IDeS (Industrial Design Structure) and Stylistic Design Engineering (SDE) applied to the mobility of the future

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Abstract

Sustainable mobility means a series of services and means of transport designed to reduce traffic, improve air quality and cut energy consumption; it is essential to integrate the various transport systems and encourage the spread of electric vehicles.
The European Commission proposes new targets for average CO2 emissions to accelerate the transition to low-emission vehicles.
The goal is to reduce emissions by 40% by 2030, in line with the Paris agreements. It is not only a question of replacing private means of transport, but also of encouraging the development of new business models and more efficient use of public and freight transport.

The present paper works on six main points:
- New standards that help manufacturers to innovate and offer low-emission vehicles on the market
- Solutions for sustainable mobility in public systems
- Investments for the diffusion of infrastructures for alternative fuels
- Revision of the combined transport directive which promotes the use of different means for freight transport
- Development of long distance bus connections across Europe
- Development of better and better batteries

The diffusion of micro-mobility systems requires a general change of context. The city must keep up with technology and become smart, the regulations and all sharing phenomena must be adequate.
In 2020, 80 billion objects connected to the world through 1200 satellites are estimated: urban mobility will be greatly influenced and will become a connecting element between the environment and those who live in it.
The micro-mobility market in Europe could reach 150 billion dollars by 2030. As the possibilities for use increase, the number of startups for mobility sharing also increases.
It is estimated that at the end of 2018 there were 5.2 million subscribers to at least one of the sharing services active in the area, one million more than the previous year.
In particular, this project aims to propose an innovative, sustainable and ecological means of transport suitable for everyone and which can be a valid alternative for getting around the city.

Keywords
Industrial Design Structure (IDeS); Car Design, Quality Function Deployment (QFD), Benchmarking Analysis, Stylistic Design Engineering (SDE); future mobility.

1. ENVIRONMENTAL ANALYSIS – A SMART CITY

In recent years, ecological and economic mobility passes through the use of means of transport such as the hoverboard, the segway and electric scooters. Routes less than 10 km are estimated to represent around 60% of daily trips. The starting point of the project is the hoverboard, a sort of skateboard that has numerous advantages:

• The cost is accessible to everyone: the price range is quite wide, but there are very cheap models.

• Batteries are rechargeable: this allows everyone to contribute to the reduction of pollution due to non-rechargeable batteries.

• All these vehicles have an autonomy that allows you to easily make short-medium journeys in city traffic.

• They are simple to use, especially for younger users, and are small in size.

The self-balancing electric scooter, commonly called the hoverboard, is a personal transportation device that uses a combination of IT, electronics and mechanics such as the segway. The first appearance of the term hoverboard was recorded in the 1960s, in a science fiction novel written by Michael K. Joseph.

Shane Chen, an American businessman who founded the company of innovative projects, claims the authorship of the invention of the device. Chen started a fundraising campaign on Kickstarter for his "Hovertrax" project in 2013. However, the project has been copied by many Chinese companies who have made it in hired variants starting from 2015.

In fig. 1 an hoverboard is represented:

fig.1 hoverboard

2. NOWADAYS – REGULATION IN EUROPE AND USA

In Europe, each country has taken different measures, for example:

• Italy: use is allowed only on cycle and pedestrian paths and in private spaces

• Germany: use is permitted only on cycle paths

• Great Britain: use on pavements in Scotland is prohibited, in England and Wales it is only possible to use them in private spaces

• France and Austria: use is permitted in pedestrian and urban areas

• Netherlands: there are no limits, people on hoverboards are treated as pedestrians

• Belgium: use between pedestrians, sidewalks and parks is allowed as they comply with current regulations

• USA: large cities are literally invaded by these new means of transport used in cycle paths and sidewalks. The mayors are providing for regulation of the means of transport.

3. TARGET

The hoverboard was born as a means of transport for an adult public and as a valid alternative to the classic means of transport, public or private, to move easily in city traffic. It is light, easy to carry and saves time on medium to short trips. The great success of the hoverboard was determined above all by social factors: it is the phenomenon of the moment, a trend that mainly affects young people thanks to the visibility that social media has given it. The growing popularity of the devices in western countries was initially attributed to the large number of famous people who were seen with the various product models. For these factors, in the reality of the moment, it is mainly used by young and very young people for fun purposes. The aim of the project will be to expand the use of the hoverboard and make it an object for everyone, to be used within cities.

4. MARKET ANALYSIS

The market analysis is carried out through QFD, functional quality implementation. It is a tool that allows you to manage product quality, shifting attention from the production process to the design. First of all, it is necessary to know the quality characteristics required by the customer and then develop the related functions at all organizational levels. It is a methodology that intercepts the real needs of users in the design requirements. It has been developed to guarantee the highest possible quality level and a high innovative level of the
Product.

The phases of the QFD are:
• The six questions
• The interrelation matrix for relative importance
• The interrelation matrix for dependence on independence.

4.1 Six Questions

WHO- is used to define the ideal target of the product you want to design, so that it has the maximum yield on the market. Initially, the hoverboard was designed for a commuter user, who needs a practical and light means of
transport for small city trips. The age range is between 20 and 35 years old.
Subsequently the aim of the project will become to design a hoverboard for
everyone. Expand the age range of people who use this means of transport, so that it can also be used by older people, to strengthen its presence on the market.
WHEN- it is an ecological and economic means of transport that can be used for daily trips, several times a day. It becomes an alternative to walking, so it can be used to: go to work, in your spare time and even within the workplace to
facilitate workers' actions.

WHERE- it is mainly used in the city, for small trips. It is useful to move around the city center being electric, to be more agile in city traffic or to move within work environments in case you have to travel medium-long distances (move
between sheds or nearby factories).

HOW- as far as functioning is concerned, it is used by shifting the weight of the body to move forward or backward and unbalancing itself to the side to bend. As for the functions, it can be used, for example, as a means of transport or as a service tool on outdoor or indoor workplaces.
WHAT- it mainly serves as a means of transport to move faster than on foot. It can also be used as an aid at work, having the possibility of moving in confined spaces or in leisure time as leisure.

