion was to get a variety of information with limited number of people. The interviewees described their opinions from the perspective of their age. 5 different questions were asked, "Why they drive mopeds, why they do not drive, when they drive, how they drive and what they need from mopeds in the future." Although some interviewees had not used mopeds for a long time, they were still able to talk about various and informative stories. All the interviewees were categorize into 5 groups, high school student, young adult, mid-aged man, mid-aged woman and old people as shown in *Table 4*.

Most interviewees in the group of teenagers (15-19) showed interest in using mopeds and there are active users. However, the use of mopeds is limited. They usually drive mopeds with their friend in leisure time. They do not drive mopeds during the winter and easily feel bared to drive mopeds. In contrast, the rest of groups are not very interested in driving mopeds. All the young adults (20-30) have moped driving experience, but they do not use them anymore. Middle aged men (30-50) are very familiar with mopeds and one of them uses it as a commuting tool. But most of them prefer to use cars or bicycles for commuting. Middle aged women (30-50) are not familiar with driving mopeds and most of them never drive it before. They do not want to carry their child with mopeds due to safety issues. Old people (Above 50) do not use them much and desire more green solutions.

Teenagers (15-19)	*When they use?*	They do not use it much for commuting, usually they drive to meet friend at their leisure, and they do not use it during the winter.
	How they use?	They drive fast, and sometime with their friends.
	Why they do not use?	They can get free traffic card from the government, and they do not want to pay extra money. They may feel bored after driving for some time.
	Why they use?	They feel free and no pressure from staying in their parents' car, usually they want to drive in a high speed.
Young adult (20-30)	*Why they do not use?*	Unpredictable weather would spoil their clothes; they need big storage for school bags, and do not want smell exhaust gas.
Middle aged women (30-50)	*Why they do not use?*	Moped seats are small and hard to handle naughty children, and safety is another issue which they care about.
Middle aged men (30-50)	*Why they do not use?*	Interviewees feel that it is expensive, and it is not a perfect choice for two passengers.
Old people (Above 50)	*Why they do not use?*	They suppose that safety and loading capacity are two important issues, all of them would like to see new environmental solutions.

Table 4 Different description from 5 groups.

2.3.1.2 Data Analysis

Questions

Most interviewees had driving experience of a moped. They usually had started to drive it since there were 15 years old, so it was not hard for them to describe their perception.

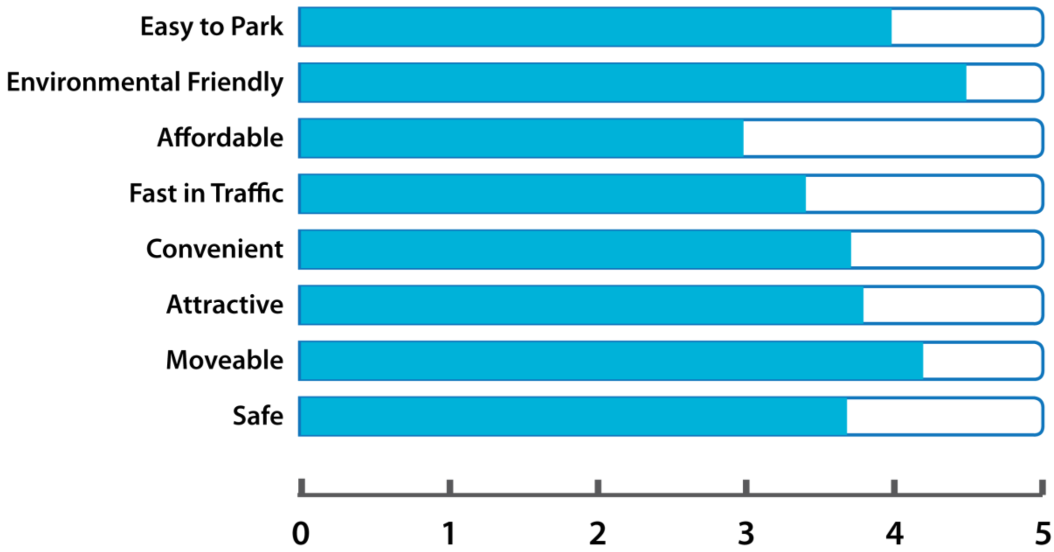


Figure 1 Impression about electric mopeds.

Environmental friendly was the most impressive feature for the interviewees, which matches the Swedish people's social value and demand. Moveable was the second important impression as what mopeds stand for. Mopeds can easily go through traffic jam during rush hour. Mopeds have some features in common with bicycles. Both are flexible vehicles and users do not need to pay extra money for parking or argue for a vacant parking space. Interviewees thought sometimes mopeds could be considered as a car because of its excessive price. Some mopeds are very expensive; for instance, one moped made by Norsjö Moped AB normally costs around 50,000 SEK. Most participants did not think it is reasonable price.

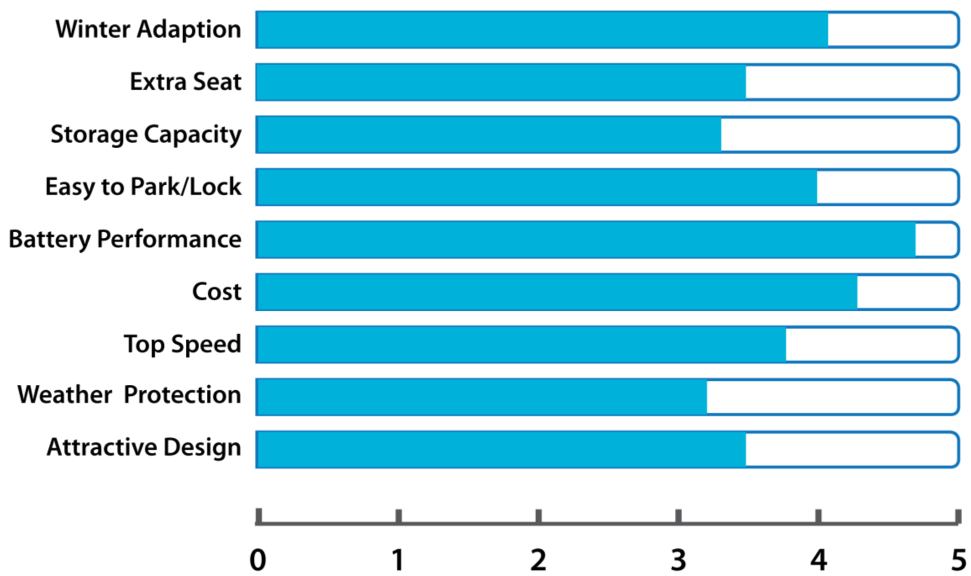


Figure 2 The important factor for buying and using mopeds.

Charging time and battery run-time were considered as the key factors for purchasing an electrical moped. People worried about charging it frequency. They preferred not to charge only after one way travel neither spend much time on charging it. Corresponding with people's impression about the price of a moped, the cost of purchasing and operation was the second important factor. According to the actual situation, some interviewees who live on the island concerned a lot about the cost. Because if their mopeds are broken or have some problems, they have to go to the main land to fix it since there are no dealers or repair shops on the island. That usually cost a lot. Scandinavia has a harsh weather comparing with the rest of Europe. Weather in Sweden is hard to predict. It rains often during the autumn, and cold and windy weather usually lasts for a long time. The situation of the northern part of Sweden is even worse. Therefore, people worried about driving a moped during the harsh weather. They thought that exposure and adaption to harsh weather were problematic. They said that if it is possible, they want to keep their body warm during cold weather.

Although they knew that weather might affect their travel with a moped, people didn't perceive that the weather protection by a roof or a simple cover was very necessary. They thought weather protectors might annoy drivers' view or prevent fresh air flow during the summer. Some people considered that a moped was a simple and direct transportation. So they would not like to use it for carrying many shopping bags. On the other hand, the others living on the island had a completely opposite opinion. They needed large storage capacity for a daily use to carry shopping bags and their children.

Open discussion

People had mentioned their needs for a moped mainly in 5 aspects: safety, power, practicability, form and price. Each group showed different expectations. In order to identify common requirements across different groups, *Table 5* was introduced. Initially, authors supposed to separate a middle age group into two: middle aged men and middle aged women. However, the results did not match the anticipation. Middle aged women did not want to use a moped, so they provided few suggestions. Therefore, middle aged men and women were combined into one group, mid-aged people. Finally, 4 groups were determined and listed as shown in *Table 5*.

	Teenagers (15-19)	Young adults (20-30)	Middle aged People(31-50)	Old people (Above 50)
Two passengers	●	●		
Weather protection(Moveable roof)	●	●	●	
Appropriate Storage Space		●	●	
Easy to handle and Drive			●	●
Driving Safety			●	●
Easy access to electricity			●	●
Avoid gas smell from other vehicles		●		●
Exercise		●		●
Comfortable Seat		●		●

Table 5 Users' common needs.

Table 6 shows the unique requirements which only were mentioned once in each group, whereas they may be important features which others haven't noticed.

Teenagers(15-19)	Young adults(20-30)	Mid-aged People(31-50)	Old people(Above 50)
• Prefer 2 wheels.	• Avoid Smell from gasoline	• Tires for icy road in the winter	• Low Cost
• Moveable roof	• Easy to lock (one button lock)	• Speed lock shift (limit high speed)	
• High speed		• 3 wheels to keep steady	
• Compact		• Easy to step in	
		• Possible travelling with kids	

Table 6 Users' unique requirements.

2.3.2 Style Perspective

In this chapter interviewee's perception about electric mopeds, especially the feeling about appearance of mopeds is mainly described. To figure out which style can be appropriate for new concepts and analyze how people perceive different forms are the aims of this part.

2.3.2.1 Data from Interviews

Additional questions regarding perception about 5 different mopeds were asked to same participants and the results of interviews were collected as shown in *Table 7*.

Interviewee	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Age	26	28	23	18	22	31	47	62	59	57	39	47	35	30	36
Perception	Selection of moped														
Stylish	D	C	C	D	D	C	C	A	A	B	C	A	C	D	B
Simple	E	E	E	E	E	A	E	E	E	B	B	E	E	-	-
Functional	B	C	C	A	C	B	C	C	A	A	-	A	B	A	C
Futuristic	D	D	D	D	D	D	D	D	D	D	D	D	D	B	B
Safe	B	B	D	C	B	D	D	A	B	-	-	C	D	C	B
Dynamic	C	C	D	D	B	C	D	D	D	D	D	A	C	D	B
Easy to drive	B	C	B	A	C	D	B	C	D	-	-	D	B	A	-
Favorite	D	C	C	D	B	C	C	A	A	B	C	A	B	D	B

A: Xingyue 125ZK B: BMW C1E C: Piaggio MP3 D: Honda 3RC E: Prototype

Table 7 Interview data about perception.

2.3.2.2. Data analysis

In order to get comprehensible analysis, collected data from interviewees is divided into 2 parts: first, perception about appearance of each moped; second, perception about a favorite moped. Then, in the first part, people's perception is split into 7 different categories: stylish, simple, functional, futuristic, safe, dynamic and easy to drive.

The Figures from *Figure 3* to *Figure 9* illustrate how interviewees think about each moped based on the 7 categories. A gauge in each picture indicates the number of interviewees who selected the corresponding model as a most descriptive moped. The reasons of selection are pointed out with words and blue lines.

Perception about stylish

Figure 3 Perception about stylish.

For “stylish”, 6 interviewees selected Piaggio MP3 as the most stylish moped. They mentioned “dynamic attitude”, “simple color”, “black color”, “nice looking” and “well finished model” as the reasons that they perceived Piaggio was stylish. Some interviewees couldn’t explain the reason of perception. Honda 3RC was selected as the 2nd most stylish moped by getting 4 votes. “Futuristic”, “nice surface”, “looks cool”, “fresh color”, “one single bobble shape” and “big and nice front wheels” were commented as the cause of selection. Xingyue XY125ZK was followed by BMW C1E; they got 3 and 1 votes respectively. According to interviewees “Integrated frame”, “orange color” and “comfortable seat” made Xingyue stylish.

As shown in *Table 7* there was notable relation between the perception of “stylish” and the age of the interviewees. Relatively young people selected Honda 3RC as the most stylish moped. On the contrary, old people perceived Xingyue 125ZK as the “stylish” one. Additionally, middle aged candidates chose Piaggio MP3 instead

Perception about simple

For the perception about “simple”, there was clear agreement among candidates. Two third of candidates, 10 interviewees selected the initial concept moped made by authors as the simplest one. “missing of details”, “clean”, “continuous contour line”, “straight line”, “straightforward feeling to sit and drive” and “looks like it has simple function” were brought up for the reason of selection. The rest of interviewees placed Xingyue 125ZK and BMW C1E into the simplest mopeds. “Basic looking” for the Xingyue and “looking easy to drive” for the BMW were commented respectively.

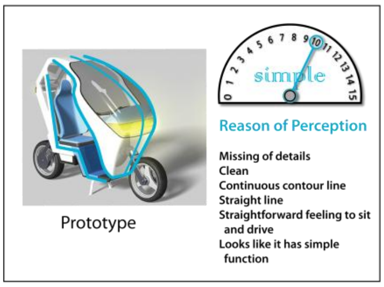


Figure 4 Perception about simple.

Perception about functional

Figure 5 Perception about functional.

In the perception about "functional", 6 applicants said Piaggio MP3 seemed to have many functions than others. Piaggio was chosen because of "easy to drive and carry extra passenger", "comfortable feeling", "looks stable due to 3 wheels", "big, not so compact", "easy to sit", and "safer with front two wheels". 5 interviewees appointed Xingyue XY125ZK as the most functional moped and they said "good seat", "easy to drive due to 2 wheels in the back", "looks steady because of 3 wheels", "lots of equipment" as the cause of perception. 3 people thought BMW C1E as the most functional and the perception was generated by "well arranged equipment", "understandable design", "basic and conventional shape of moped".

Perception about futuristic

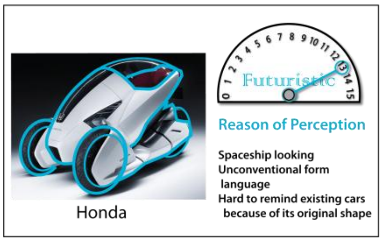


Figure 6 Perception about futuristic.

General agreement was shown in the perception about "futuristic". 13 out of 15 interviewees selected Honda 3RC as the most futuristic moped. Only 2 people presented different thought and they perceived BMW C1E as the most futuristic moped. Among 13 people, majority of candidates pointed out "spaceship looking" as the reason of futuristic feeling. One interviewee who is studying design stated analytic and concrete reasons for the perception of futuristic. "Unconventional form language" was pointed out and he explained the reason: "It is hard to remind existing vehicles from it because there are no previous models looking like it".

Perception about safe

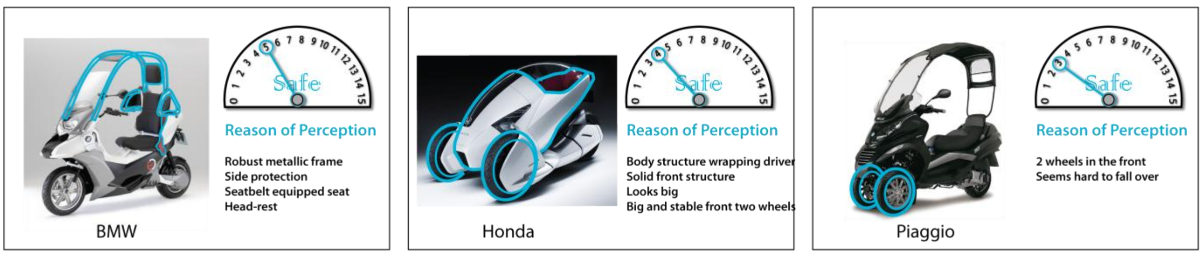


Figure 7 Perception about safe.

5 interviewees perceived BMW C1E as the safest moped due to “robust metallic frame”, “side protection”, “seatbelt equipped seat” and “head-rest”. 4 interviewees selected Honda 3RC and mentioned “body structure wrapping a driver”, “solid front structure”, “looks big”, “big and stable front two wheels”. 3 people thought Piaggio MP3 as the safest moped and “two wheels in the front” and “seems hard to fall over” were the reason of perception. 1 interviewee said “Xingyue 125ZK looks safe because of the solid body frame and the back-rest”.

Perception about dynamic

Figure 8 Perception about dynamic.

For the perception about “dynamic”, shortly more than half of interviewees selected Honda 3RC as the most dynamic moped. According to a few interviewees “curved top”, “looks fast” and “futuristic image” created dynamic feeling. Most of participants who selected Honda 3RC could not give the clear reason of perception. They said “Honda 3RC just looks dynamic”. Piaggio MP3 was placed the 2nd most dynamic moped by getting 4 votes. The interviewees pointed out “alert and sporty shape”, “aggressive feeling”, “dynamic color and front grill” and “motor sports looking vehicle” as the causes of dynamic feeling. BMW C1E and Xingyue 125ZK were placed the 3rd and the 4th dynamic moped respectively. “Straight line” and “sharp angled shape” of BMW C1E was indicated for the reason of dynamic feeling.

Perception about easy to drive

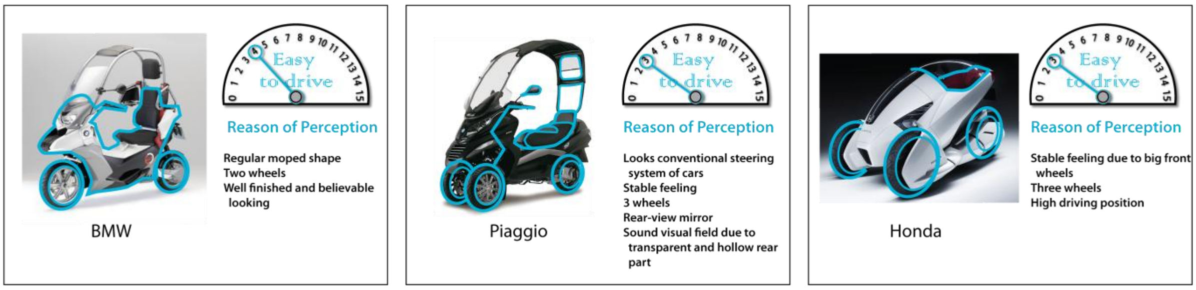


Figure 9 Perception about easy to drive.