WHY- it is used to move faster than on foot, without effort and to save time. Also because it is practical, easy to transport, light and ecological.

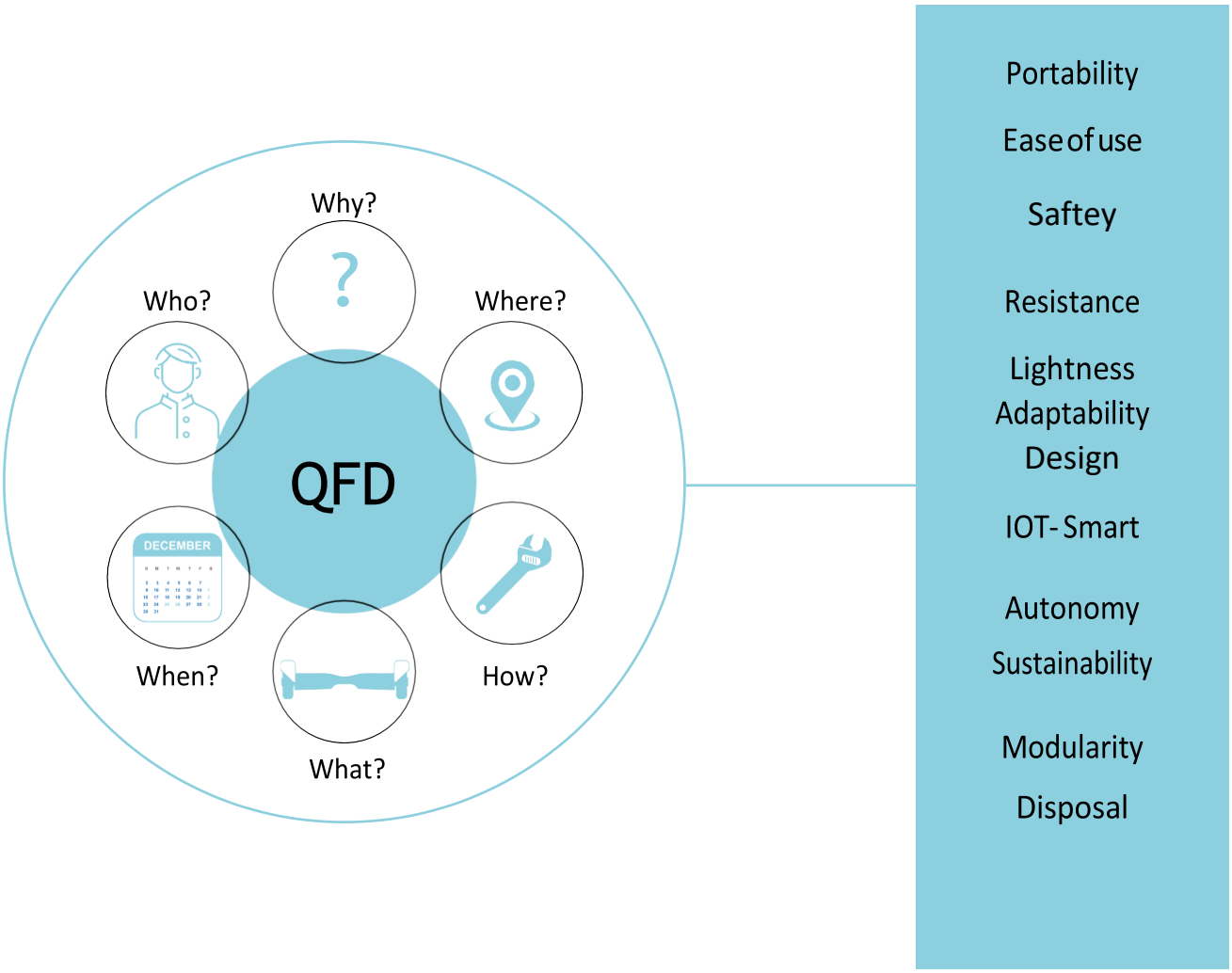


fig.2 six questions

4.2 Interrelation matrix for relative importance

This matrix serves to detect the most important requirements in relation to themselves.
The same requirements are inserted in a table both in the column and in the row. The requirements must be placed in the same order so that in the first place in the row you have the same requirement

that is found first in the column. By crossing the keywords, I assign to each of the values evaluated on a scale of 0, 1, 2. 0 means that the requirement on the row is more important than that on the column, 2 the opposite. 1 instead indicates parity. The diagonal that starts from the top left corner of the table will have all values equal to 1. After evaluating all the boxes, I add the values by column. I keep in consideration the 4 with the highest rating.

The results are:
- Portability
- Safety
- User Friendly
- IOT-Smart

	Potability	Ease of use	Safety	Resistence	Lightness	Adaptability	Design	IOT- Smart	Autonomy	Sustainability	Modularity	Disposal	Cost
Portability	1	1	2	1	0	0	1	2	0	0	1	0	0
Ease of use	1	1	2	1	0	0	0	1	0	0	0	1	0
Safety	0	0	1	0	0	0	0	1	0	0	0	0	0
Resistence	1	1	2	1	1	0	1	2	0	0	1	1	0
Lightness	2	2	2	1	1	0	2	2	0	0	1	2	0
Adttability	2	2	2	2	2	1	2	2	1	2	2	2	2
Design	1	2	2	1	0	0	1	2	0	1	1	1	0
IOT- Smart	0	1	1	0	0	0	0	1	0	0	0	1	0
Autonomy	2	2	2	2	2	1	2	2	1	2	2	2	2
Sustainability	2	2	2	2	2	0	1	2	0	1	2	1	0
Modularity	1	2	2	1	1	0	1	2	0	0	1	2	1
Disposal	2	1	2	1	0	0	1	1	0	1	0	1	2
Cost	2	2	2	2	2	0	2	2	0	2	1	0	1
	17	19	24				22						

fig.3 Interrelation matrix for relative importance

4.3 Interrelation matrix for Indipendence-dependence

This matrix is used to identify the most independent requirements.
As before, I enter the same values both on the row and on the column, in the same order.
At this point I attribute values equal to 0, 1, 3, 9. With value 0 it means that the row is totally independent of the column. With value 9 that the row is totally dependent on the column.
Values 1 and 3 are the middle ground for both dependence and independence of requirements.
After evaluating all the requirements, I add the columns. This allows to obtain the most independent values. The others will be included in the project being dependent on those found.

The results are:

- Lightness
- Design
- Modular
- IOT-Smart

	Portability	Ease of use	Safety	Resistence	Lightness	Adaptability	Design	IOT- Smart	Autonomy	Sustainability	Modularity	Disposal	Cost
Portability	-	0	1	1	9	0	0	0	3	0	9	1	0
Ease of use	3	-	3	0	1	1	3	3	0	0	3	0	0
Safety	0	3	-	3	1	1	0	9	0	0	1	0	0
Resistence	0	0	1	-	3	1	1	0	0	0	1	0	3
Lightness	1	0	1	3	-	3	3	0	1	0	3	0	3
Adabtability	3	3	1	3	1	-	0	0	3	0	1	0	1
Design	3	9	3	1	1	1	-	1	0	0	9	1	1
IOT- Smart	0	0	1	0	0	0	1	-	0	0	0	0	2
Autonomy	0	0	1	0	1	3	0	1	-	0	0	3	0
Sustainability	0	0	0	0	0	0	0	0	1	-	0	9	0
Modularity	1	1	0	1	3	0	3	0	0	0	-	3	0
Disposal	0	0	0	1	1	0	0	3	3	3	3	-1	0
Cost	1	0	0	3	3	3	9	9	1	1	3	0	-
					24		20	26		33			

fig.4 Interrelation matrix for Indipendence-dependence

5. COMPETITORS ANALYSIS

At this point it is necessary to understand which hoverboards are already on the market and what their characteristics are. By evaluating these products, it is determined what is the limit beyond which an innovative project is obtained. Knowing what has already been patented allows you to identify an ideal product and the times to get the maximum profit.

5.1 Benchmarking

A benchmarking analysis is therefore made which allows me to outline:

- How many parameters should be considered in the analysis of competition
- Which services are called top
- Which performances are considered flops
- How many and which performances I have to obtain to have an innovative product

This type of analysis does not only serve to understand which hoverboards are already on the market, but above all to understand the characteristics to be met in order to have an innovative product. The table then analyzes eight of the most famous hoverboards on the market.
Each of these is classified according to sixteen technical characteristics. These characteristics are mainly related to the geometry of the hoverboard: dimensions, weight and battery are analyzed

because portability, lightness and autonomy were among the requirements found thanks to the matrices.
Not all characteristics are evaluated with the same unit of measurement: km / h, cm, h, kg are present or with yes / no answers.
The same criterion for all hoverboards will be put on the lines in order to have a direct comparison.
For each row I evaluate the best criterion, not necessarily the highest one. It will depend on the requirements to be met. For example, if one of the criteria is portability, the hoverboard with a lower weight will be chosen. A final column shows all the best values that characterize the best hoverboard ever. Not all the features are adaptable to a single model, both for the large number
and because some come into contrast with others. For example, it will be difficult to have a reduced weight and size but with very high autonomy since the batteries cannot be reduced indefinitely.
To determine which and how many requirements are sufficient to have an innovative hoverboard, I use top-flop analysis.

	Razor Overtrax 2.0	Segway MiniPro	Epikgo	Swagtron T1	HyperGogo	Nilox Doc UI 2272	Halo Rover	GeekMe	Hoverboard- innovation
Carried weight (kg)	100	100	100	100	90	100	102	120	>120
Weight (kg)	23.5	13	14	20	14	12	14	13.5	<12
Recharge time (H)	4	4	3	1	2-3	2-3	2	2-3	<1
Full speed (km/H)	12	18	17	15	10	10	16	15	>18
Autonomy (h)	1.30	2.15	1.3	2	1.3	2.3	1.3	1.3	>2.3
Bluetooth	no	si	si	no	si	si	si	si	si
Lenght (cm)	61	55	59	58	71	78	71	75	<55
Width (cm)	22	26	18	17	22	31	22	30	<17
Height (cm)	21	28	20	26	21	31	24	29	<20
Engine power (Watt)	750	800	800	800	800	750	800	750	>800
LED	si	si	si	si	si	si	si	si	si
Balancing	si	si	si	si	si	si	si	si	si
N° engines	2	2	2	2	2	2	2	2	2
Battery	lithium	lithium	lithium	lithium	lithium	lithium	lithium	lithium	lithium
Wheel size (inch)	6.5	10.5	8.5	10	8.5	8.5	8.5	8.5	<6.5
Cost (euro)	350	532	600	280	430	200	450	250	<200
TOP	5	7	7	8	6	8	6	6	
FLOP	5	2	2	1	3	5	1	2	

fig.5 Benchmarking

5.2 Top-flop analysis

Top-flop analysis is a method used to achieve a good degree of innovation by applying few technical but very targeted characteristics. As mentioned above, top and flop must be analyzed for each

characteristic, therefore for each row of the table. For each hoverboard (following the columns), you need to determine the number of top features, highlighted in green, and flops, in red. Then, for each column, the difference is made between the number of best and worst features. A positive or negative value is obtained for each hoverboard. The largest number obtained is considered: this will be the number of features to be implemented in the hoverboard to have an innovative product. This type of analysis is reported in the lower part of the previous benchmarking table. Once the minimum number of requirements to be met is obtained, it is necessary to understand which of the proposed ones are the most important. The choice is made by applying the what-how table. All the technical characteristics of the benchmarking table are put on the row; on the column are the eight requirements obtained from the matrices of importance.