The result of the perception about easy to drive was different from other items. The selection of moped was quite equally distributed except the prototype moped. BMW C1E got 4 votes and “regular moped shape”, “two wheels” and “well finished and believable looking” were the reason of selection. Both Piaggio MP3 and Honda 3RC got 3 votes. “looks conventional steering system like cars”, “stable feeling”, “3 wheels”, “rear-view mirror” and “sound visual field for the back due to transparent and hollow rear part” were reason for Piaggio and “stable feeling due to big front wheels”, “three wheels” and “high driving position” were for Honda. Xingyue got 1 vote and no comment was presented.

Overall perception of mopeds

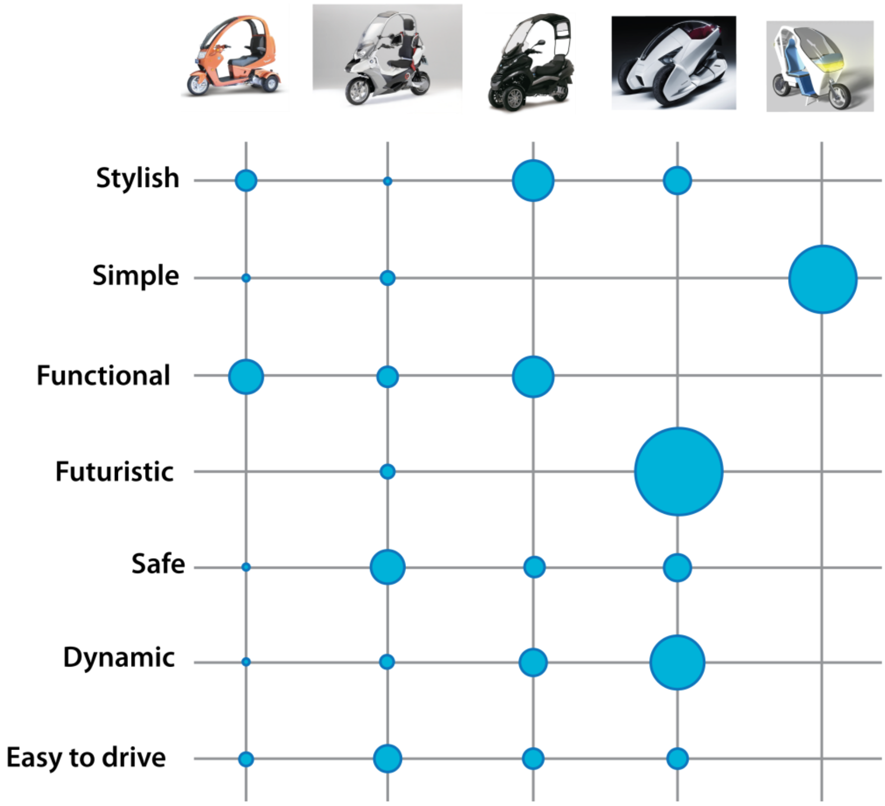


Figure 10 Overall perception.

Figure 10 illustrates the overall perception of 5 different mopeds. However, one limitation of this info-graphic is that only one moped which matched with each point of perception was counted. In other words, only the first place is considered because interviewees were asked to select only one moped for each question.

BMW C1E got at least one point throughout every perception and safe was dominant feeling of it. Xingyue 125ZK was placed in almost every article, but except functional and stylish, other feelings were not strong. Piaggio MP3 was ranked in relatively high position except simple and futuristic parts. Honda 3RC got very strong perception regarding futuristic and dynamic also stylish and safe feelings were marked relative high. Authors' pervious prototype moped got strong point from the simple part but did not get any point from other parts.

Perception about favorable moped

From the question about the favorite moped, 4 mopeds were selected without the previous concept moped and the number of votes was positioned between 3 and 5. *Figure 11* shows the result of the favorite moped and the average age of interviewees who selected it. As shown in *Table 7*, similar aged interviewees preferred similar mopeds. While the average age of whole interviewees was 37.3 years, the average age of interviewees who selected Honda 3RC was 24.7. Young interviewees preferred Honda 3RC. On the other hand, old interviewees preferred Xingyue 125ZK and the average age of them was 56.0 years. Middle aged interviewees preferred both BMW C1E and Piaggio MP3. The average age of each moped was 37.5 and 33.6 years respectively.

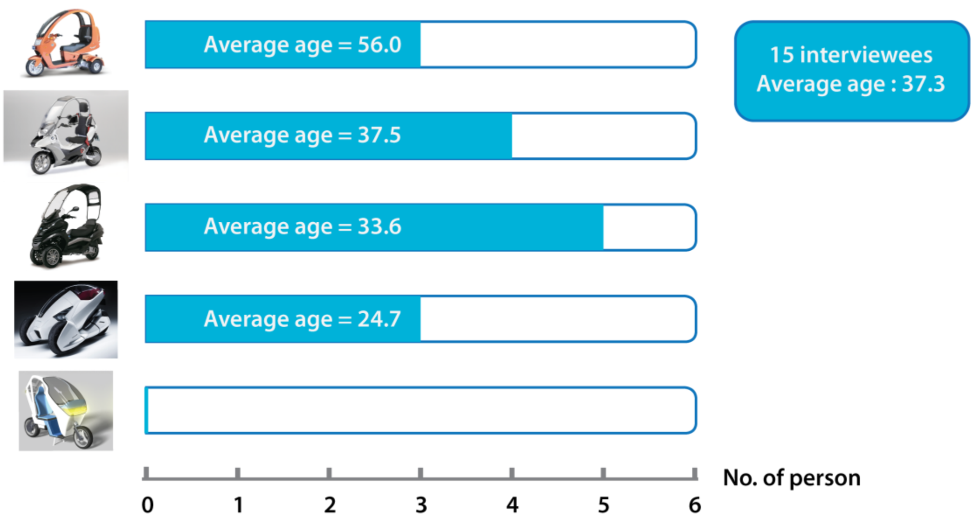


Figure 11 Favorable moped and average age.

2.4 Discussion

2.4.1 Functional Requirements

Passenger cars stand for more personal space, fast speed and comfortable driving experience. On the other hand, mopeds stand for flexible usage, short distance travel and less cost. Young adults just step into their career path and most of them prefer to have their own car not a moped. The disadvantages of a moped determine that it is hard to replace a passenger car. The results from user needs analysis tell that it is not possible to design a moped to fit everyone's taste mainly caused by different age. Therefore, in order to achieve the aim, to select proper target groups and make the product satisfy as many people in different age groups as possible are critical.

Young people prefer compact mopeds with 2 wheels which may represent their personalities. Meanwhile, middle aged and old people like steady mopeds with 3 wheels which may symbolize their behavioral methods. If the product could fit as many people as possible, the moped should have two different versions. Two requirements, carrying an extra passenger and a child can be solved by an additional seat. Although not every group needs large storage, the capacity should at least be enough to contain one helmet, one jacket and one brief case.

According to the users, if they live in an apartment, charging a battery is not easy to handle since apartments usually do not give electricity access at the ground floor or basements. Therefore the battery has to be removable, and users can carry it home for charging. The battery of electric mopeds is composed of a set of single pieces encased into one package. From the reason, another requirement can be added. The battery should be easy to carry. The weight of the Li-ion battery for mopeds is usually over 10 *Kg* which needs extra efforts to be carried.

The weather in Sweden is unpredictable and harsher than other countries. It usually rains from October to November and begins to snow since December. Weather protection by the roof of a moped may be helpful for the users. Even though it could not completely prevent heavy rain, people would feel being protected while driving. Most people would like to ride a moped with the sun shining and the cool wind blowing on their face like driving in a convertible sedan. Therefore, it is better that the roof could be removable.

Some special requirements are novel and useful. In *Table 6*, there are two demands stated as "avoiding gas smell from other vehicles while driving a moped" and "doing exercise on a moped". Both of them present good ideas, but they are hard to achieve in a reasonable way.

2.4.2 Style Requirements

Different interviewees showed different responses to every moped. Sometimes participants presented similar opinions and responses to same moped. A model of consumer responses to product suggested by Bloch (1995) well explains the results of interviews regarding different perceptions. When product form characterized by shape, scale, proportion, material, color, reflection and texture is subjected to customers or users, they response it based on different factors. People's responses named as psychological responses are influenced by individual tastes and references and situational factors.

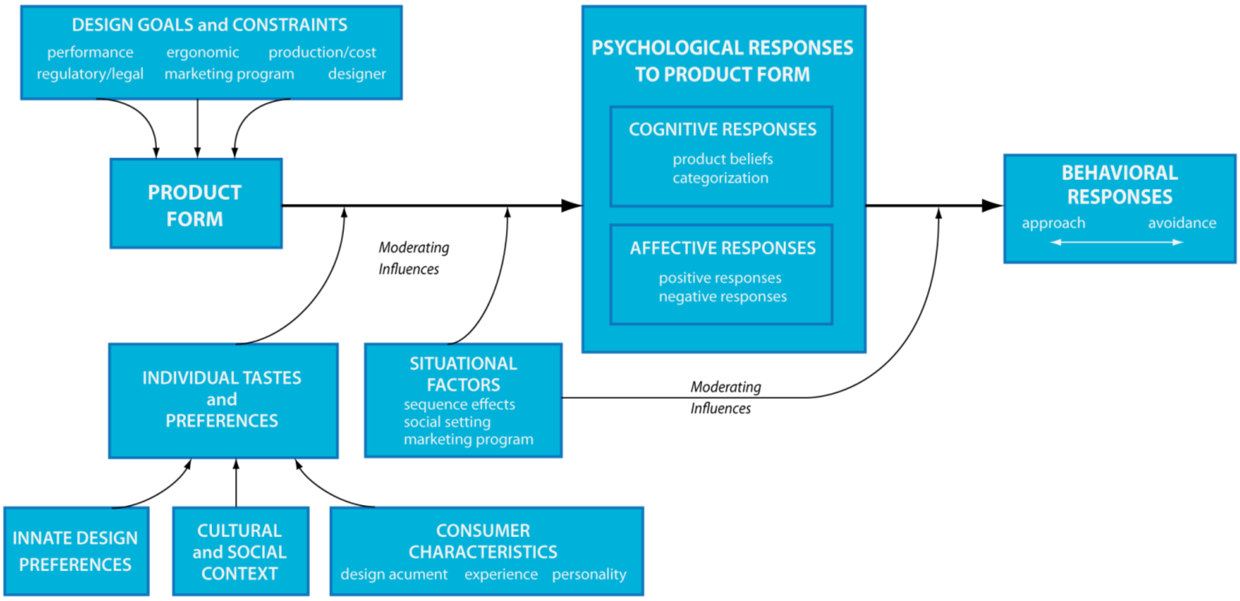


Figure 12 A model of consumer responses to product.
Source: Bloch, 1995.

There were strong agreements on the subject of simple and futuristic feelings. It is because two mopeds have strong product form and interviewees may have similar background or experience. Except the perception about simple and futuristic, interviewees showed various responses on each moped. It is natural according to Bloch's model because individual may have different tastes enacted by innate, cultural and personal factors. Interviewees from similar age groups showed similar responses on favorable forms. Young people preferred dynamic shapes while old people liked static shapes. It also can be illustrated by the part of cultural and social context in Bloch's model. Similar aged people usually share similar cultural and social context and it affects their responses.

Strong relation between the perception about stylish and the favorite moped were observed. Most interviewees indicated same mopeds from two different questions: one is about "which is the most stylish moped"; the other is about "which is the favorite moped". It contradicts to the result of important factors for buying and using mopeds from the functional perspective part. Even though interviewees rated attractive design and image at low priority, they selected stylish moped when asked "what do you prefer to buy?" It explains that people's behavior is not always governed by their thought, but rather unconsciousness may dictate their behavior. Otherwise, it can be assumed that some interviewees did not recognize their actual thought from the bottom.

2.5 Conclusions

Most people agree that an electric moped is an environmental friendly vehicle and they are interested in driving it. People also think that battery performance represented by charging time and runtime is the most important issue for buying a moped. However, not many people are willing to buy a moped since they are used to drive a bicycle or a passenger car. Additionally, the relatively high price of a moped affects the purchasing decision.

In general, people have a clear opinion of requirements for the functions of mopeds and most people want as many functions as possible. On the other hand, most people feel hard to describe their opinions concerning the style of a moped. The requirements both for functions and style vary for different people since people have different tastes. On the other hand, similar tendency can be observed in a similar age group. Generally, younger people prefer 2-wheel mopeds with dynamic and futuristic feeling, and older people prefer 3-wheel mopeds with comfortable and safe feeling.

To promote more people to use a moped and to satisfy more requirements derived from user needs analysis developing different types of moped for different age groups can be considered. Considering purchasing power the middle aged group can be one target group, and this positioning could include some from old people. Teenagers can be another target group since they are typical users of a moped. Providing two types, a 2-wheel moped for teenagers and a 3-wheel moped for middle aged people can be a good solution. To realize this solution research on technologies and production are essential. Furthermore, extensive research to deal with market and ergonomic perspectives can increase the degree of completion of the solution.

3 Research

User requirements for electric mopeds were identified in the chapter 2. In this chapter, extensive research and theoretical background will be dealt with to discover methodologies for satisfying the requirements and to verify the methodologies. Research will be divided into 4 parts: first, product and market; second, technology and material; third, ergonomic; finally, platform and modularity.

3.1 Product and Market Research

3.1.1 Product Research

The definition of Mopeds

A moped is defined as a low-powered motorcycle designed to supply economical and safe transport with minimal license. In the early years, mopeds were equipped with pedals like bicycles and the term "moped" was originated from motor-pedal. Recent mopeds do not have any pedals. Now a two wheeled vehicle with pedals and extra power generated by an engine or a motor is categorized as a hybrid bicycle/bike or an electric bicycle/bike. In some regions like North America or East Asia an electric moped is usually called as an electric scooter. An electric moped is the moped using an electric motor instead of an internal combustion engine.

The term, EU mopeds is widely used in EU countries. The maximum speed of EU mopeds is 45 *km/h* (28 *mph*) and the maximum volume of an engine could not exceed 50 *cc* (cubic centimeters). In most regions the regulation regarding top speed and engine volume is almost same to EU mopeds. However, when it comes to electric motors, it is not totally identical. In EU countries the maximum power of electric motor should be lower than 4.0 *kW*. On the other hands, allowed maximum power is 1.5 *kW* in Canada and 0.6 to 2.0 *kW* in New Zealand. Unlike any other countries in Europe there are two types of mopeds in Sweden. One is the class 1 moped and the maximum speed, the volume of engine and motor are exact same with EU mopeds. The other is the class 2 mopeds which can have the maximum speed of *25 km/h* (*16 mph*) and the maximum power of 1.0 *KW*. The class 2 moped can be driven without license if a driver's age is over 15 years old and it is also allowed to drive on most bicycle roads.

Basic layout

As shown in *Figure 13*, the basic layout of mopeds can be categorized into 3 types: a two-wheeler; a 1+2 type of three-wheeler; a 2+1 type of three-wheeler. A four-wheeler is difficult to be included in this category since the whole structure and the total weight of it could be complex and heavy. Therefore, it is obvious that a four-wheeler needs an extra-powered engine or a motor and it is not matched with the definition of a moped.

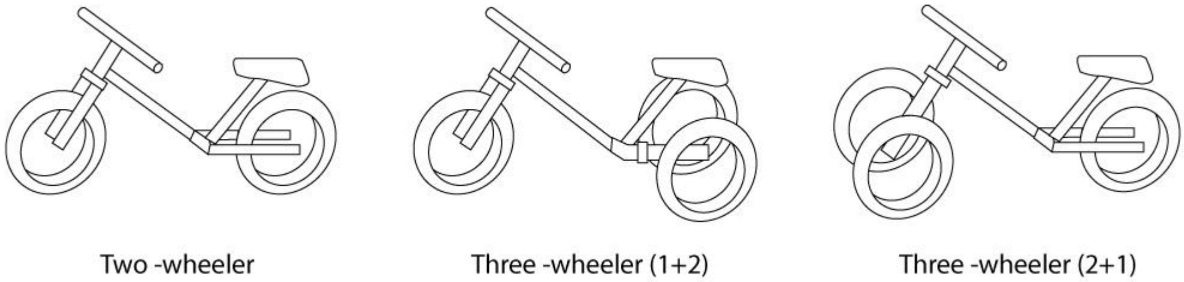


Figure 13 Three different layouts of a moped.

A two-wheeler is the most popular layout for mopeds because of a simple structure and an easy way of driving. Most conventional and recent scooters, bikes and motorcycles including mopeds use two wheels. The first motorcycle made by Gottlieb Daimler and Wilhelm Maybach followed the 2-wheel type of layout like a bicycle. Except main 2 wheels, 2 auxiliary wheels are attached into side body but it can be categorized into a 2-wheeler.

A 1+2 type of three-wheeler is not very popular but it gives more stability at a low speed range. The layout of a tricycle is equivalent to this type and it is mainly used for kids since they usually have problem with riding in balance. A three wheeled motorcycle which looks like a tricycle has been introduced by the development of technology. The French company, Sidam introduced Xnovo in 2008 but it is hardly a moped. The size of an engine is around 500cc to carry a heavy body caused by complex suspensions and driving systems.

The last one, a 2+1 type of three-wheeler has a most exceptional layout because front two wheels are operated as steering wheels. Unlike general cars with 4 wheels, the front wheels of it should be tilted toward side directions for cornering. Because of complex steering mechanism it is most heavy and expensive among 3 types. It means a 2+1 type is probably the last one which can be applied for a moped.

		
First motorcycle (1885) by Daimler & Maybach	Sidam Xnovo (2008)	Gilera Fuoco (2007)
2-wheeler	Three-wheeler (1+2)	Three-wheeler (2+1)

Table 8 Examples of different layout.

Target Specifications

There are many different 2 wheelers named as a moped, a scooter or an electric bike. For categorization technical aspects were considered as main points than shapes or functions. To set overall target specifications on maximum speed, maximum power, price and battery capacity existing mopeds which are similar to potential concepts of this project were reviewed. Then, 4 most plausible mopeds were selected as shown in *Table 9*.

Model	Top Speed	Max. Power	Price	Battery & Range
 Libert-E Xero R	45 *km/h*	1,200 *W*	$ 3,000	LiPo, 110 – 130 *km*
 ZAP Zapino	45 *km/h*	3,000 *W*	$ 3.500	Lead acid, 48 km
 Io Scooter	45 *km/h*	1,500 *W*	$ 3,300	Lead acid, 40-55 *km*
 Eped City	60 *km/h*	1,200 *W*	$ 1,900	Crystal battery, 55 *km*

Table 9 Four models for comparison.

Source: Libert-E Motor,2010; ZAP,2010; iO,2010; Epeds,2010.

The top speed of 3 out of 4 mopeds was 45 *km/h* which is an allowed maximum speed for small motorcycles or mopeds in most countries. The maximum power of electric motors was ranged from 1,200 *W* to 3,000 *W* and the values satisfy the regulative requirement, maximum 4,000 *W*. The price of mopeds varied between 1,900 USD and 3,500 USD. For a battery, most existing mopeds used a lead acid type which is conventional type. Libert-E Xero R used a lithium polymer battery and Eped City used a Crystal battery which is the new type of battery and not well known.

Through product research, approximate target specifications of new concepts were decided. All the specifications for 2 wheel version were decided by comparing with existing mopeds as shown in *Table 9*. But target specifications for 3 wheel version were roughly decided because 3-wheel mopeds were not common and there was not much information about it. The top speed of 2-wheel version was set as 45 *km/h* corresponding to EU mopeds. 2 types of top speed, *45 km/h* and *25 km/h* were chosen. *25 km* was allocated for class 2 since potential users of 3 wheel version would be middle-aged and old people. For maximum battery power both two types got around 1,200 *W* and extra power was added into 3 wheel version in case of lack of power due to heavier body. However, there is limitation on the power of class 2 mopeds. According to Swedish regulations for mopeds the maximum power of class 2 mopeds could not exceed 1,000 *W*. The regulations or the target specification of the concept might be changed. The price of mopeds was hard to predict since all the elements like production process, technologies, the price of parts would affect it. The potential price was regarded as 3,000 USD which is slightly higher than the average price of existing mopeds. For the battery Li-ion battery was already selected from the beginning of project. And the driving range of battery was set as 60 *km*. 60 *km* is the approximate distance when the moped is driven for 1 and half hour with maximum speed of 45 *km/h* and it is the enough range for park and ride.

Target specification	2-wheel version	3-wheel version
Top speed	45 *km*	45 *km*/25 *km*
Max. battery power	1,200 *W*	1,200 to 1,500 *W*
Price	$3,000	$3,000 +
Battery type and range	Li-ion, 60 *km*	Li-ion, 60 *km*

Table 10 Target specifications for the concepts.

3.1.2 Market Research

According to Frost & Sullivan the Growth Partnership Company, the need for integrated mobility and first & last mile connectivity solution is gradually increasing. And electric scooters and motorcycles are the best vehicles for providing sustainable environmental friendly mobility (Kwiecinska, 2010) Growing concerning about environment and global warming and soaring oil prices have driven people to use a fuel-efficient vehicle (Tollefson, 2008). China is the biggest market for electric mopeds and lots of different mopeds and electric bikes have been producing in China. 16 million to 19 million of electric bikes were produced during 2006 in China and over 21 million of electric bikes were produced in 2007 (ADB, 2009). The research work regarding the sales of motorized vehicle in China showed strong growth of electric 2-wheeler as shown in *Figure 14* (Weinert, et al., 2008). In that graph G2W stands for gasoline 2-wheeler and E2W for electric 2-wheeler. The volume of sales for all 3 types of vehicles had increased during the whole period. The most dramatic change was observed in electric 2 wheelers, and the volume of it was increased 7 times between 2002 and 2006.

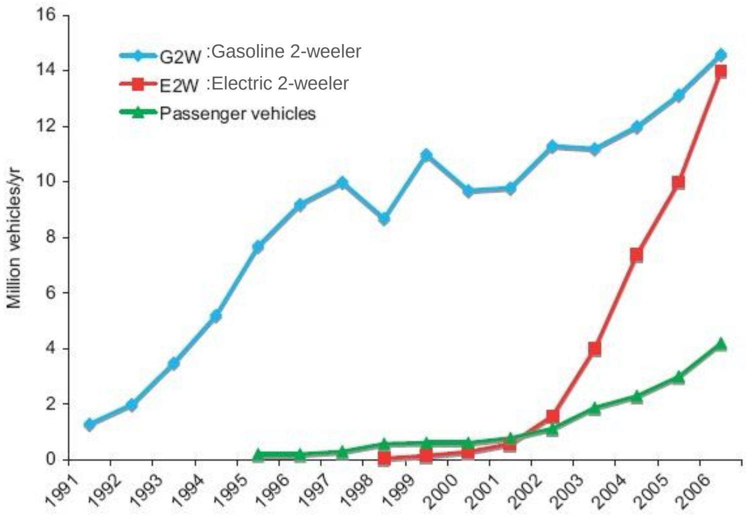


Figure 14 Motorized vehicle sales in China.
Source: Weinert, et al., 2008.

The growing need for mopeds is not only the story of China. The demand for mopeds in South East Asia, Europe and North America is also increasing. According to Electric Bikes Worldwide Reports (Frank & Edward 2005 cited in AVERE, 2005), the total sales of electric bikes had been increased all over the world as shown in *Table 11*. However, except China, the portion and growing rate of Europe and the other countries were not outstanding. It illustrates indirectly that most people in developed countries perceived the need and the importance of the electric vehicle for environment but they bought conventional vehicles instead of electric bikes. The reason is probably that most people are used to drive conventional cars and the facilities for electric vehicles are not well prepared yet. However, recently there was little movement toward electric vehicles. US President Barack Obama announced that 2.4 billion dollars will be invested in electric vehicle developments and a million of electric vehicles will be produced by 2015 (Burdick, 2009). This announcement probably would boost the sales of electric mopeds in US also it would affect other countries.

	2002	2003	2004	2005	2006
China	1,600,000	4,000,000	7,500,000	9,500,000	12,000,000
Japan	185, 000	190,000	194,000	197,000	200,000
Europe	70,000	90,000	105,000	115,000	125,000
Taiwan	10,000	12,000	13,000	14,000	15,000
SE Asia	15,000	18,000	21,000	24,000	25,000
United States	10,000	15,000	25,000	45,000	55,000
Total	1,890,000	4,325,000	7,858,000	9,895,000	12,420,000

Table 11 Worldwide electric bikes sales.

Source: Frank & Edward 2005, cited in AVERE, 2005.

3.2 Technology Research

3.2.1 Batteries

Short history of batteries for vehicles

The word, battery was used to explain an array of charged glass plates by Benjamin Franklin in 1748. Later, many scientists and chemists invented different types of batteries and it was started to be integrated with vehicle in different ways. In 1834, Thomas Davenport invented the electric car with non-rechargeable batteries. In the early 1900, electric cars were successful but electric cars were totally replaced by gasoline engine-cars until 1910's (EAA, 2005). The limited driving range and the shortage of infrastructure of electricity made electric cars fail. But by growing needs for extra devices such as power assisted window and steering, lights, radio, air conditioner batteries became the main part of vehicles. Most vehicles now use lead-acid batteries for starting, lighting, ignition and electric devices. The growing concern about environment and new environmental regulations like ZEV (Zero Emission Vehicle) which was enacted in 1990, California, US, have influenced on the development of electric vehicles and batteries.

Types of battery and characteristics

A battery provides electricity by converting chemical energy into electrical energy and it is composited electrochemical cells. Anions and cations are contained in cells of a battery and electricity is generated by chemical reactions. There are two types of batteries: first, primary batteries and second, secondary batteries. Primary batteries are also called as disposable batteries since they can be used only one time. On the other hand, secondary batteries can be recharged after consuming the energy completely since their electrochemical reactions can be reversible. Hence, they are named as rechargeable batteries. There are 5 most common types of secondary batteries: lead-acid, Ni-Cd, NiMH, Li-ion and Li-Po batteries.

Lead-acid batteries are widespread and used for all kinds of vehicles including mopeds. The advantages of lead-acid batteries are low cost and long life. Its energy generation-cost rate is 5 to 8 *Wh* per 1 dollar which is around 1.5 times more than Li-ion batteries. In other words, it costs 60 to 70% of Li-ion batteries. The lifespan of lead-acid batteries is 5 to 8 years comparing with 2 to 3 years for Li-ion batteries. But it contains lead which is poisonous material also lead is heavy metal. Growing concerning about environment has been pushing to use more environmental friendly material, so it is great disadvantage of lead-acid batteries. The energy density is 30 to 40 *Wh/kg that* is 4 to 5 times less than Li-ion battery. It means 4 to 5 times of weight are needed to supply same amount of energy with Li-ion batteries.

Ni-Cd batteries are usually used for small electric gadgets and rarely used for electric vehicles. It is more stable and hard to be damaged by deep discharging during long period comparing with Li-ion batteries. Its cycle times for charging and discharging are 1500 times, which are most large cycles among general rechargeable batteries. However, self discharge rate is high with 20 percent per month and it has memory effect which is a big drawback of Ni-Cd batteries. Memory effect is losing of charging capacity when a partially discharged battery is recharged. The cost of Ni-Cd batteries is higher than others due to the price of raw material, Nickel and Cadmium.

NiMH, nickel-metal hydride batteries are similar with Ni-Cd batteries and different thing is hydrogen-absorbing alloy is used for NiMH batteries instead of cadmium. The performance regarding energy density and specific power of it is better than Ni-Cd batteries, but discharge rate and recharging cycle are weak comparing with Ni-Cd batteries. NiMH batteries have been used for fully electric vehicles like GM EV1, Vectrix scooter and hybrid vehicles like Toyota Prius and Honda Insight.

Li-ion batteries have been developed since 1970's and its commercial type was introduced in the early 1990's. The basic principal is same with other secondary batteries and lithium salt in an organic solvent performs as the electrolyte for carrying electrode to produce electricity. It is applied in various fields like consumer electronics, automobile and aerospace industries because of its high efficiency. The energy density of Li-ion batteries is much higher than others, so it can be made smaller and lighter. Also the performance regarding charging efficiency and discharge rate is better than others. Furthermore, it does not have memory effect. However, it is less stable and durable. The efficiency is reduced under the high temperature and its internal resistance is high. Also it can be easily damaged under the overcharging and overheating. Consequently, an extra circuit is necessary to protect it from damages. Both the price of lithium and additional components for safety increase the cost of Li-ion batteries. The cost is the main issue for Li-ion batteries being replaced with lead-acid batteries even though it has many advantages.

Li-Po, lithium-ion polymer batteries were developed from Li-ion batteries and specifications related with performance are similar with Li-ion batteries. The most different thing is Li-Po batteries use solid polymer composite instead of organic solvent used in Li-ion batteries.

Type	Voltage (*V*)	Energy density		Efficiency (%)	E/$ (*Wh/$*)	Discharge rate (%/month)	Cycle (no.)	Life (years)
		(*Wh/kg*)	(*Wh/L*)					
Lead-acid	2.1	30-40	60-75	70-92	5-8	3-4	500-800	5-8
Ni-Cd	1.2	40-60	50-150	70-90	1.25-2.5	20	1,500	
NiMH	1.2	30-80	140-300	66	2.75	30	500-1,000	
Li-ion	3.6	150-250	250-360	80-90	2.8-5	5-10	1,200	2-3
Li-Po	3.7	130-200	300		2.8-5	5	500-1,000	2-3

Table 12 Specifications of rechargeable batteries.
Source: Panasonic , n.d; HOB, n.d.

Application on mopeds

According to Robert Aronsson (2009), the vice president of ETC AB, battery and FuelCells Sweden AB, the size of 1 cell of a Li-ion battery is 8x200x150 *mm* and the weight of 1 cell is 0.42 *kg*. It provides 3.6 *V* and 20 *Ah*. To operate a moped appropriately around 1.7 *kWh* of power should be supplied from a battery pack.

The volume energy density of Li-ion battery is 250 to 360 *W·h/L* and the specific energy density is 150 to 250 *W·h/kg* as shown in *Table 12*. The approximate size and weight of the battery for a moped can be calculated from the battery power and energy densities.

Volume of battery = battery power / volume energy density----------------(1)
Weight of battery = battery power / specific energy density-----------------(2)

Thus the volume of a battery is around 4.7 to 6.8 *L* from the equation (1) and the weight of a battery is 6.8 to 11.3 *kg* from the equation (2).

Figure 15 Li-ion battery, left: cell, right: battery pack.

The average capacity of electric motors to drive mopeds is around 1.5 *kW* from *Table 9*. Therefore, the moped equipped with a 1.7 *kWh*-battery pack and a 1.5 *kW*-motor can be driven over 1 hour from the equation (3).

W (energy) = P (power) X T (time)--(3)

3.2.2 Electric Motors

Types of electric motor and characteristics

Electric vehicles are driven by electric motors instead of internal combustion engines and it has been developed with electric motors as well as batteries. An electric motor moving vehicles was introduced by Robert Anderson during the 1830's and it was the first electric vehicle (About.com 2010). Now various types of motors are used in different areas and the importance of electric motors in the automotive industry has been increasing by the growing needs for electric vehicles.

Electric motors are composed of main 3 parts: stator, rotor and commutator. The stator is stationary part made of permanent magnetic or electromagnetic to generate magnetic field which the rotor interact with to produce the spinning force described as torque. The rotor called also armature is the rotating part of motors. It is wrapped by the stator and usually smaller than the stator. Finally, the commutator is electrical switch to reverse the direction of current periodically. It is attached into the stator and makes the stator produce rotating force continuously.

Electric motors are generally categorized into three by the type of the power supply: DC (direct current) motors, AC (alternating current) motors and universal motors. DC motors use direct current as a power supply and batteries are most common sources of power. On the contrary, AC motors use alternating current supplied by electric grid or inverter system with batteries. Universal motors are designed to use both DC and AC power.

Four types of electric motors are most common in electric vehicles and they are a DC motor with wound stator, a permanent magnet DC motor, a brushless DC motor and an AC induction motor. The basic structure and features of each motor are described in *Table 13*.

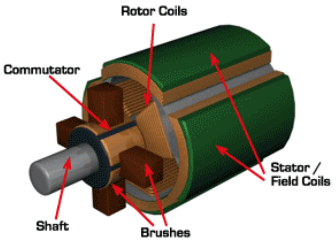
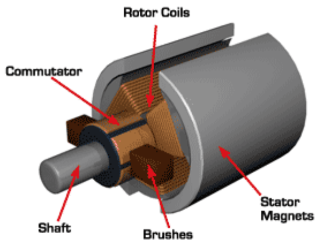
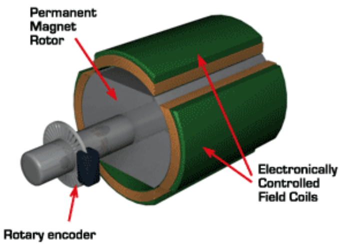
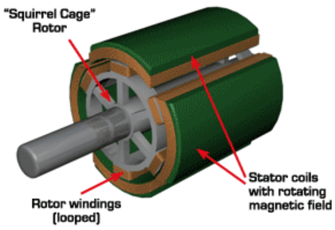
Type	Structure	Features
DC Motor with wound stator		Most common for electric vehicles. Stator is made of field coils. Economical and very efficient.
Permanent magnet DC Motor		Stator is made of permanent magnetic. Simple structure. Noisy.
Brushless DC Motor		Rotor is made of permanent magnetic. No brush and commutator. Rotary encoder is needed to sense rotor position. Efficient and powerful but expensive.
AC Induction Motor		Three phase induction type is common. Needs a variable-speed inverter under DC power (batteries). Powerful but expensive.

Table 13 Different types of motors.
Source: ZEVA, 2010.

The DC motor with wound stator is most common type. The advantages of this motor are low price and high efficiency. Even though the commutator reduces the efficiency, the total efficiency goes up to 90 %. The permanent magnet DC motor is simpler than DC motor with wound stator because its stator is made of permanent magnet. But it has a major drawback: it is noisy. The basic structure of brushless DC motor is different from previous two. A rotary encoder is used to sense the position of the rotor. It does not have the brush and the commutator, so it is efficient and powerful. However, the large permanent magnet and the complex rotary encoder increase the cost. The AC induction motor is the least popular motor among 4 and three phase induction type is most common.

Being used for electric vehicles with batteries, it needs a variable-speed inverter which costs a lot. The remarkable advantage of this type is excellent generative braking which means to generate energy while braking. Electric vehicles equipped with the AC induction motor can be driven further since the battery of vehicles can be recharged by generative braking.

New technologies

As technologies have been developed in automotive industry, new concepts of electric motors also have been introduced. The development of electric motors is not achieved by itself rather it is developed with other systems like suspension, steering and brake system. The main directions of new technologies regarding electric motors are being integrated and being compact. By reducing the number of components and size first, the cost can be reduced and second, the energy efficiency of vehicles can be increased. A transmission system composed with many gears, belts and chains conveys power from engines or electric motors to wheels. Recently developed motors and driving systems use in-wheel motors called as hub motors or wheel motors. In-wheel motors are electric motors which are incorporated into wheels without a transmission system. A transmission system causes energy losses by friction between many components. Thus, the efficiency of vehicles with in-wheel motors is higher than vehicles with conventional motors.