	Carried W.	Weight	Recharge time	Full speed	Autonomy	Bluetooth	Dimensions	Engine p.	LED	Balancing	N° engines	Battery	Wheels	Cost
Portability	2	10	0	0	8	0	10	0	0	0	2	0	10	0
Ease of use	0	2	2	4	0	0	8	2	2	10	0	0	8	0
Safety	8	4	0	6	2	0	4	2	10	10	0	4	6	0
IOT- Smart	0	0	0	0	4	10	0	0	0	0	0	0	0	0
Lightness	4	10	0	0	0	0	10	0	0	0	6	4	8	0
Modularity	0	0	0	0	0	0	10	0	0	0	0	0	4	0
Design	4	6	0	2	0	0	10	0	4	0	8	2	8	0
	18	32			14		52		16	20	16		44	

fig.6 Top-flop analysis

I attribute to each intersection values equal to 0, 2, 4, 6, 8, 10 based on how much the column is influenced by the row. For example how much portability is affected by weight, speed etc. Then I add the values of the columns. I consider a number of requirements equal to or greater than the number obtained from the top-flop analysis. Those obtained are the requirements that guide the design and that allow to obtain an innovative product, not yet present on the market. In the case study the requirements are: weight, hoverboard and wheels dimensions, autonomy.
Then there are the characteristics already present in all hoverboards: LED, balance and number of motors equal 2.

6. PRODUCT ARCHITECTURE

6.1 First architecture

The next step is the study of the architecture produced. Taking a standard hoverboard we study how the internal components are arranged and determine the minimum obtainable dimensions. The motors are integrated in the wheels, the gyroscope is located in the central part and in the rest of the space sensors, battery and motherboard must be arranged.

Motherboard Engines Sensors Gyroscope Battery

fig.7 hoverboard: internal components

Once the parts are defined, the study of the form begins. Shapes and dimensions are assumed, also very similar to those already existing, to define the starting point and evaluate the innovation range. In the case study ten starting architectures are hypothesized, very different from each other.

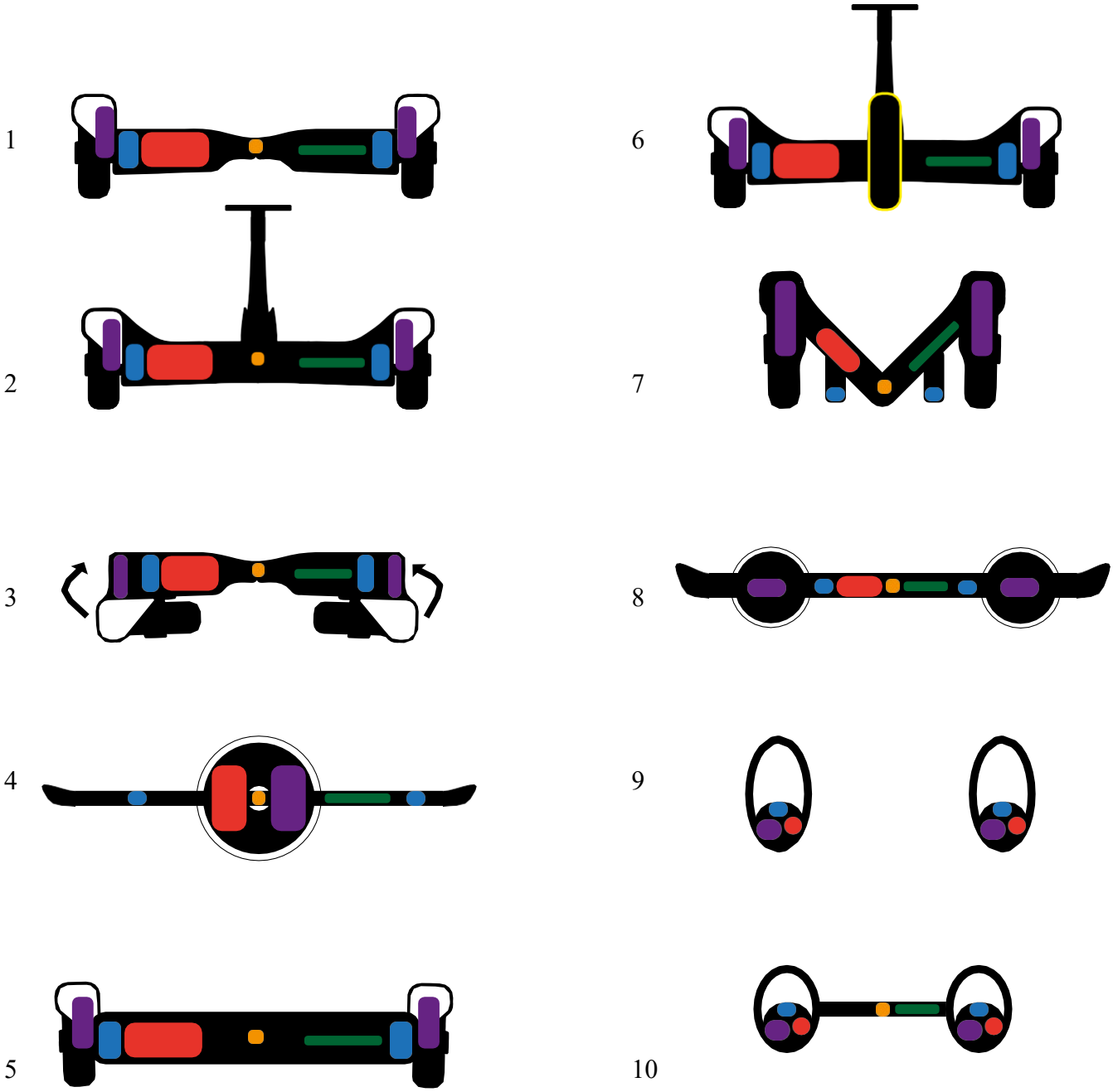


fig.8 hoverboard: starting architectures

6.2 Product Architecture Matrix

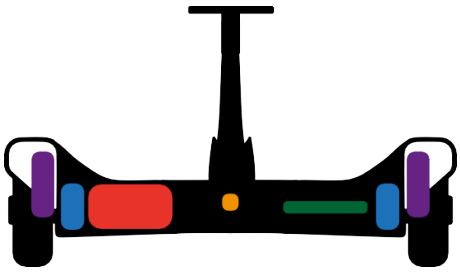
Having to choose only a few cases to be studied, a matrix is set: in the row the various architectures, in the column the innovation requirements. Values from 0 to 10 are given and, by adding the columns,

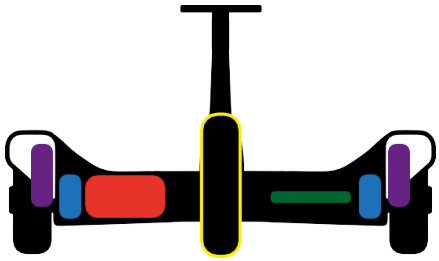
the best models are identified.