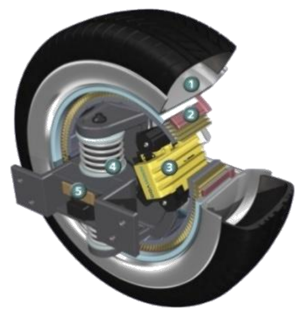
		
Siemens eCorner	**Michelin Active Wheel**	**MIT RoboScooter**
(1)For electric or hybrid vehicles. (2)Totally integrated wheel hub motor. (3)Suspension, steering and brake system also integrated.	(1)For electric or hybrid vehicles. (2)Integrated electric drive motor. (3)Suspension, brake system also integrated.	(1)For electric scooters. (2)Integrated in-wheel motor. (3)Suspension, brake system also integrated.

Table 14 New technologies on electric motors in vehicles.

Some companies and technology schools invented new type of wheels integrated with electric motors; for instance, Siemens eCorner, Michelin Active Wheel and MIT RoboScooter. In 2006 Siemens VDO announced eCorner which is a convergence of different technologies (Autoblog, 2006). Suspension, steering and brake system are integrated into it as well as an electric motor. Unlike others the electric motor, eCorner is totally inserted into wheel like one of the components. The main different thing is the structure of a wheel hub motor. Usually a stator of all kind of motors is placed inside of a rotor but eCorner has opposite structure. The rotor is placed outside of the stator and connected directly to the wheel to rotate it.

Michelin Active Wheel is similar with eCorner but less advanced and condensed type than eCorner. It has an integrated motor, a suspension and a brake (Michelin, 2008). Integrated wheels like eCorner and Active Wheel are mainly developed for 4-wheel vehicles because passenger cars have big and heavy wheels in which more parts can be integrated.

However, MIT RoboScooter as small electric scooter has an integrated wheel. It has integrated motors, suspension and brake like Active Wheel. Its structure is much simpler than gasoline-powered scooters by using the in-wheel motor and a battery. RoboScooter consists of around 150 components comparing with the 1,000 to 1,500 for gasoline-powered scooters (Smart Cities Group, n.d.). Its production and maintenance cost can be reduced due to simple structure.

3.2.3 Driving (Joint) System

The need of driving system

Conventional mopeds or scooters with 2 wheels do not need an extra driving or joint system since the body can be tilted to lateral directions. *Figure 16* explains the basic dynamics regarding cornering. While cornering a centrifugal force is generated. The centrifugal force causes a rolling moment which makes mopeds tumble over. To overcome tumbling mopeds should be tilted inward. Both the tilting angle and the total weight of a moped plus a driver generate a new moment against to the rolling moment. Therefore, the mopeds can do cornering without tumbling.

Unlike two wheelers, 3 wheelers either 2+1 type or 1+2 type could not be tilted to lateral directions without an extra joint system because of the structure. A conventional tricycle for children is a good example of 3-wheeler and it could not be tilted. At a low speed range, the centrifugal force is relatively weak so the rolling moment is not enough to turn over mopeds. A rigid body structure like conventional 3 wheelers needs an extra mechanism to be tilted at a high speed range without falling. New technologies and concepts regarding driving and joint system have been developing to make 3-wheeler tilt.

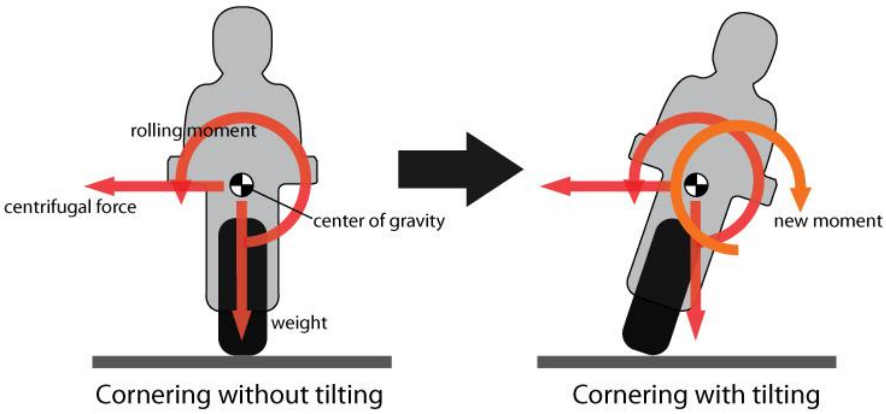


Figure 16 Simple dynamics for a two wheeler while cornering.

New technologies

Piaggio MP3 is the most successful 3-wheeler and it has a special driving system. Two Independent tilting wheels guarantee more stable riding than other scooters. An innovative parallelogram suspension is fixed to the body frame. Four cast-aluminum arms are connected to the central tube and two guide tubes are located above the each wheel. The motion of wheels is governed by the double parallelogram structure. Each wheel is connected to each guide tube and moves jointly. The parallelogram structure is the basic principal to combine 2 wheels and make them tilt together. The double parallelogram structure is a good solution but it is complex and costly since it is designed to perform steering and tilting. The price of Piaggio MP3 is higher than any other motorcycles due to its new but costly technology.

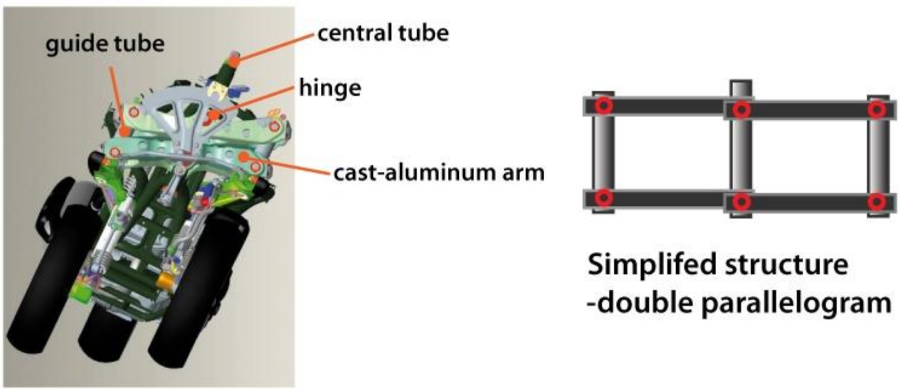


Figure 17 The structure of parallelogram suspension, Piaggio MP3.

New concept of joint system for 1+2 type was developed by Department of Mechanical Engineering at University of Pauda, Italy. A driving and joint system for 2+1 types is relatively common comparing with 1+2 type. Students from University of Pauda introduced a four-bar linkage as shown in *Figure 18*. The four-bar linkage consist of two connecting bars and two bars fixed to the front and the rear frame respectively. The smaller bar located in the lower is connected to the front frame and a seat is also connected to it. While cornering the front frame is tilled along with the seat also the body of a driver. At the same time, two connecting bars rotate and limit the motion of the smaller bar but the longer bar connected to the rear frame is not move. The structure of the four-bar linkage is simpler than the double parallelogram. The whole structure of this concept is not much different from the structure of conventional 1+2 type. It is simple and not costly but the performance at high speed range is not as good as double parallelogram. For the four-bar linkage concept only a front body can be tilt without a rear body. It means the four-bar linkage concept tolerates limited amount of rolling moment from moderate speed range.

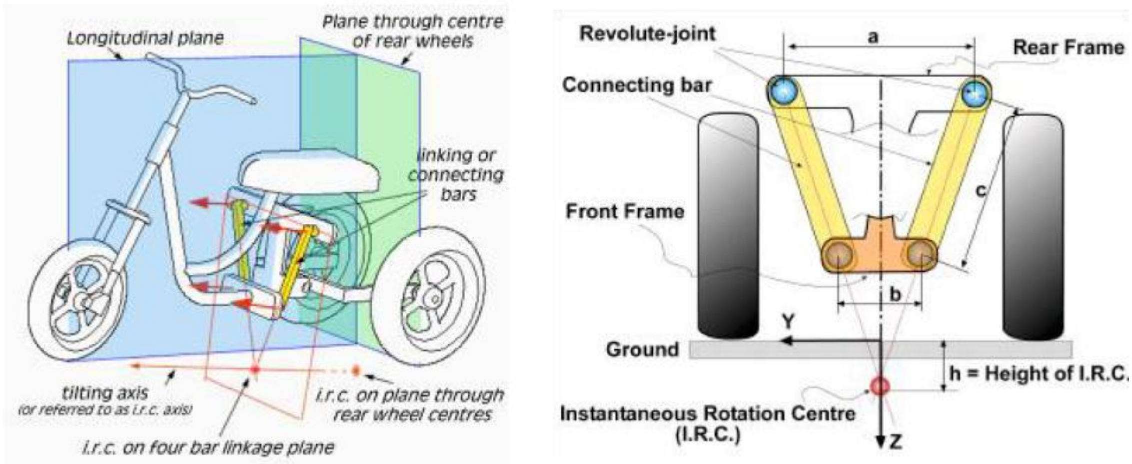


Figure 18 The structure of the four-bar linkage system.
Source: Lista, et al., n.d.

3.3 Material Research

Development tendency

Growing concern about environment and soaring energy price due to limited amount of resources have been affecting the design and the material of vehicles. Being lightweight and environmental friendly are two main aims of material development. The use of lightweight material directly increases the energy efficiency of vehicles. For environment, global regulations have been constraining the use of harmful material like heavy metals and toxic materials. Furthermore, regulations on ELV (End-of-Life Vehicle) drive the recycling rate of ELV. According to European Union resignation (European Union, 2000) the rate of reuse and recovery has to be increased at least 95 % until 2014. The rate of re-use and recycling should be increased to a minimum of 85 % at the same time. Most regulations and movements are mainly relevant to passenger vehicles but mopeds and motorcycles will be influenced by main stream.

Material inventory of motor vehicles

Mopeds and scooters roughly consist of several materials according to the research by ADB (2009). *Table 15* illustrates the type and the percentage of material used in electric bikes in China. It is assumed that a moped and a scooter-style electric bike indicate a same vehicle even though the terminology is different. Steel is main material of electric bikes and it is around 40 % of total weight. Plastic is second major material of electric bikes. A scooter-style electric bike uses more plastic than a bicycle-style. The portion of lead is relatively high as over 20 percent. Lead is only used for batteries but it takes a forth of total weight. The portion of rest materials like fluid, copper, rubber, aluminum and glass is not high.

Weight of Electric Bike Materials (kg / weight percentage)		
	Bicycle-Style Electric Bike	Scooter-Style Electric Bike
Total Steel	18.15 / 44.0	26.18 / 39.8
Total Plastic	5.67 / 13.7	15.22 / 23.2
Total Lead	10.28 / 24.9	14.70 / 22.4
Total Fluid	2.94 / 7.1	4.20 / 6.4
Total Copper	2.55 / 6.2	3.46 / 5.3
Total Rubber	1.14 / 2.8	1.22 / 1.9
Total Aluminum	0.52 / 1.3	0.58 / 0.9
Total Glass	0.00 / 0.0	0.16 / 0.2
Total Weight (kg / %)	41.25 / 100	65.73 / 100

Table 15 Material inventory of electric bikes.
Source: ADB, 2009.

To compare the material inventory of electric mopeds with passenger vehicles *Table 16* is presented. The most outstanding part is the percentage of steel. Passenger vehicles use more steel and iron than mopeds and the average portion of steel and iron is nearly 70 percent of total weight. The safety issue may be the important factor for high percentage of steel and iron. Plastic is only used around 10 percent in passenger vehicles. But both mopeds and passenger cars use small amount of non ferrous metal like aluminum and copper.

As shown in *Table 15* and *Table 16*, vehicles including mopeds depend on steel which is conventional material. Steel is widely used because of its high performance, relatively low price. However, new materials replacing steel have been introduced to meet new market requirements and trends. The movement is usually started from passenger cars and it spreads to other vehicles including mopeds. Therefore, the future material trend of mopeds can be observed in the present trend of passenger vehicles.

Material	Material Ratio (% by weight)		
	Generic US Vehicle	Generic Japanese Vehicle	Generic EU Compact Vehicle
Steel and iron	67	72.2	65
Plastic	8	10.1	12
Glass	2.8	2.8	2.5
Rubber	4.2	3.1	6
Fluids and Lubricants	6	3.4	2.5
Non ferrous metal	8	6.2	8
Other materials	4	2.2	4
Total weight (kg)	**1438**	**1270**	**1210**

Table 16 Material composition of different vehicle types.
Source: Kuhndt & Bilitewski 2000 cited in Lucas, 2001.

Application on mopeds

Steel would be remained as main material in the future but the structures of frames and the property of steel will be changed toward lightweight. *Table 17* illustrates the possible trends for future materials depending on volume and circumstances. Zinc coated steel will probably be used as main structure of passenger vehicles. For the main frame of mopeds, aluminum would be a most possible alternative which replaces steel and it is used in a main structure and closures. For closures, polymer would be a main material for mopeds. Synthetic polymer like synthetic rubber, Bakelite, nylon, polystyrene, polyethylene and polypropylene are already used in many parts of vehicles. Carbon fiber is new material which is mainly used for high performance vehicles because of its excellent properties concerning weight and strength. However, it may be not the proper material for mopeds since the price is very high and the properties are redundant for mopeds.

Throughput	Anticipated conditions			
High Volume Ca 250 000/ yr.	Main structure	Option 1 Continued use of Zinc coated steel -HSS 70%+ -Forming grades	Option 2 Aluminum Spaceframe (Audi A2)	Option 3 Hybrid mix: -steel structure HSS grades BH, IF, D·P TRIP.
	Closures	Zinc coated BH Steel (BMW) or Polymer (Saturn)	Aluminum 6016 (Audi A2/A8)	Aluminum 6016 (Audi A2/A8) or Polymer for Bolt-on panels (Saturn)
Low volume	Main structure	Option 4 Zinc coated steel (L. Rover) (Espace) (SMART)	Option 5 Aluminum Spaceframe (Ferrari Modena) or Punt (Elise) or Monocoque (Jaguar XJ)	Option 6 Carbon fibre Composite + Al profiles (A-M Vanquish)
	Closures	Aluminum (L. Rover) or Polymer (Saturn) (Espace) (SMART)	Polymer Bodyshell (Elise)	Polymer shell or Aluminum
Throughput	Accelerated conditions			
High volume Ca 250 000/ yr.	Main structure	Option 7 Downsized zinc coated HSS (ULSAB-AVC) or Aluminum Spaceframe (Audi A2) (GM EV1)	Option 8 Carbon fiber + Aluminum profiles (Vanquish) Pre-prepared carbon fiber construction (Ultima)	Option 9 Aluminum/composite Honeycomb based platforms
	Closures	Polymer panels Polycarbonate Self colored (Smart) or (GM EV1) -RIM Horiz. -SMC Vertical	Polymer shell and Closure(Elise)	Polymer panels (Smart) Self colored (Saturn)
Low volume	Main structure	Option 10 Aluminum Spaceframe (Ferrari Modena) or punt (Elise) or Monocoque (Jaguar XJ)	Option 11 Carbon fiber Composite + Al profiles (A-M Vanquish)	Option 12 Complete carbon fiber composite structure (McLaren F1)
	Closures	Polymer Bodyshell (Elise)	Polymer shell or Aluminum	Polymer Bolt-on panels. (Saturn, SMART)

Table 17 Possible trends for future materials utilization depending on volume and circumstances. Source: Davies, 2003.

3.4 Ergonomic Research

In many ways, the structure of modern mopeds has not changed much since the invention of motorcycles which are their ancestral products invented over 100 years ago. Between 1940s and 1960s, the post war period a motorcycle evolved to have functional designs to replace a car (Bust, 2009). According to Bust, with the rise of reasonably priced cars, the 2-wheel vehicles used at leisure also began to be used as a main transport. In the manner of engineering, 2-wheel vehicles are kept static and balanced during driving. All the factors including view of a driver, NVH and climate condition are involved into the riding (Chou & Hsiao, 2005). Reasonable ergonomic design should be taken into consideration to provide a good solution for the riders.

3.4.1 Physical environment

By their nature, mopeds leave riders exposed to the environment; for instance, weather and wind (Stedmon 2007 cited in Bust, 2009). This can influence the stability and safety of the moped riders and ultimately the effect will lead the moped to different driving conditions. The moped rider drives without much protection, so that the body is totally exposed to sun, rain and wind. Hence the environment effect has to be seriously concerned.

Besides the natural environment, the traffic environment also affects the driving. According to Bust (2009), the rider may experience turbulence generated by other vehicles or by the ambient wind. In terms of the control of lateral position on the road, constant wind can be easier to deal with, but sudden lateral gusts are more likely to cause problems. Even big trucks or vans can lead turbulence which usually happens at their back side, when they pass by under a high speed. Turbulence can shake drivers' body and the moped. If they are not prepared in advance, it may cause an accident.

The road condition is another issue for the moped drivers. The bump terrain directly influences the comfort of driving, and the long trip also makes riders tired if they do not have comfortable seat. Research recently carried out by Roberston (1986 cited in Bust, 2009) mentioned that "Rider comfort studies have identified vibration as a key issue with 22 % of riders suffering discomfort in this way". There are 3 ways to improve the discomfort driving: the utilization of soft material for the filling of seats; increase the contacting size between seat and hip; invitation of backrest. Whilst the motor of an electric moped usually does not generate as much vibration as the engine does, that increases the possibility of comfortable driving for riders.

3.4.2 Interaction Environment

A moped gives an interesting problem to ergonomists: it is a constrained operational area in which there is very limited available adjustment to suit the different need of riders (Roberston 1986, Porter 1987 cited in Bust, 2009). According to the research, there are two issues to be addressed: the need of the rider in different size to fit the same workstation; the relationship between the posture of the rider on the moped and effectiveness of the riding task. Any ergonomic research should take these two problems as the primary targets.

Because the speed of the moped is not the aim which the project wants to pursue, the maximum speed of this concept would stay under 45 *km/h*. In order to design the practical operation space and clear interface with the operation of the vehicle, authors believe that the anthropometry is needed to be taken into account to fit of the workstation for the user.

3.4.3 H-point

According to Chou & Hsiao (2005), anthropometry is defined as "a research method of ergonomics dealing with the measurement of the dimension and certain physical characteristics of the human body." The H-point or hip-point is an important parameter in anthropometry, and it is also widely used in product design, especially automotive design.

The H-point stands for the location of a people or manikin hip, and it is the theoretically parameter. It specifies the pivot point between the torso and upper leg portions of the body. The H-point is the major factor in the overall design of a vehicle including roof height, aerodynamics, visibility, comfort and ease of entry and exit (My Ford Freestyle, 2005). In the design development chapter the h-point is the main parameter which authors use in technical drawing.

3.4.4 Research

Swedish people are generally taller than others. Therefore, the height of a roofed moped should not encumber riders to keep their body or neck straight even when wearing a helmet.

In order to check dimensions regarding basic ergonomics, two mopeds were examined. Firstly, authors started the research on a Yamaha moped. It is a typical compact EU-moped with 2 wheels and allows two people to ride at the same time. The test was done by one of authors. The author was 24 years old male, and the height and the weight were 1.80 *m* and 62.5 *kg*. The author almost reached the average height of Swedish people, 1.815 *m* (Lundin, 2010).

Figure 19 The scene of testing a moped.

The instrument panel was located right above the knees. The upper leg and the H-point could be kept in horizontal direction. The interiors of the moped had two concaves shapes which were in front of the knees and allow even taller people to place their legs. The seat was wide and soft and it could provide comfortable sitting even for the people who have a big body. The other research was aimed at the roofed moped which was produced by Chinese electric moped manufacturer, Xingyue. The type of the moped was DM82 for only one person and it could be used for daily commuting or some tasks such as mail delivery as shown in *Figure 20*.

Figure 20 Examples of different purposes, DM82.

Apart from the investigation on Yamaha, the test driving of DM82 was performed. It had a unique turning progress: the rider should tilt his or her body when he or she want to turn, then the main body of the moped will tilt by his or her movement but all the wheels are still kept straight. In the beginning, riders may feel a little nervous to this situation, hence they may need some time to get used to this characteristic.

The instrument panel was located diagonally below the steering wheel, whilst the side mirrors were mounted lower than normal mopeds. It seemed hard for riders to read the meter and watch the other vehicles from the behind. The space of workstation was roomy and the vaulted roof on the top provided larger space for the riders. It was useful for the taller riders. Even though the windshield was leaning with the angle around 45 degree, it did not affect the sight of drivers.

The technical drawings provided from the project leader shows top, front and side views of the DM82 as shown in *Figure 21*.

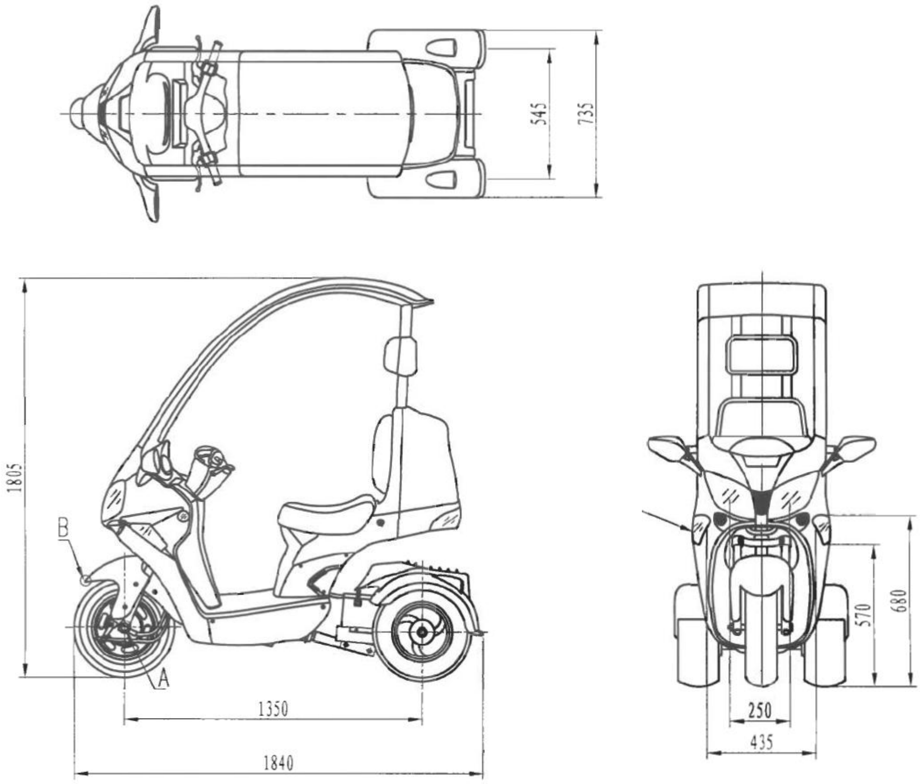


Figure 21 The dimensions of Xingyue DM82.

3.5 Platform and Modularity Research

Background of platform and modularity

The target of automotive industry has been changing from mass production to mass customization. Cost reduction through mass production has been the most important goal of the automotive industry and it is still significant. However, more and more customers need customized vehicles with low price. Low price and customization are hard to satisfy at the same time. According to trade-off theory, price or customization might be sacrificed to maximize one value. Automotive companies have introduced new ideas to minimize trade-off. A platform and modularity concept is the way to maximize customization with low cost.

Definition of platform and modularity

According to Meyer and Meyer (1997), product platform is defined as “the serial of components or parts which are used in different products to increase product variation and production efficiency”. The serial of components or parts is named as a module. The idea of modularity was developed in a same manner with platform and it is part of platform design. Baldwin and Clark (1997) defined modularity as a model to break down complex system into similar parameters or tasks which are interdependent within a system but independent across different modules.

3.5.1 Platform

Platform design for passenger cars

Recently platform strategy is widely used in many companies having a product family. Common parts or modules are used among similar products called as product family. Robertson and Ulrich (1998) presented the benefits of platform strategy: first, companies can develop various products efficiently; second, companies can increase the flexibility and responsiveness; third, companies can secure a competitive position. Platform strategy also has an advantage regarding brand identity. By sharing similar components and modules which are exposed outside, end users can get more change to watch products. According to Pandremenos (2009), car manufacturers can cover the entire market segments through the platform strategy. Volkswagen is one of the leading companies for platform strategy and *Table 18* shows the product family of Volkswagen. In a hatchback segment, Audi A3, VW Golf, Seat Cordoba and Skoda Octavia share a platform. In the sedan, VW Bora, Seat Toledo and Skoda Octavia have a same platform.

Brand	Body style						
	Hatchback	Sedan	Estate	Convertible	Coupe	Pick-up	Niche
Audi	A3			TT	TT		
VW	Golf	Bora	Golf	Golf		Caddy	Beetle
Seat	Cordoba	Toledo					
Skoda	Octavia	Octavia	Octavia				

Table 18 Example of platform strategy, Volkswagen.
Source: J. Pandremenos, 2008.

Application on mopeds

The platform strategy in the automotive industry is not only the story of passenger cars. Motorcycle companies also have a platform strategy. *Table 19* illustrates examples of platform design by Derbi, Spanish Motorcycle Company owned by Piaggio. Sonar 50 2S and 125 4S are sharing the body structure and most components except the engine. Platform design is also applied to Atlantis series, 50 2T and 50 4T. The only difference between two models is the size of the engine like Sonar series.

Series	Model	
Sonar	50 2S	125 4S
		
Atlantis	50 2T	50 4T
		

Table 19 Examples of platform design, Derbi scooter.

3.5.2 Modularity

Modularity concept for passenger cars

Modularity concept was introduced during 1960's to reduce the complexity (Starr, 1965). Complexity of vehicles increases the lead time to assemble many components and it increases the possibility of errors. A motorized vehicle is one of the most complex products and the application of modularity concept is more efficient than other products. Passenger cars are composed of 16,000 to 20,000 parts and divided into five modules: front-end, floor, roof, upper body and rear-end as shown in *Figure 22*. Each module is split again into sub-modules and sub-elements.

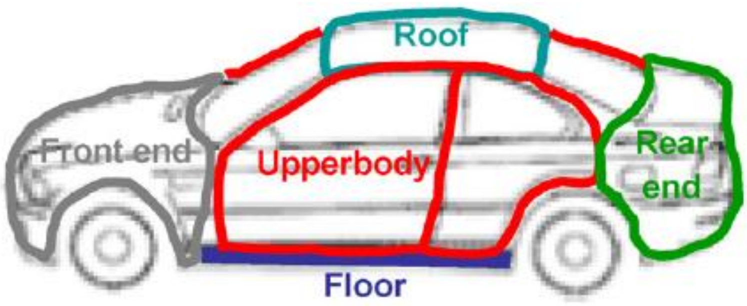


Figure 22 Car body modules.
Source: Pandremenos, et al., 2009.

According to Feitzinger and Lee (n.d.), there are three advantages of modular design. First, parts can be standardized with postponed differentiation of products. It means modules can be assembled into different products during any time period upon request. Second, a total lead-time can be reduced since modules can be manufactured separately. It can be understood in a relationship between OEMs/final product makers and suppliers. Final product makers assemble modules which are produced by different suppliers. Therefore, whole assemble time can be reduced by simultaneous work flow driven by many supplier. Third, final product makers can easily cut off potential quality problems. In the same manner with second part, suppliers can take potential problems by producing modules. Final product makers can switch a supplier having low quality into a new supplier. Furthermore, suppliers voluntarily keep high-quality to satisfy final product makers as customers.

Application on mopeds

Application of modularity concept across a product family is common for passenger cars since passenger cars are more standardized than mopes. Mopeds can be divided into several modules but only same series of a moped share same modules rather than across a product family as shown in *Table 19*. To apply modularity concept across a product family, the platform strategy should be considered together. Mopeds can be split into two modules, a front and a rear, as shown in *Figure 23*. The front module can be used as the platform for a 2-wheel version and a 3-wheel version. The rear module with 2 wheels can be replaced by another module with 1 wheel to form a new moped. As a result, two different mopeds can share the front module.

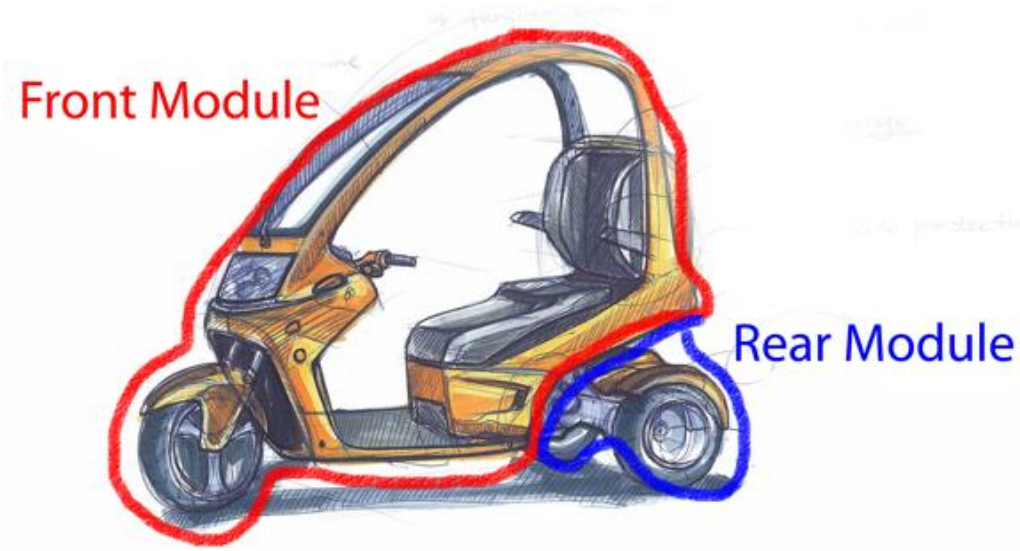


Figure 23 The modularity concept for mopeds.

4 Design Development

In this chapter, the whole process of design development will be described. Based on the accumulated information from previous research, an actual design phase was started. The design development part consists of 4 consecutive procedures: first, design goals; second, form development; third, design verification; finally, 3D modeling.

4.1 Design Goals

The design goals are established mainly from user needs analysis and market research. They are supposed to provide the design guidelines and direction. They define the target groups of products and core values. The mood boards present the core values in a visual way.

4.1.1 Target Group

Generally speaking, the electric moped usually can be seen as a transportation tool for short distance travel. People do not purchase it as their first vehicle. The reasons come from different aspects. The first one is the climate effect: moped cannot provide the protection as the car does. In Sweden, during the winter, heavy snow sometimes blocks the road for many days. Bicycles, mopeds and motorcycles are rarely used there. The second reason is that the moped cannot carry as much stuff as the car does. People would like to carry their bicycles, pets, shopping bags and some use trailers to carry furniture or even larger objects.

Based on the discussion in the users need analysis part, the target customers are separated into 2 groups: a primary target group, middle aged men and a secondary target group, teenagers. Middle aged men usually have stepped into family lives. They have stable income, and most of them already have their first cars. So mopeds can be considered as the second vehicle instead of an additional car in such families.

Through the investigation about commute behaviors of families, two situations have been categorized. In a fortunate case as shown in *Figure 24*, working places of husbands and wives could be in the same area or direction. So they can share one car. Normally, if there is only one car in the family, the husband usually plays the role of a driver. He takes his child and wife to the school and to her working place. Afterward he will drive to his working place. But in most cases, parents do not work in the same area, thus one of the parents has to choice the public transport as shown in *Figure 25*.

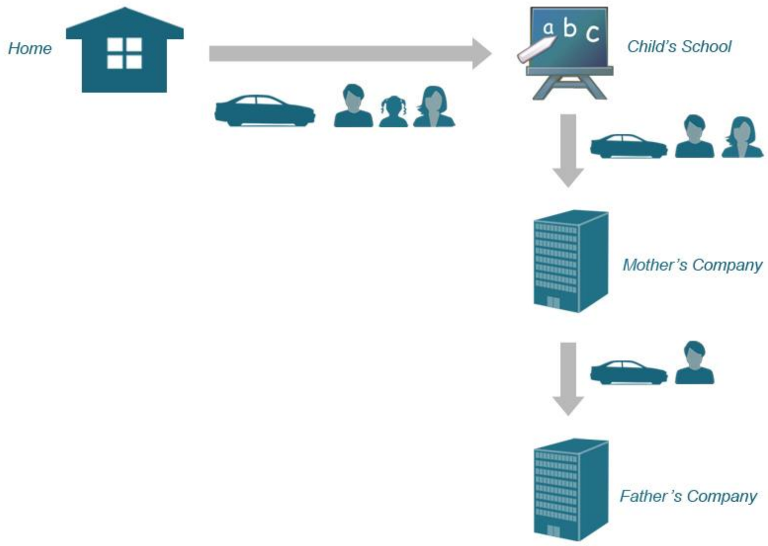


Figure 24 The way of commuting for family, case1.

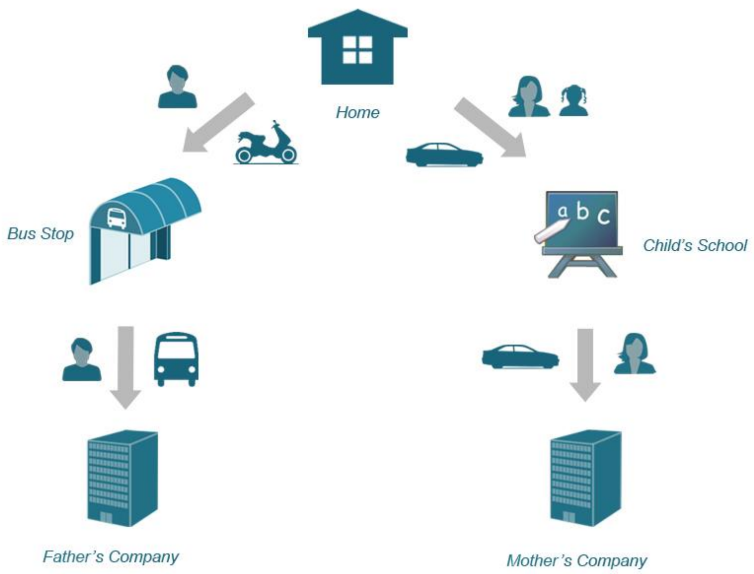


Figure 25 The way of commuting for family, case2.

The adoption of a moped can solve this problem and it will change the way of family commuting. One of the parents drives to the public transport spots by a moped, and then he or she transfers to buses or trains to go the working place. The other parent can first take their child to the school. Afterward he or she can drive to the working place as shown in *Figure 26*. In this situation parents would not be involved in the long trip any more, therefore they could have more flexible time after work. They can save a large amount of money if they do not have to buy another car.

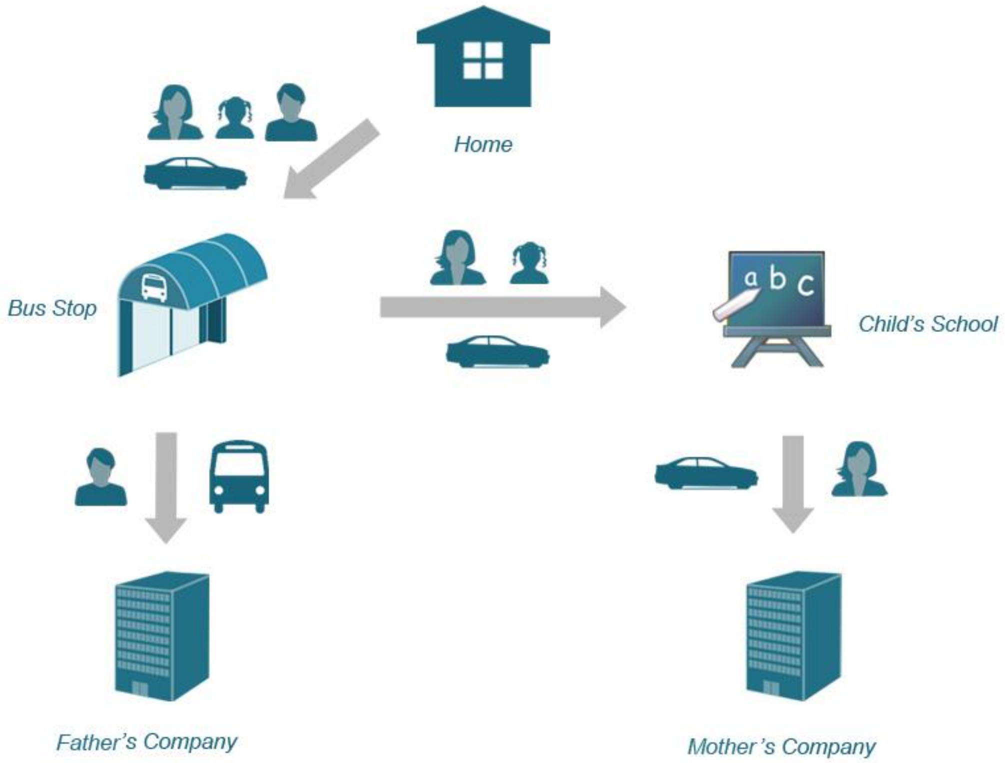


Figure 26 The way of commuting for family, case3.