	1	2	3	4	5	6	7	8	9	10
Portability	4	2	8	4	10	0	2	4	10	10
Ease of use	4	8	4	2	10	10	4	4	0	2
Safety	2	8	2	2	10	10	4	4	0	2
IOT- Smart	0	4	2	0	0	0	0	0	0	0
Lightness	4	2	4	6	8	0	2	4	10	8
Modularity	0	8	6	0	0	6	0	0	0	8
Design	4	6	4	4	0	6	4	4	6	2
		38			38	32				32

fig.9 Product Architecture Matrix

Once the 4 best hypotheses have been obtained, a list of pros and cons for each model is drawn up.





PROS

Ease of use

Modularity

Space for external components

Safety

Ease of use

Modularity

Space for external components

Safety

CONS

Weight

Difficult to carry

PROS	
Ease of use	Ease of use
Modularity	Transportable
Transportable	Safety
Design	
CONS	
Weight	Design
Difficult to carry	Little space for external components

fig.10 four best hypotheses of architecture

7. PROBLEMS

7.1 Innovation degree

At this point of the design two problems arise: the very low degree of innovation and the unsuitable target. As regards the degree of innovation, reference is made to the requirements obtained in the what-like matrix. We try to improve these characteristics in models similar to hoverboards already on the market without however great results: the dimensions do not decrease much because space is needed for batteries and motors. As regards transportability, it is not possible to improve a case study found as optimized to the maximum.

Fig. 11 hoverboard already on the market with small dimensions

Further reducing the size also negatively affects the target. The smaller the hoverboard, the more difficult it is to use, therefore the range of useful users decreases. Failing to find an adequate solution, an initial criterion was changed: the hoverboard is no longer designed for commuters, but must become a means for everyone. Widening the target of users becomes a degree of product innovation. Commercial hoverboards are difficult to control, unstable, and most people are afraid of falling without support. The solution is found going back in time, in a product that resembled a chariot. The front bulkhead increases the feeling of security, as well as the possibility of holding on to something. The support surface very close to the ground makes you feel more secure.

Therefore, the requirements to be respected change: it is no longer necessary for the product to be light, compact and transportable, but it must be safe, suitable for a large audience. Another impediment to the success of the project is highlighted by the study of current regulations: they are so restrictive that the hoverboard can circulate only in selected areas or in private courtyards. For this

reason it is decided to move to the street. The dimensions are increased, to improve stability and recreate a driving style similar to the car.

At this point, the reference models change.

A second benchmarking is then made which takes the microcars and covered scooters as references. It allows you to understand the size, type of battery and motor, autonomy and charging times. In this case too, a top-flop analysis is carried out and there are at least two characteristics to be improved in order to have an innovative product.

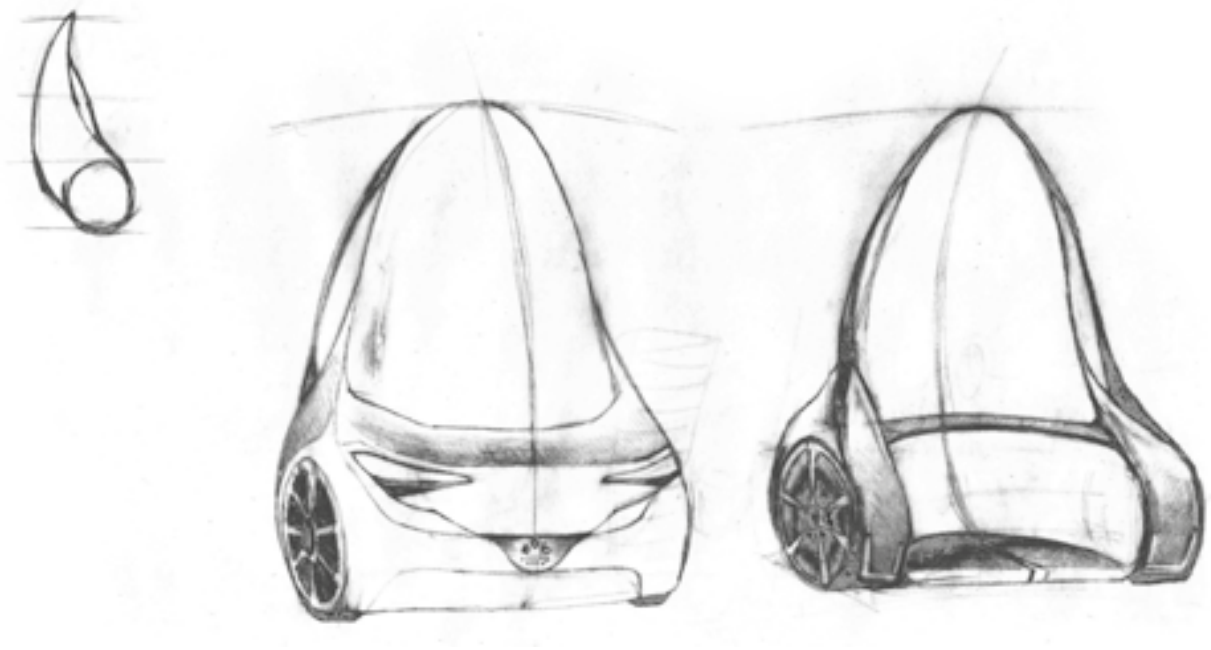


Fig. 12 some modifications - the final project

8. ID CITYTOWER

After some modifications we arrive at the final project. The hoverboard maintains the support table and proximity to the ground, to minimize the sense of insecurity. The front is completely closed and acts as a shelter. On the inside there is a dashboard on which are located: steering wheel, buttons for switching on and off and release by fingerprint. There is also a display that can be connected to the phone via an app. you can set maps, music or call by voice command. It has been chosen to prefer driving via a steering wheel because it allows the user to feel safer and have greater control over the vehicle. The rear part remains open to facilitate the ascent. Furthermore, having an open element recreates a sense of lightness that would be lacking given the proportions of the product. The front view in fact immediately shows the significant difference between the width and height of the new hoverboard. As for the technical part, the ID CityTower also maintains the operation of the hoverboard, albeit with a more powerful gyroscope and battery, similar to those of micro cars. The gyroscope will have to be more powerful to oppose the imbalance due to the geometry of the product: the weight is in fact almost all placed in the front. The wheels still integrate the engines and the battery is placed under the internal dashboard. In addition, the motherboard and all the electronic part of the hoverboard are maintained.

As per legislation, this new hoverboard has front and rear lights. Strengths of this project are therefore:

- The electric motor that allows you to move freely in the city, without adapting to restrictions or prohibitions. It is ecological, respectful of the environment and in line with the principles of

mobility 4.0

- It is user-friendly. The ease of driving and the frontal protection allow anyone to use this new means of transport. The target audience is expanded and the required degree of innovation is respected.

- Is connected. The presence of a display connected to the phone and the possibility of unlocking with a fingerprint make the ID CityTower a cutting-edge product.

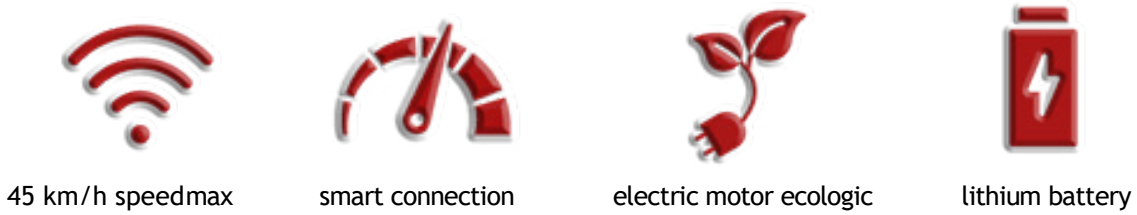


Fig. 13 Strengths of project

9. SDE - STYLISTIC DESIGN ENGINEERING

Having determined the characteristic features of the product, it is necessary to adopt the style that best suits. The trend was born as a creative hypothesis, nothing consolidated, to a starting point on which you can work. It is something that is not there to give body. In recent years, four trends guide the analysis of style: retro, natural, stone and advance. For this project, the natural trend is not analyzed because it is considered to be little in line with the characteristics of the product.

RETRO' STYLE

Characterized by rounded and rounded shapes, it incorporates the style of the 1950s. Emblem of change are first of all Smeg appliances with rounded shapes and pastel colors, but also furnishings such as lamps and armchairs. As for the automotive field, the FIAT 600 or the Volkswagen Beetle is iconic. Precisely this will be a model of inspiration in the realization of the sketches.

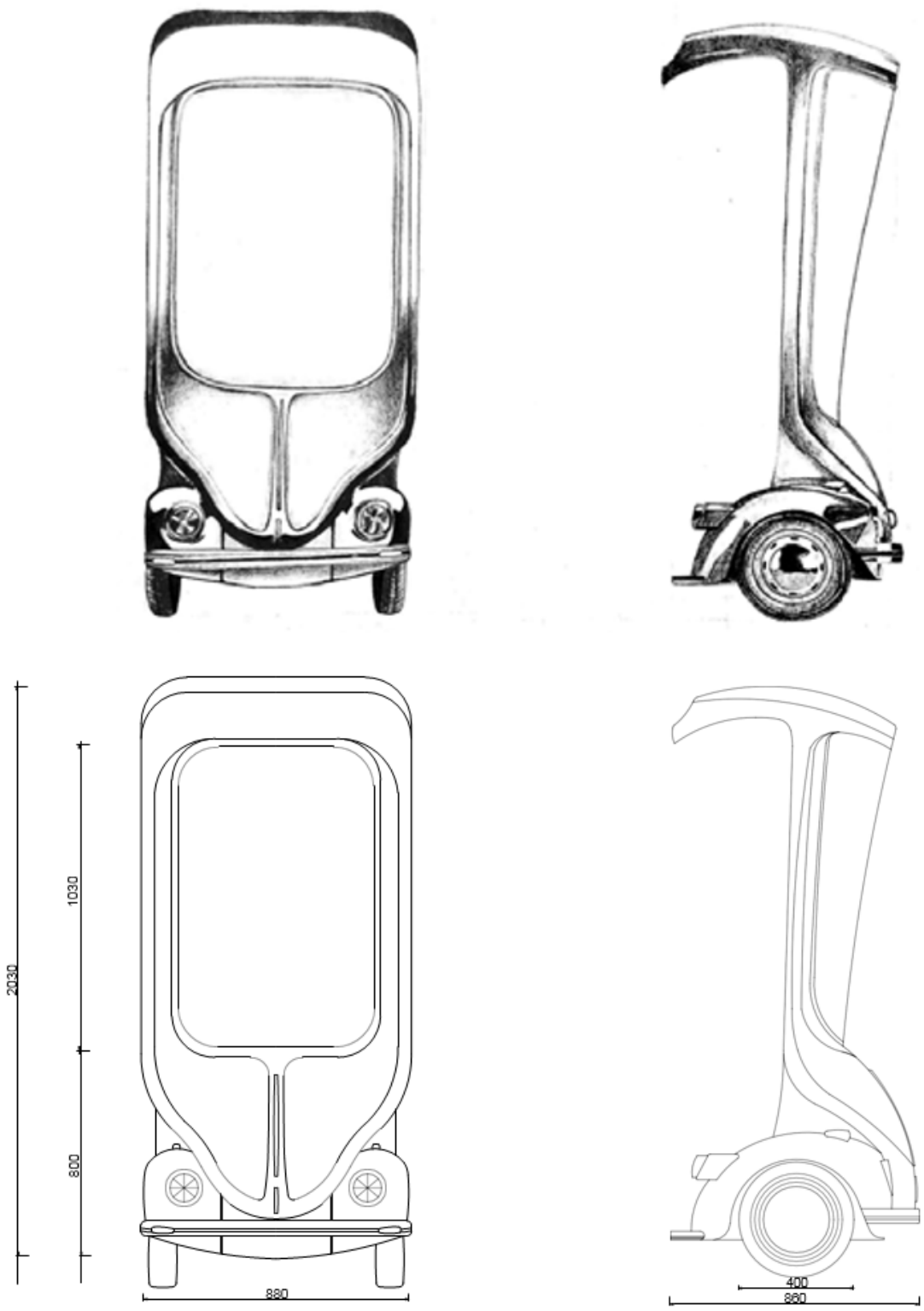


Fig. 14 Retrò style

ADVANCED STYLE

Futuristic and characterized by clean lines, even the advanced style refers to the automotive field. The new electric car concepts perfectly reincarnate the advanced style. Shapes out of the future, soft and sinuous lines. For this concept, the shapes of John Baltazar's Astrum Meera were taken.