The secondary target group is teenagers, aged around 15-19 years old. In Sweden, people are allowed to drive a moped after reaching 15 years old, but they cannot drive a car until they reach 18. Therefore, the moped can be a good choice for them. Teenagers do not always prefer the trip by sitting in their parents' car, so they may feel stress from it. They have a strong requirement to have more private space to make them feel free. They would like to have their personal vehicle and take charge of it at their disposal.

4.1.2 Core Values

According to Karjalainen (2009), core brand values are generated by interaction between product and brand meaning and they are expressed by the various product features. The new moped concept does not belong to any brand, so it should be endowed with some values which can represent common aesthetic values and could be acceptable to the Swedish markets. The research has been done on some famous Nordic brands such as Volvo and B&O in order to find out some common value deep inside. After the research, 4 aspects were chosen to represent the core values of the mopeds which correspond with the relevant target groups.

4 core values were selected: Scandinavian, dynamic, practical, family and friendly. The first is Scandinavian. It is a term used to represent Scandinavian design and it emerged in the 1950s in the three Scandinavian countries, Denmark, Norway and Sweden. It is a design movement characterized by simple designs, minimalism, functionality, and low-cost mass production (Fiell & Fiell, 2003). Authors want the concept to have decorative forms such as BMW's flame surfacing, but the whole image is supposed to convey the simple and clean feeling.

Dynamic is the second value which is important to the concept. Based on the survey of users' perception about the design, dynamic is an attractive element for the target groups. Sporty features fit their aesthetic tastes and behavior methods.

Practical is the third core value. Practical Design challenges traditional standards to develop efficient solutions for today's project needs. Innovation and creativity are necessary for the project to accomplish practical Design (MDoT, n.d.). All the research suggests that the new concept should provide more possibility for moped riders to have access to practical features and functions. The practical value means that the innovation is not only about the form but about the functions.

Family and friendly is the forth core value. The moped concept concentrates on the daily life in the family. Although it is supposed to be designed for single people, riders also want to drive with their friends or family members on some occasion. The new concept is aiming to involve more concerns about the second passenger.

4.1.3 Mood Board

The mood board is the collection of the pictures which can represent core values and it is a visual tool to quickly inform others of the overall feel that the concept is trying to achieve (Tong & Robertson, 2008) and it will keep the concept running in a proper direction. Every set of images corresponding to the core values was established in the last chapter.

Figure 27 Mood board.

4.1.4 Functional Requirement

Based on the user's common needs illustrated in *Table 5*, some discussion and verification took place with project leader. After evaluation of every common requirement, there are 7 items picked, which all the results suggest to continue developing in the future. The picked ones showed in *Table 20* present useful functions, which are feasible to be innovated in the concept.

	Picked requirements
1	Providing weather protection against rain or snow
2	Be able to carry extra passenger
3	More storage capacity for shopping bags and personal brief case
4	Easy access to electricity when they battery runs out
5	Easy to handle(drive) the moped
6	Comfortable seats
7	Be able to do exercise when they riding, such as riding bicycles

Table 20 Functional requirements from the users.

4.1.5 Style Requirements

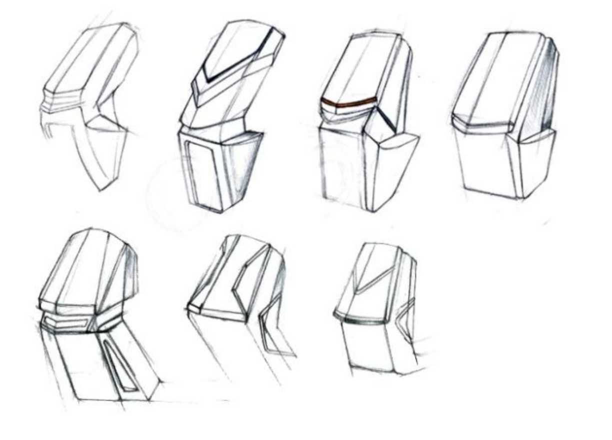
The result of the perception about stylish described in perceptional perspective part gives guide lines to design a moped. Style requirements for new concepts can be set based on the favorable styles selected by interviewees. In selecting favorable styles, the opinions from middle-aged people as the main target group and young people as the secondary target group are mainly reflected. 4 style requirements are decided as shown in *Table 21*.

	Style requirements
1	Dynamic
2	Simple and fresh color
3	Clean surface
4	Futuristic

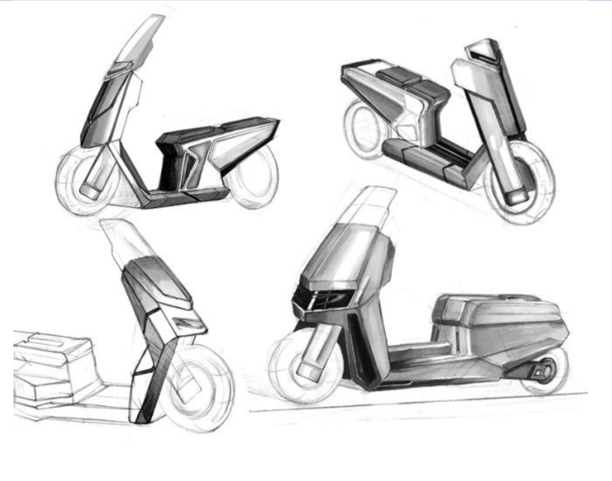
Table 21 Style requirements from the users.

4.2 Form Development

Plenty of information derived from the research part and guide lines set from the design goal part were prepared for the next step. Idea generation and visualization based on accumulated information and values were main tasks in from development phase. Sometimes the work flow went reversely to verify the form and structure of concepts. Some technology specifications or limitation and ergonomic issues were reviewed again. To confirm finally developed concepts, the design verification stage as an independent process was added after the form development phase. To get as many ideas as possible, being creative and conceptual are important, therefore free hand sketching was used at all times.



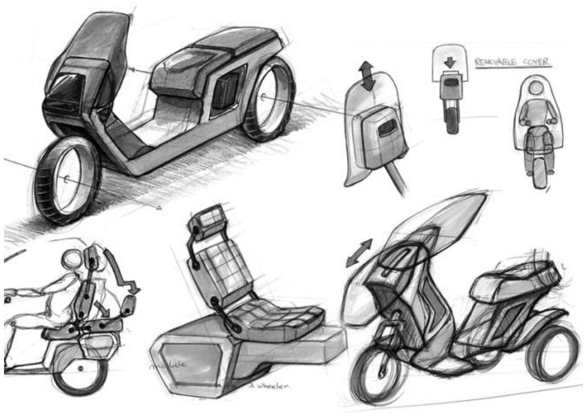
Stage 01



Stage 02

In stage 01, different shapes were studied through brainstorming. Idea generation, selection and development were repeated to find interesting and correspondent shapes which meet as many as possible of requirements from previous stages. Different versions of simple and dynamic shapes were mainly generated to follow design goals and what users also authors want.

In stage 02, further development was achieved based on several selected shapes. To produce harmonious feeling of simple and dynamic design, entire body shapes along with some details were developed. Styling and conceptual feeling were more focused than functionality and feasibility until stage 02. Some problems regarding platform and modularity design were identified. The 2-wheel and the 3-wheel versions should have shared components as a platform and had own modules being separated into each moped.



Stage 03

Stage 04

Stage 05

To realize not only new utilities and functions but also platform and modularity design functionality and feasibility were considered from stage 03. Universal body structures for platform design also components like seat and cover were developed in this stage. Getting new and innovative ideas to make concept mopeds futuristic and functional was one of the aims of this stage.

As the result of consecutive form development, the images of the 2-wheel version which would share a platform with the 3-wheel version were finalized in stage 04. Except the rear module explained in the modularity part of this report, the only difference between the two-wheel version and the three-wheel version is that the two-wheel version has a short and simple windscreen since the main target of it is young people who want be cool and casual. Riding and sitting posture of a driver and a passenger were evaluated roughly. Approximate proportion and dimensions were also reflected from existing models. Furthermore, detailed shapes, colors and materials were discussed.

Finally, the images of the 3-wheel version modified from the 2-wheel moped were visualized in stage 05. The rear module and the roof were mainly developed in this stage. Also further details on the control panel and the rear light were finished. Developing the rear module and the removable roof was most demanding task among entire stages. The general structure of the joint system hinted from Xingyue mopeds was visualized without technical review. For the feasibility of concept mopeds, technical review and verification will be described in the next part of this report.

4.3 Design Verification

The overall design of mopeds was decided in the form development part where creative and conceptual ideas were prioritized. Therefore, technical review and verification is needed for concept mopeds being feasible before going to the final stage, 3D modeling. For verification, authors visited EV Adapt, the electric car producing factory located in Nödinge, outside of Gothenburg in Sweden where the GPP-project was keeping 5 electric mopeds that had been acquired from the Xingyue factory in China. In the factory area, authors did test driving and checked the technical structures of drive systems, including a joint system for a 3-wheel version. Regarding the technical possibility of in-wheel motors, short discussion was done with the technician of the factory.

4.3.1 Technical Point

Designing and developing a proper joint system for the 3-wheel version was the most demanding task in the technical point of view. A joint system should be a simple structure which can be easily separated as a single module to share a platform across 2 concepts. For that reason, the joint systems presented in the technical research part of this report is not suitable for new concepts. The joint system from Xingyue DM82, one of the tested mopeds emerged as an alternative method. The overall structure of it seemed appropriate to the new concept. However, a full technical review and verification on this joint system was not executed. Technical drawings and specifications obtained from Xingyue did not include the joint system, probably because of patents or copyrights issues. It was decided to adopt the general idea and structure of the joint system of Xingyue. The introduction of two in-wheel motors for the 3-wheel version was reviewed with the technician of EV Adapt. The technician mentioned that two in-wheel motors can be mounted in the 3-wheel version and each in-wheel motor can be operated separately by a controller. Hence, a 3-wheel version can do cornering more smoothly by electric differential.

Figure 28 The joint system of Xingyue DM82.

4.3.2 Ergonomic Point

After the research and analysis on existing mopeds, basic constraints which solve ergonomic issues of driving a moped were decided as shown in *Figure 29*. Considering the requirements from the users, the design is trying to give people a comfortable and safe driving experience.

The total height of the moped is around 1.8 *m*. The dummies are set to be 1.8 *m* high just as same as the average height of Swedish males. As the storage would be placed under the seat, the clearance distance is set to around 0.25 *m*.

Keeping the riders in a low position will make it easier for them to control the vehicle and maintain balance when encountering a turning or sharp braking. So based on the clearance distance and pre-established storage capacity, the H-point is placed 0.7 *m* above the ground, which the upper leg can be placed horizontal, and the second rider sit right behind the front one, his H-point is 0.798 *m* above the ground.

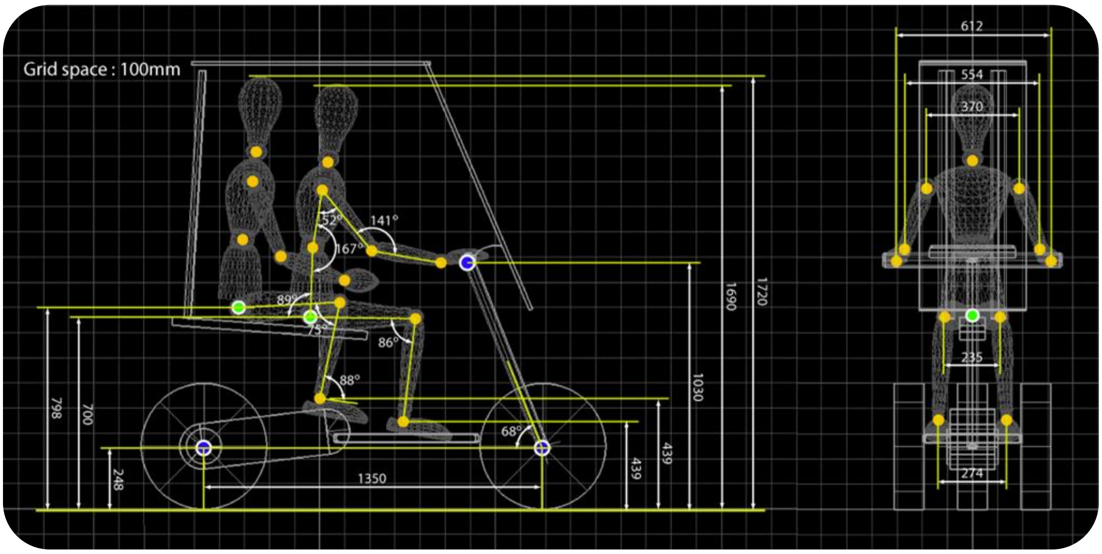


Figure 29 The drawing of basic constraints.

4.4 3D Modeling

As the final stage of designing concept mopeds, 3D modeling was completed. In most cases of design works, physical prototypes are made as the final result of a design process. Then, the prototypes are verified again for mass production. Physical prototypes were discussed in the beginning of this project. However, physical prototypes were not made because the time and budget constraints. To make up for the absence of physical prototypes, extra efforts regarding production possibility were put in the 3D modeling phase.

4.4.1 Side View/Front View Drawing

Figure 30 Side view drawing by hand.

The initial side view drawing was made by freehand sketch based on the finalized sketches from the form development phase and the drawing for basic constraint from previous phase. Every line of the drawing was carefully added to reflect the image of sketches and hard points which cannot be changed due to ergonomic and technical issues.

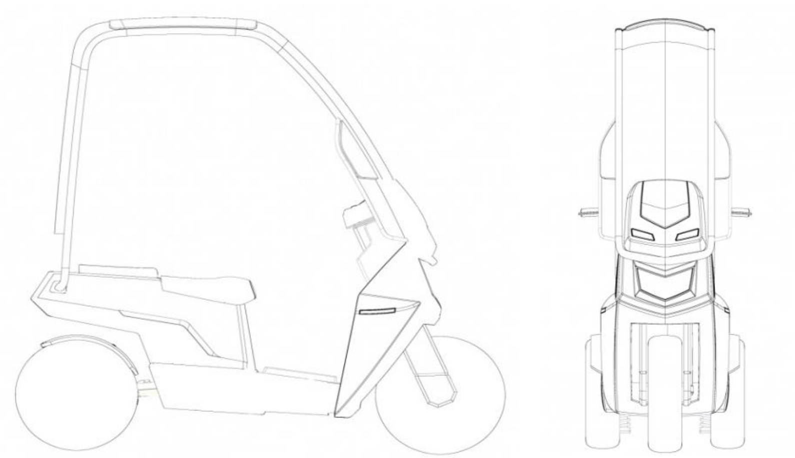


Figure 31 Side and front view drawings by 3D modeling program.

The initial side view drawing was imported into 3D modeling program, Alias Studio tools to form 3-dimentional curves. Rough lines by freehand sketch were refined and transformed into 3D. *Figure 31* illustrates projected 3D curves on side view and front view.

4.4.2 Body Modeling

The whole modeling process was separated into two parts, a main body and a front body and the separation point was the connector on which a driver put his or her feet. First, two manikins were placed to simulate the posture of a driver and a passenger. Second, two seats were created. More efforts were put for designing the front seat for a driver since mopeds are mostly driven by one person. The third step was to create the main body based on the position of seats. The forth step was to build the front body and connect it to the main body. In this step, the appropriate volume and size of the connector was also reviewed to contain a battery pack. Finally, a roof and wheels were added to complete the overall structure.

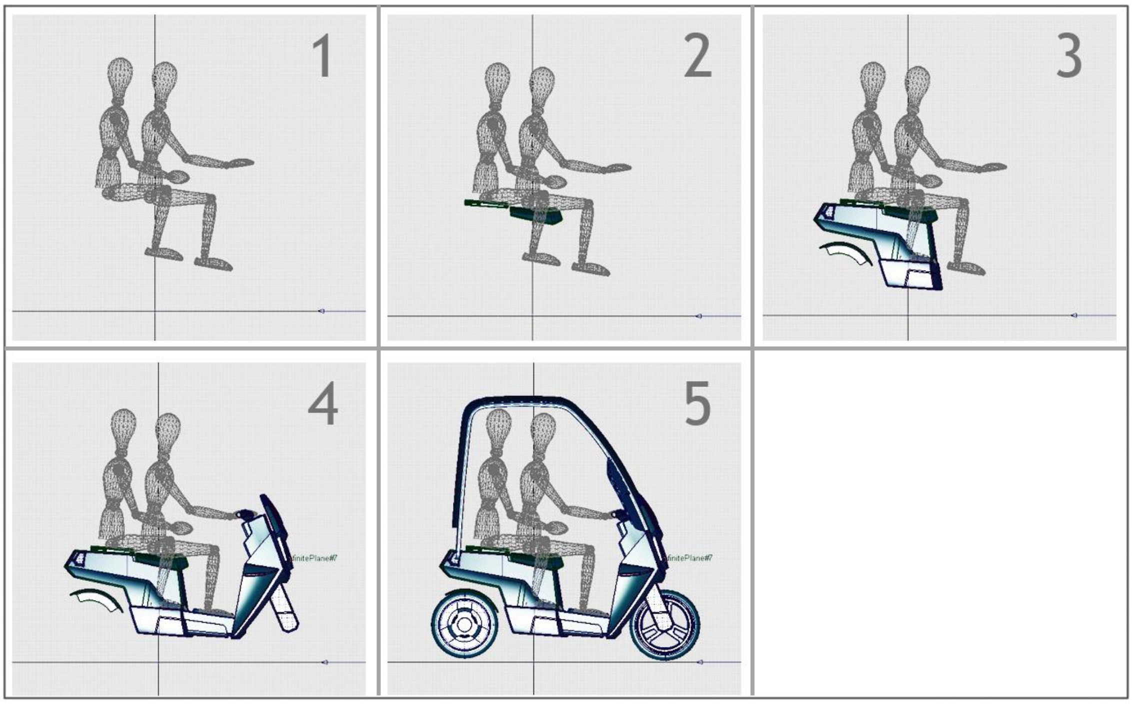


Figure 32 The process of body modeling.

4.4.3 Detail Modeling

Details of the mopeds were modeled to enhance the completeness and reality of 3D models. Details of lights, the dashboard, the in-wheel motor, the joint system were visualized in 3D. The overall body created in previous stage was reviewed and edited again. Also two rear modules for platform and modularity design were modeled in this part.

4.4.4 Selection of Material and Color

As the final process of 3D modeling, materials and colors were applied into the finalized 3D models. Even though some inner components were not modeled, the materials of them were taken into consideration. In selecting materials, weight of materials also trends of the automotive industry were considered. Polymer panels were applied into the entire body shells of concept mopeds also into the removable roof. Aluminum was used for most metallic components including the hollow frame of the roof. To provide weight reduction it would be used for the space frame of concept mopeds. For the seat, artificial leather was applied into the cover of the seat and PU foam would be used for the filling of the seat.

5 Results

In this chapter, the final concept will be shown. The content will describe how the final concept comes up and how the solutions deal with the problems and satisfy user needs based on the research and analysis. Meanwhile, the technical solution will be mentioned.

5.1 Final 3D Model

The final concept has 2 different versions which share the front module as the platform were made: first, the 3-wheel version for the primary target group, middle aged people; second, the 2-wheel version for the secondary target group, young people.

Figure 33 illustrates 3 orthogonal views of the 3-wheel version: the front, the side and the rear view. From the 3 orthogonal views, the overall size and proportion of the 3-wheel version can be checked. The length of the 3-wheel version is 1830 *mm* and the wheel base is 1358 *mm*. To secure more space between the front module and the rear module the wheel base was increased by 8 *mm* from the basic constraints shown in *Figure 29*. The width of it is 714 *mm* and the height is 1790 *mm*.

Figure 33 Orthogonal views of the 3-wheel version.

To present as many as details of the 3-wheel version additional isometric views were added as shown in *Figure 34*.


Figure 34 Isometric views of the 3-wheel version.

The 2-wheel version for young people was also finished. Except the rear module, the 2-wheel version is totally same with the 3-wheel version since both concepts use the same front module, the front module. By following the needs of young people, the roof is excluded from the final model. However, the roof can be easily attached on it.


Figure 35 Isometric views of the 2-wheel version.

5.2 Discussion

In this chapter, how the final results meets the requirements which were set out in the beginning of this project will be discussed. This project was started with the preliminary design criteria requested from the GPP-project. Through various researches, specific design goals to realize requirements both from the main project and potential users were prepared. The achievement of requirements will be reviewed based on the three parts: first, functional points; second, style points; third, technology points.

5.2.1 Functional Points

Functional requirements were mainly derived from the user needs analysis. The final concept mopeds were designed to realize as many functions as possible. All the requirements for functions and solutions to achieve them are presented together in *Table 22*. Every function to solve each requirement will be presented in order. However, all the requirements were not satisfied by the final concepts.

	Functional requirements	Functional solutions
1	Providing weather protection against rain or snow	Removable roof
2	Be able to carry an extra passenger	Extra passenger seat and baby seat
3	More storage capacity for shopping bags and personal brief case	Large storage under the seat
4	Easy access to electricity when they battery is out	Removable battery set placed under knees
5	Easy to handle(drive) the moped	3 wheeler keep stable
6	Comfortable seats	Ergonomic seat and rotated backrest
7	Be able to do exercise when riding	

Table 22 Functional requirements vs. functional solutions.

5.2.1.1 Removable Roof

The Removable roof shown in *Figure 34* can be assembled and disassembled at home or at working places. The disassembled roof can be stored in a garage or. Users can decide to use it or not based on the weather condition and their tastes. A driver can be protected from rain, snow and wind. Furthermore, a driver won't miss sunshine and soft wind while driving.

Figure 36 The extra passenger seat.

5.2.1.2 Extra Passenger Seat and Baby Seat

The extra passenger seat located in the back of the main body allows one more rider. The extra passenger seat can be replaced by a baby seat so parents can take their babies or children. Because of the safety problem with carrying babies or children the maximum speed of the 3-wheel version would be limited to 25 *km/h* to be classified into a class 2 moped, and also to use bicycle lanes which is safer.

Figure 37 The removable roof.

5.2.1.3 Large Storage under the Seat

The storage is placed under the front seat. The capacity of the storage is around 23.2 *L* which is enough volume to contain a normal paper shopping bag. Users can leave their helmets, brief cases or school bags inside of it.

Figure 38 Large storage capacity.

5.2.1.4 Removable Battery

The battery pack is placed inside of the connector on the drivers' feet rest. In case there is not a charging station or electricity connection available, users can pull the battery from the moped and charge it indoor with general socket. A charger can be integrated into the pack for convenience. The calculated weight of the battery pack was around 6.8 to 11.3 *kg*. For theft security, an aluminum frame wraps the pack and an electronic locking system is equipped with.

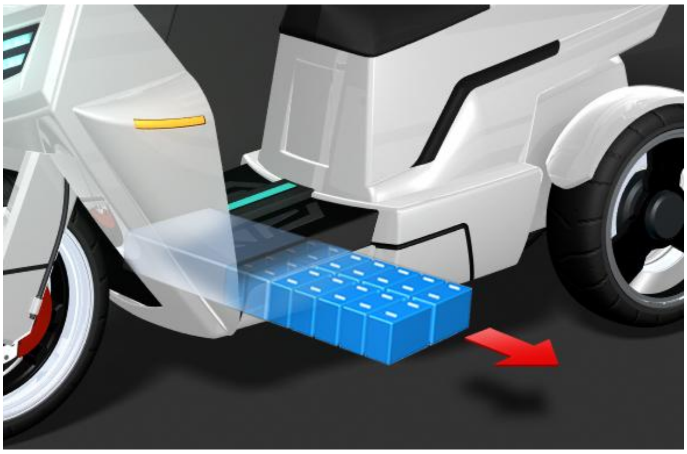


Figure 39 The removable battery pack.

5.2.1.5 Three Wheeler

The 3-wheel version gives more stability for who have problems with driving 2 wheelers, and drivers can keep their body steady all the time. Drivers do not have to use feet to keep balance when they stops or driven very slowly. The moped can keep upright position by joint system consisting of couplings and gears controlled electronically. Also this is a good solution if it is used for professional purposes, for instance, mail delivery.

Figure 40 Two Wheels in the back.

5.2.1.6 Ergonomic Seat and Rotated Backrest

The front seat has ergonomic shapes fitted to people’s buttocks. Artificial leather and PU foam are used for shaping the seat and it provides comfortable riding. Additionally, the back seat can be used as a backrest when there is no other passenger. A driver can adjust the back seat.

Figure 41 The adjustable seat.

5.2.1.7 Clear Dashboard

The front seat has ergonomic shapes fitted to people's buttocks. Artificial leather and PU foam are used for shaping the seat and it provides comfortable riding. Additionally, the back seat can be used as a backrest when there is no other passenger. A driver can adjust the back seat.

Figure 42 The dash board.

The introduction of a hybrid power system was discussed to solve the requirement about exercise. Equipment like pedals could be mounted on a moped to generate electricity. However, it was decided to exclude this function since it is an excessive requirement. First, it increases the cost of a moped and second, the nature of an electric moped is closer to providing a quick and easy ride than exercise. Also there are already bicycles and hybrid bikes for people who want exercise.

5.2.2 Styling Points

4 style requirements derived from user needs analysis were set as design goals which are dynamic, simple & fresh color, clean surface and futuristic. Being Scandinavian and dynamic were the first and the second core value. And simple is one of the main characteristics of Scandinavian design. Thus, “Simple” and “dynamic” were set as main styling themes to meet the style requirements also core values. Straight and uncomplicated character lines along with achromatic colors like white, grey and black convey simple feeling. For dynamic feeling, most surfaces were sculptured to have sharp angles and overall character lines inclined forward. Finally, overall image of the moped gives trendy or futuristic feeling by using many surfaces, which is latest design trend in the automotive industry, especially among passenger cars.

Figure 43 Character lines of the concept.

5.2.3 Technical Points

5.2.3.1 In-wheel Motor

The overall structure of the in-wheel motor is illustrated in *Figure 44*. The rotor looking like a red ring is completely inserted into the wheel like Siemens eCorner presented in *Table 14*. The stator looking like a blue button is covered by the rotator. Like other in-wheel motors studied in the research part, the suspension of the new concept is also integrated into the wheel.

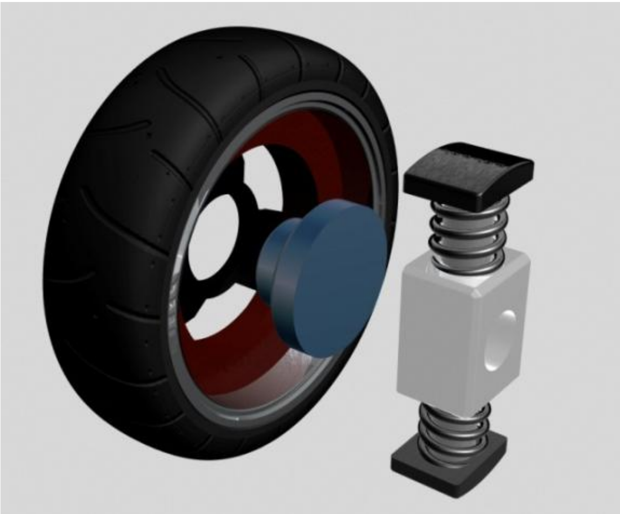


Figure 44 In-wheel motor

5.2.3.2 Li-ion Battery

The volume of the Li-ion battery was decided as 5L and it is smaller than the average volume calculated from recent technologies and capacity. The size of the battery was designed as 67x250x310 *mm*. Electricity is provided to each in-wheel motor from the battery as shown in *Figure 45*.

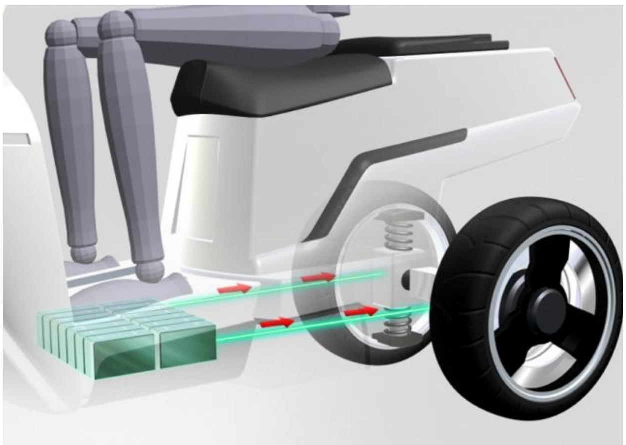


Figure 45 Li-ion battery and in-wheel motors.

5.2.3.3 Joint System

The joint system was roughly designed and the working mechanism was introduced form Xingyue DM82. The detail of components and structure was not fully designed. As shown in *Figure 46*, the joint system can be rotated by tilted body of a driver while 2 wheels connected to the front body of the moped by the joint system sustain a driver and the moped.

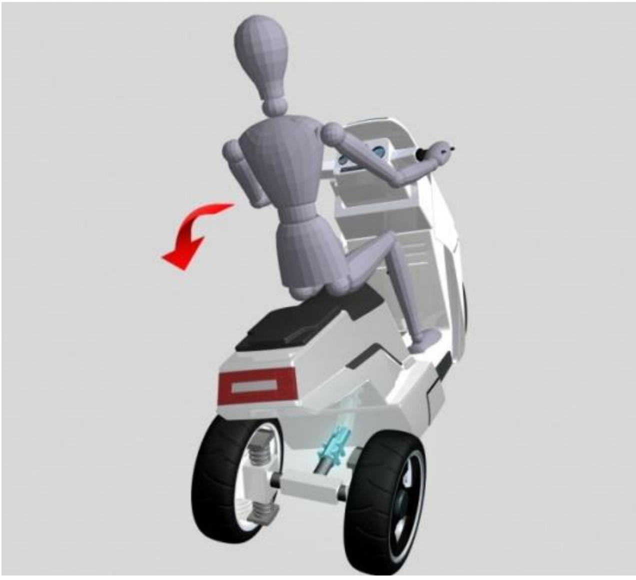


Figure 46 Joint system

6 Discussion

The aim of this master thesis project was to design a moped and Sweden was considered as the main market. The moped market and industry are not much developed In Sweden comparing with other markets and industries. But most people perceive the needs of alternative vehicles including electric mopeds since environmental issues are regarded significantly in Sweden. Therefore, authors' concept mopeds would be helpful both for the industry and environment of Sweden. The mopeds possibly meet specific needs of Swedish customer. The removable roof of authors' concepts is suitable for unpredictable weather in Sweden. And it is designed for most people from a baby to old people. While designing the 3-wheel version, old people were considered as potential users of it.

Even though the final concepts satisfy most requirements of users and the style is probably attractive enough, there is uncertainty regarding the success of this concept. From the interviews authors found that most people are more familiar with driving bicycles or passenger cars. Most people have a good impression about electric mopeds but it is not sure that they would buy it. Usually, it is not easy to accept a new product, especially when it changes people's life style or habits. People would prefer to watch others who are driving moped than doing it themselves. This issue is related to the theory of planned behavior, a psychological effect. "Sometimes people care more for others' thinking than their own thinking." said by Professor Karl Kottenhoff (2010) who invented electric mopeds before. How to persuade and promote people to use an electric moped is as much as important as how to design it.

Most information regarding user needs was collected from 15 interviewees. Their needs for functionality were quite clear and specific. Almost all the interviewees explained well their requirements for an electric moped. In functional requirements, excessive feedback could be more problematic than the lack of feedback. However, it was difficult to get clear opinions about the perception regarding the appearance and style of mopeds. The communication problem caused by misunderstanding was probably one reason for that. While interviewing, English was neither authors nor interviewees' native language. Also describing their feeling or objects is usually harder than describing technical or functional matters. Some interviewees who are studying design explained well about their feeling even the reason of it since they are trained to state emotional aspects. On the other hands, most interviewee felt hard to describe their thought regarding emotional aspects. There is possibility that interviewees are not familiar with these subjects.

One of the most demanding tasks was to design a roof. In the beginning of this project, the GPP-project requested that a roof was set as a preliminary element of mopeds to distinguish it from other models of mopeds which are available on the market. However, authors found out that most potential users did not show much interest to the roof of mopeds. They perceived that the roof could not protect them well from harsh weather. The survey that was later conducted in Ale by one of partners of the GPP-project also shows the same result. The interest rating as to whether protection ranked in the bottom. However, in order to distinguish it from other mopeds and focus on Swedish market, authors have kept the initial idea and came up with a solution, the removable roof. Even though they do not like a moped with a roof, they would accept a moped with a removable roof since they can decide to use it or not. Authors believe that the flexible solution regarding the roof will give future consumers smart alternatives. As for the driving characteristic for 3-wheel version with a joint system, it seems that further research and technical innovation are needed.

7 Conclusions

This project was started as one of several sub-studies to verify the feasibility and effectiveness of the green commuter concept also called as "park and ride". A new generation of roofed electric mopeds was presented as feasible "feeder vehicle" for green commuters. As the last part of this project, authors want to present the important findings throughout the whole project also some recommendations for further development and utilization of electric mopeds.

7.1 Important Findings

Most people have noticed the need of electric mopeds but still prefer to use cars.

It is widely accepted that using electric mopeds is beneficial for solving environmental problems. Actually, "Environmental friendly" was the strongest impression upon electric moped according to user needs analysis. Most formalized questions were focused on the use of electric mopeds so it is seemed that many people want to use electric mopeds. But the recognition of the need of electric mopeds is not directly connected to the behavior. Most interviewees preferred to use passenger cars or bicycles than electric moped when they are asked with open questions. Sometimes people care more about other's opinion and eyes than their own. Thus, it will take time for an electric moped to become popular in countries like Sweden where a passenger car has been established completely and become part of the lifestyle.

People want many functions from mopeds even though the nature of mopeds is simplicity.

Functionality is a contradictory issue in designing mopeds. Different groups of people need different functions from mopeds and some people preferred mopeds having very many functions. But minimized size with simple functions is the main reason for using mopeds, which also corresponds to environment friendly concepts. As design engineers authors tried to solve two problems, first, securing as many as functions and seconds, keeping simplicity at the same time and presented final concepts as an innovative solution.

The style of mopeds is turned out as an important factor for purchasing them; however some people do not notice that they prefer a stylish moped.

The result of questions regarding important factors for buying mopeds showed that "Attractive design" is the least important. In contrast, most interviewees picked up the same moped as the favorite and the stylish one. It is turned out that the style of mopeds is very important to attract people as it influences unconsciously people's behavior. Authors hope that final concepts will attract people, inspire to further moped development and be helpful for the wider use of electric mopeds in Sweden and other countries.

The market for electric vehicles is growing along with the development of relevant technologies.

Electric vehicles including electric mopeds are becoming popular due to glowing concern about environment friendly vehicles which solve problems with environment and resources constrains. To cope with this new movement, new technologies for electric vehicles have been developing quickly. The need for electric mopeds is also increasing. Now, the need and consumption are mainly concentrated in the specific regions like China and some other Asian countries. However, there is probably a strong possibility of market growth also in European countries including Sweden where environmental issues are considered significantly.