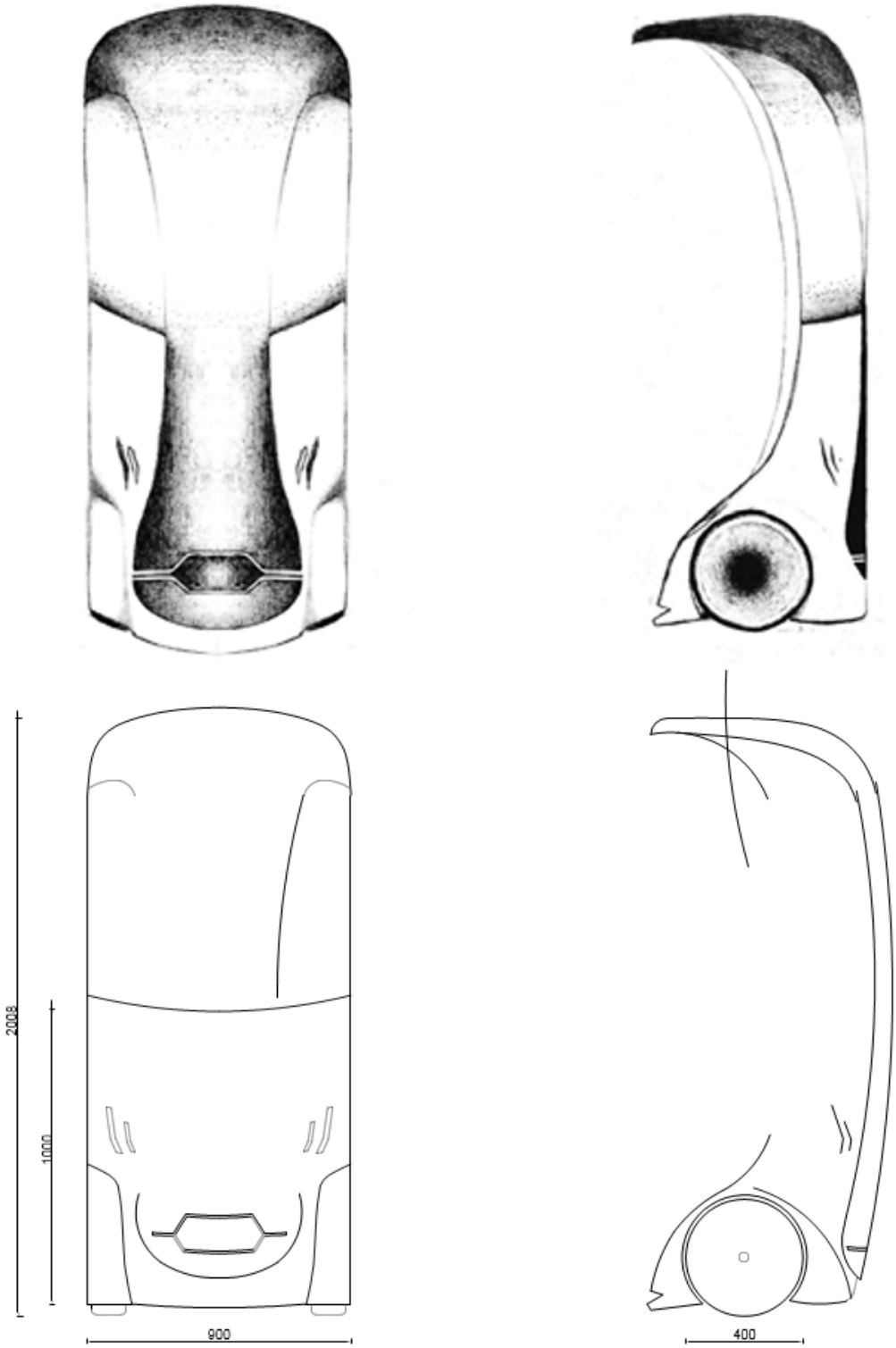


Fig. 15 Advanced style

STONE STYLE

It is immediately attributable to the automotive field: sporty and luxury SUVs characterized by massive dimensions and defined angles. The hard lines and square shapes are imposing and exaggerated. To define this style the inspiration model was: Mercedes Eqc. The stone style will be the one that most reflects the character of the CityTower ID.