7.2 Recommendations

Infrastructure for mopeds

According to Horn (2010), retired aerospace scientist the success of gasoline-powered vehicles is because of vast gasoline distribution and electric vehicles need comparable infrastructure to be successful. The result of user needs analysis illustrated that "charging time & battery runtime" was the most important factor for buying mopeds also it explains indirectly that charging facilities are essential for the utilization of moped. Additionally, more roads for electric mopeds should be established since most existing infrastructure is fitting for passenger cars or bicycles.

Constant promotion and subsidy

To change people's behavior more active and effect marketing should be introduced by moped manufacturers. Also governments need to provide incentives such as discounts or tax rebates for electric mopeds as it has been done in Sweden with respects to environmental friendly cars in the last several years. The continuous growth of hybrid cars like Toyota Prius proposes the direction of electric mopeds.

APPENDIX I

The questionnaire used in the interview

Section 1

1. Opening questions

Age, education background, job, hobby and **driving experience** about mopeds

2. Impression about electric mopeds

	Strongly agree				Strongly disagree
Safe	☐	☐	☐	☐	☐
"Passable"	☐	☐	☐	☐	☐
Attractive, good image	☐	☐	☐	☐	☐
Convenient	☐	☐	☐	☐	☐
Fast in traffic	☐	☐	☐	☐	☐
Affordable	☐	☐	☐	☐	☐
Environmental friendly	☐	☐	☐	☐	☐
Easy to park	☐	☐	☐	☐	☐

Any other comments?

3. The important factor for buying and using mopeds

	Very Important				Not important
Attractive design, image	☐	☐	☐	☐	☐
Weather protective roof/cover	☐	☐	☐	☐	☐
Speed	☐	☐	☐	☐	☐
Cost of purchasing and operation	☐	☐	☐	☐	☐
Charging time and battery run-time	☐	☐	☐	☐	☐
Quick and easy to park & lock	☐	☐	☐	☐	☐
Storage and luggage capacity	☐	☐	☐	☐	☐
Extra seat for child or another passenger	☐	☐	☐	☐	☐
Winter adaption	☐	☐	☐	☐	☐

Any other comments?

Section 2

4. Spontaneous feeling and perception about each moped

	Best	Worst
Stylish		
Simple		
Functional		
Futuristic		
Safe		
Dynamic		
Easy to drive		

5. Preferable Moped among 5 and the reason

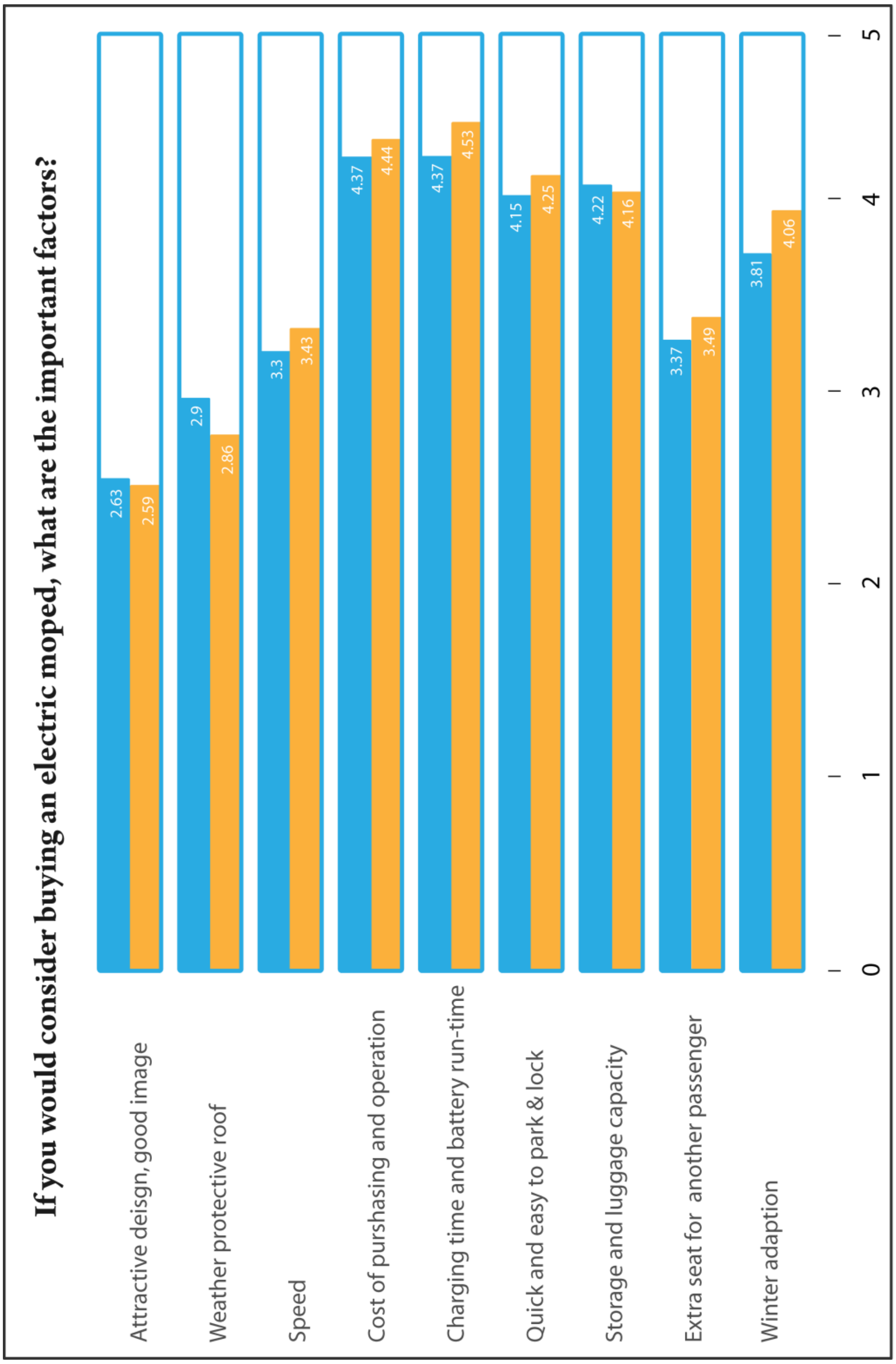
	Best	Worst
Stylish		
Reasons		
	Best	Worst
Simple		
Reasons		
	Best	Worst
Functional		
Reasons		
	Best	Worst
Futuristic		
Reasons		
	Best	Worst
Safe		
Reasons		
	Best	Worst
Dynamic		
Reasons		
	Best	Worst
Easy to drive		
Reasons		

APPENDIX II

The picture of 5 mopeds used in the Section 2 of the interview

APPENDIX III

Data analysis of the survey distributed in Ale Municipality, Question 1



Blue bars: the average score of who showed great interests (27)

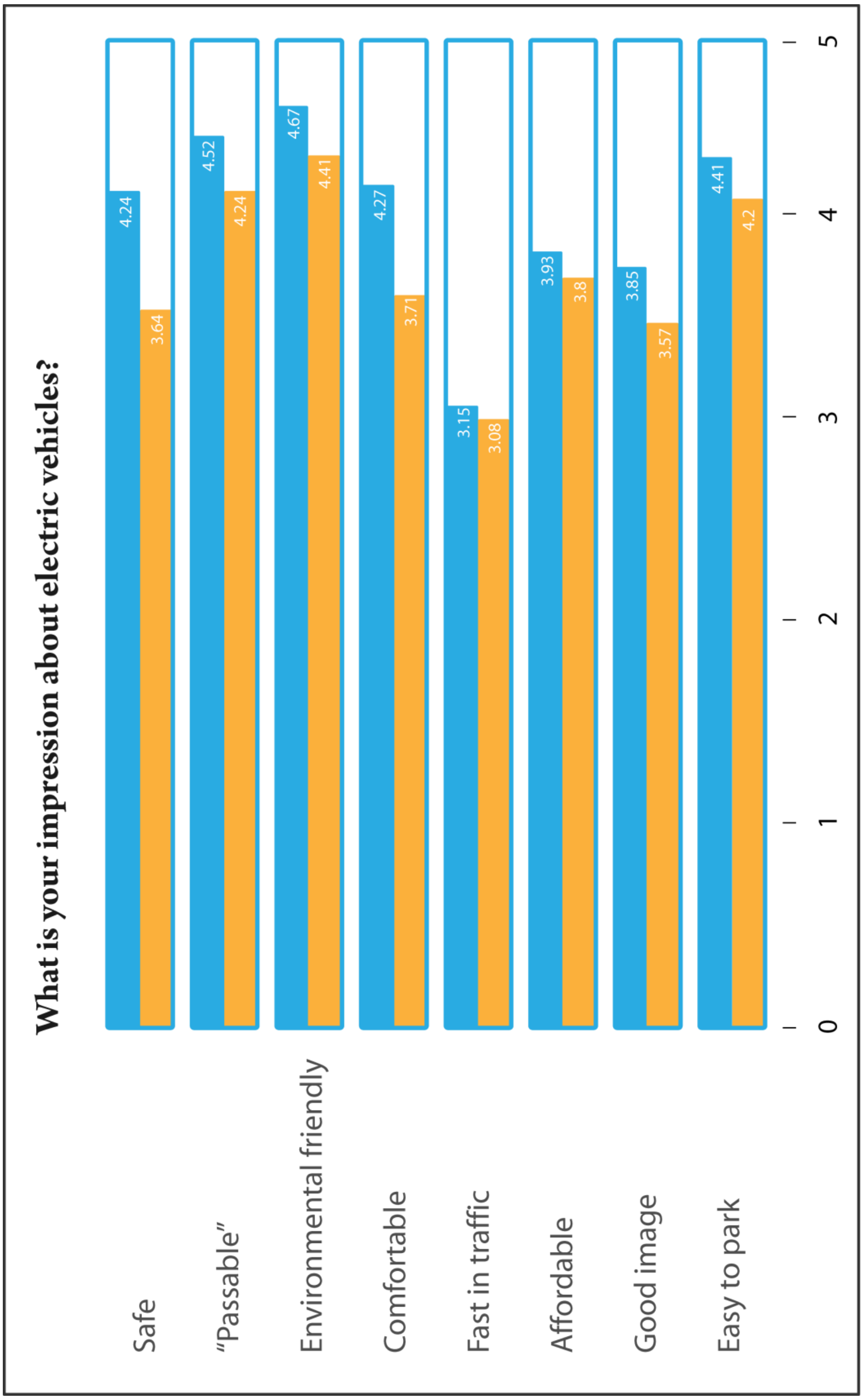
Orange bars: the average score of total response (81)

There were 81 sets of valid questionnaire responses to the question.

Among them, 27 sets showed great interest to the electric mopeds

APPENDIX IV

Data analysis of the survey distributed in Ale Municipality, Question 2



Blue bars: the average score of who showed great interests (27)

Orange bars: the average score of total response (94)

There were 94 sets of valid questionnaire responses to the question.

Among them, 27 sets showed great interest to the electric vehicles

REFERENCES

About.com, 2010. *The history of electric vehicles*. [internet]
Available at: http://inventors.about.com/library/weekly/aacarselectrica.htm
[Accessed 13 August 2010].

ADB (Asian Development Bank), 2009. *Electric Bikes in the People's Republic of China*: impact on the environment and prospects for growth, Philippine: ADB.

Aronsson, R., 2009. ETC, Battery and FuelCells Sweden AB. *Technical specifications of Li-ion battery*. [Conversation] (Personal communication, 22 September 2009)

Autoblog, 2006. *Siemens VDO announces eCorner motor-in-hub concept.* [internet]
Available at: http://www.autoblog.com/2006/08/10/siemens-vdo-announces-ecorner-motor-in-hub-concept/
[Accessed 18 August 2010].

AVERE (The European Association for Battery, Hybrid and Fuel Cell Electric Vehicles), 2005. *JARI Symposium on Electric Vehicles: Tokyo motor show symposium 2005*. [Online]
Available at: http://www.ieahev.org/pdfs/annex_11/tokyo_2005/11_1105_avere.pdf
[Accessed 4 August 2010].

Baldwin, C., Clark, K., 1997. Managing in an age of modularity. *Harvard Business Review*, 75(5), pp.84–93.

Bloch, P. H., 1995. Seeking the ideal form: product design and consumer response. *Journal of marketing*, 59(3), pp.16.

Burdick, D., 2009. Obama's electric vehicle plan: $2.4b in new grants. *Huffington Post*, [internet] 20 Mar.
Available at: http://www.huffingtonpost.com/2009/03/20/obamas-electric-vehicles_n_177286.html
[Accessed 09 August 2010].

Bust, P. D., 2009. *Contemporary ergonomics 2009*. Taylor & Francis

Chou, J., Hsiao, S., 2005. An anthropometric measurement for developing an electric scooter. *International Journal of Industrial Ergonomics*, 35 (11), pp.1047-1063.

Davies, G., 2003. *Material for automotive bodies.* Ch.9.

EAA (Electric Auto Association), 2005. *Electric Vehicle History.* (Rev: 20050516)

Epeds, 2010. *Epeds City.* [Internet]
Available at: http://www.epeds.co.uk/mopeds
[Accessed 17 March 2010].

European Union, 2000. *Directive on end-of life vehicles: commission statements*. [Online]
Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0053:EN:NOT
[Accessed 15 September 2010].

Feitzinger, E., Lee, H., Mass customization at Hewlett-Packard: the power of postponement. *Harvard Business Review*, 75(1), pp.116-121.

Fiell, C. & Fiell, P., 2003. *Scandinavian Design*. Taschen

HOB (House of batteries), n.d. *Lithium-Ion and Polymer*. [internet]
Available at: http://www.houseofbatteries.com/productsearch.php?Chemistry=Lithium-Ion%20and%20Polymer
[Accessed 21 March 2010].

Horn, M., 2010. Road map to the electric car economy. *The futurist*, March-April 2010, pp.40-45.

iO Fahrzeuge Produktions- u. Handels GmbH, 2010. *Technische daten*. [Internet]
Available at: http://www.io-scooter.com/1500gt.html
[Accessed 17 March 2010].

Karjalainen, T. M., 2008. *Design for visual brand recognition*, Helsinki School of Economics.

Kottenhoff, K., 2010. *Discussion about mopeds* [Conversation] (Personal communication, 12 March 2010)

Kwiecinska, M., 2010. Frost & Sullivan: European electric scooters and motorcycles first / last mile connectivity will drive this market. *PR Newswire Europe*, [Online]
Available at:
http://proquest.umi.com/pqdweb?did=1944050031&sid=3&Fmt=3&clientId=19460&RQT=309&VName=PQD
[Accessed 17 March 2010].

Lista, P. et al., n.d. *Analysis of the dynamic behavior of actual and new design solutions for motorcycles using the multibody code of MSC.visualNastran*. University of Pauda.

Liter-E Motor, 2010. *Specification.* [Internet]
Available at: http://www.libertemotor.com/xero_r_specification.html
[Accessed 17 March 2010].

Lucas, R., 2001. *End-of-life vehicle regulation in Germany and Europe-problem and perspectives.* Wuppertal Institute for climate, Environment and Energy.

Lundin, A. 2010. Svenskarna längre och tyngre. *Dagens Nyheter AB* , [Internet] 29 February 2008.
Available at: http://www.dn.se/nyheter/sverige/svenskarna-langre-och-tyngre-1.640426
[Accessed 8 May 2010].

Meyer, M., Lehnerd, P., 1997. *The power of product platforms: Building value and cost leadership.* New York, NY: The Free Press.

Michelin, 2008. *Michelin Active Wheel: 2008 Paris motor show.* [online]

Missouri Department of Transportation, 2006. *Practical design*. [online]
Available at: http://www.modot.mo.gov/business/PracticalDesign.htm
[Accessed 20 August 2010].

My Ford Freestyle, *2005 Ford Freestyle Design*. [Internet]
Available at: http://www.myfordfreestyle.com/specs/2005_freestyle_design.php
[Accessed 8 August 2010].

Panasonic , n.d. *OEM batteries short form catalog.*[Online]
Available at: http://www.panasonic.com/industrial/includes/pdf/Panasonic-Batteries-Shortform-08-09.pdf
[Accessed 21 March 2010].

Pandremenos, J., et al., 2009. Modularity concepts for the automotive industry: a critical review. *CIRP Journal of Manufacturing Science and Technology*, 1, pp.148-152.

Robertson, D., Ulrich, K., 1998. Planning product platforms. *Sloan Management Review*, 39(4), pp.19–31.

Smart Cities Group, MIT, n.d. *Mobility: RoboScooter with ITRI and SYM.* [internet]
Available at: http://cities.media.mit.edu/index.html
[Accessed 19 August 2010].

Starr, M., 1965. Modular production, a new concept. *Harvard Business Review*, 43(6), pp.131-142.

Tollefson, J., 2008. Charging up the future. *Nature*, 456, pp.436-40.

Tong, M.C., Robertson, K. 2008. Political and Cultural Representation in Malaysian Websites*. International Journal of Design*, [Online]. 2(2)
Available at: http://www.ijdesign.org/ojs/index.php/IJDesign/article/view/286/167
[Accessed 30 August 2010].

UNFCCC (United Nations Framework Convention on Climate Change), 2009. *Decision -/CP.15: Copenhagen accord.* [Online]
Available at: http://unfccc.int/files/meetings/cop_15/application/pdf/cop15_cph_auv.pdf
[Accessed 12 September 2010]

Weinert, J. et al., 2008. The future of electric two-wheelers and electric vehicles in China. Davis, CA: University of California.

ZAP, 2010. *ZAPINO standard vitals.* [Internet]
Available at: http://www.zapworld.com/zapino-electric-scooter
[Accessed 17 March 2010].

ZEVA (Zero Emission Vehicles Australia), 2010. *Tech info: motors.* [internet]
Available at: http://www.zeva.com.au/tech.php?section=motors
[Accessed 12 August 2010].