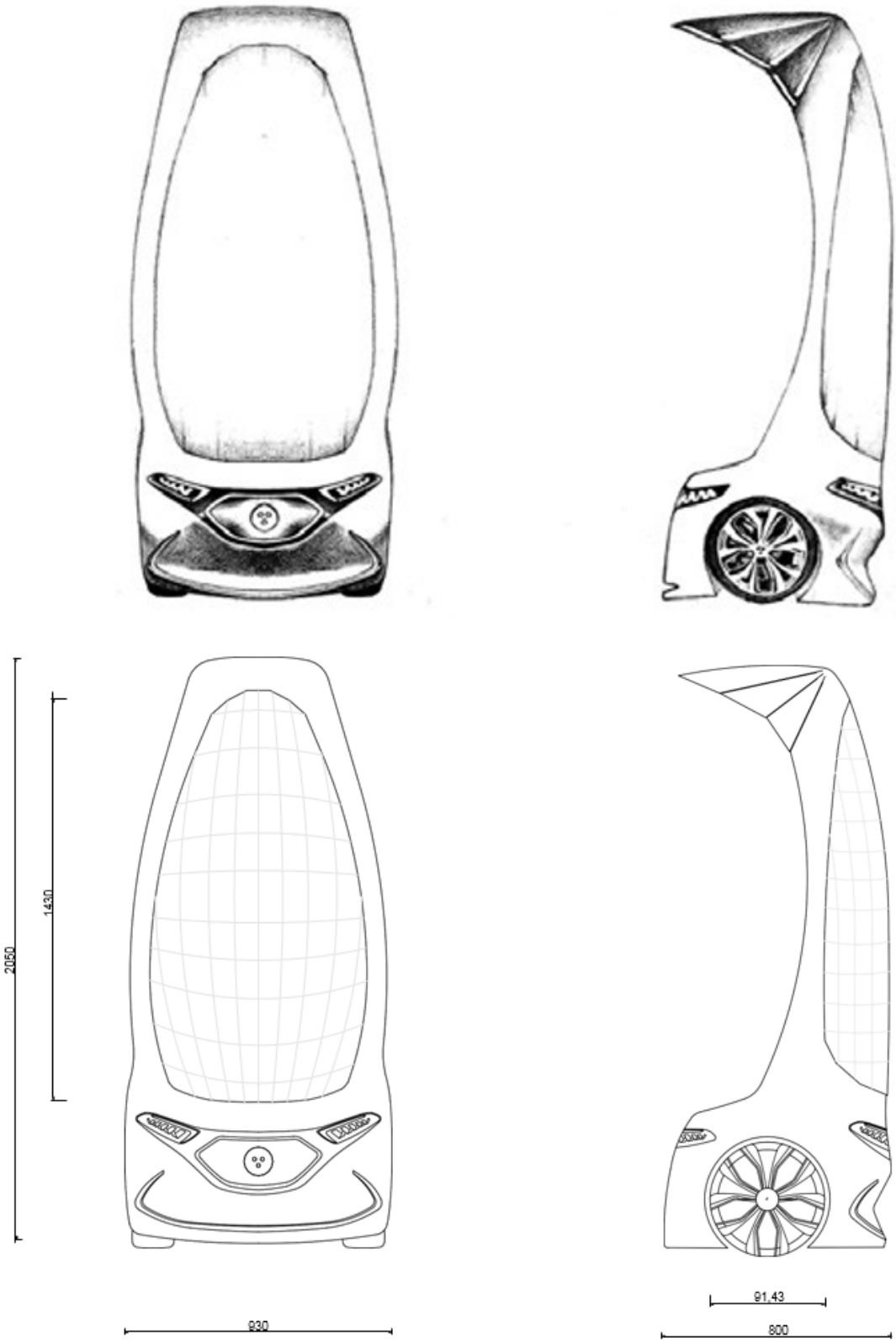


Fig. 16 Stone style

10. MODELING

First the modeling is done through CAD2D-3D and then the rendering is done.

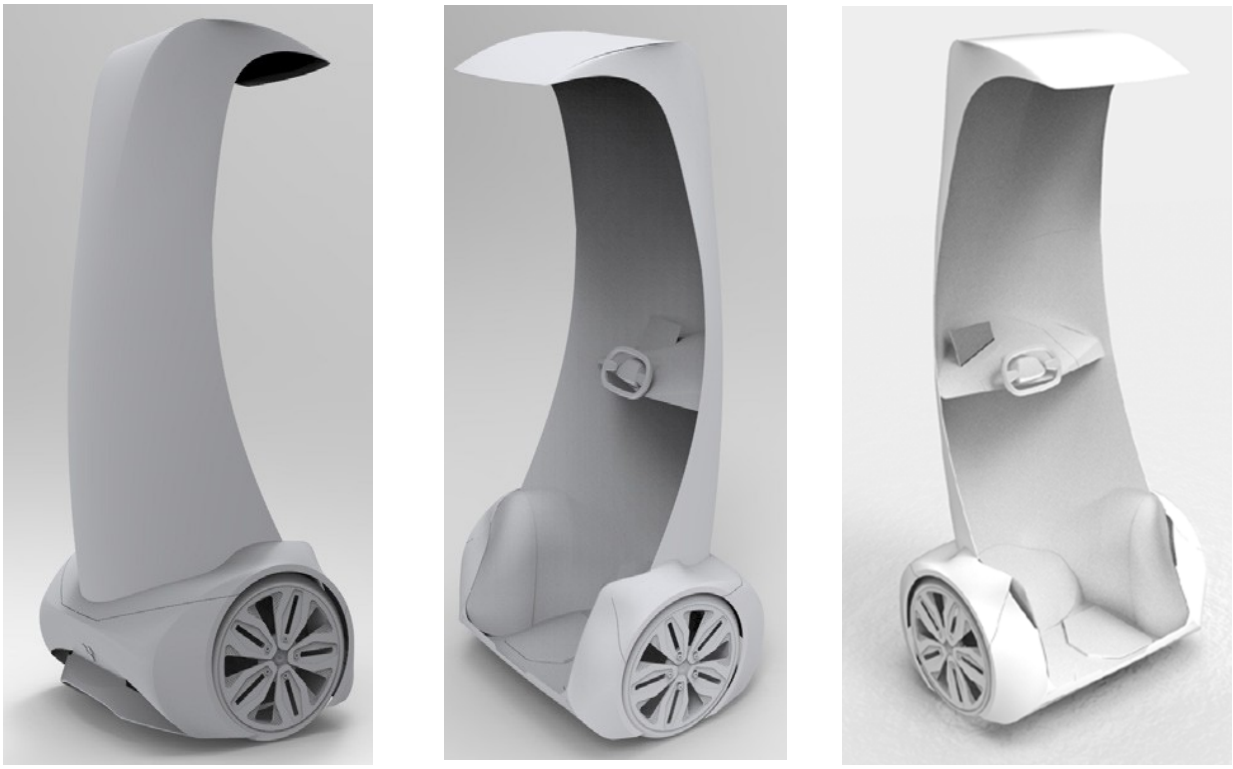


Fig. 17 CAD 3D Model

Fig. 18 Rendering Model

19 CAD Fig. 19 Rendering Model in city environment

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