Design for Six Sigma (DFSS) and Industrial Design Structure (IDeS) for a New Urban Sustainable Mobility

Leonardo Frizziero, Giampiero Donnici, Alfredo Liverani, Gian Maria Santi, Davide Bolzani, Lorenzo Golinelli, Federica Marchi
Department of Industrial Engineering
Alma Mater Studiorum University of Bologna
Viale Risorgimento, 2 – 40136, Bologna, Italy
leonardo.frizziero@unibo.it, giampiero.donnici@unibo.it, alfredo.liverani@unibo.it

Abstract

In the last decade citizens mobility is changing towards a more environment-friendly, more flexible and more shared way of moving around the city. The objective, now, is to decrease the levels of pollution. Notwithstanding people mobility is based on rapidity, sustainability is becoming always more important.
In order to follow the new needs of future customers, the present work is presenting a new approach to design in order to obtain an innovative product with the aforementioned characteristics.
The new approach is to combine two innovative methodology to design: the first one is Design For Six Sigma (DFSS) and it is useful to structure the project into five main phases (Define, Measure, Analyze, Design, Validate), systematically; the second one is Stylistic Design Engineering (SDE) and it is dedicated to the aesthetic development of a new product following an engineering structure of all the phases of the work. DFSS and SDE will be applied in the present paper in order to give an answer to the arising problem of the new mobility of the future, providing for a new innovative urban means, matching the different characteristics of an hoverboard and of a kick-scooter. The output of the study, described along the paper, is the adaptability of the abovementioned methodologies and the proposal of a new product concept for the scopes illustrated.

Keywords (12 font)
DFSS, IDeS, SDE, QFD, BENCHMARKING.

1. Introduction
1.1 Contestual Search
In the last decade citizens mobility is changing towards a more environment-friendly, more flexible and more shared way of moving around the city. The objective, now, is to decrease the levels of pollution. Notwithstanding people mobility is based on rapidity, sustainability is becoming always more important.
The use of electrical mobility is increasing thanks to the fact that electrical disposable are light, fast, comfortable and most importantly, zero-impact. Changing the way you move around the city becomes the imperative to pollute less and less. The idea of mobility today is based on speed, but it is also sustainable. Electric transport devices are becoming more and more popular because they are light, comfortable and fast and above all with zero impact.

1.2 The origin of the hoverboard
The birth of hoverboards seems to have no origins. However, today we are surrounded by thousands of different typologies of hoverboards, produced by more than 1.000 companies. They are taking over the market, supplying a demand exceeding the highest expectations. This is unleashing fights about the right of creation of this innovative skateboard. Data shows that hoverboards have their roots in the Chinese production/ in China. Joseph Bernstein has traced the origins of hoverboards back to Shenzen, a powerful industrial district in the South of China.
He/The researcher described how Chinese succeeded in developing the idea, starting from the realization of a new need, and how they were able to produce such an enormous quantity of products in a small amount of time. This is a stunning number, because the enormous quantity of products is not produced by one of the Chinese market leader,

Foxcom, which is responsible for supplying the pillars of the computer science industry, but it comes from thousands of small and medium enterprises, who are ready to modify their production line or change them for new ones just to keep pace with needs, trends and innovations. The term hoverboard means flying board, thereby the board to be 'hover' should not touch the ground. Moreover, the idea has been inspired by the surface skateboard in the movie 'Back to the future'. During an interview, Robert Zemeckis, the trilogy's producer, stated ironically that hoverboards actually existed and that they would fluctuate on a 'magnetic energy'. However, he added that their sale has been banned, as the producing company, the Mattel (actual brand printed on Hoverboards) considered them too dangerous. As a consequence of what affirmed, Mattel's enclosures were assaulted by thousands of calls, and the myth on the existence of hoverboards was denied. On August 5th 2015, the first hoverboard on two wheels was presented by the car manufacturer Lexus.

1.3 What they are and how they function?

The hoverboard is a 'self-balancing scooter'. They are vehicles with two parallel wheels that, with the use of gyroscopic and on board sensors, are able to put themselves on an horizontal balance. However, the whole movement cannot disregard the passenger's ability of staying in balance. The gyroscope is a rotating physical device that, thanks to the effect of the law of conservation of angular momentum, tends to keep its rotation axis oriented toward a fixed direction. The hoverbord has been designed to be mainly used on smooth surfaces, particularly to avoid any possible unbalance. Although, some special models exist, disposing of particular wheels that permits them to deal with prominent path and with not necessarily smooth surfaces, such as unpaved roads.
The hoverboards, as previously stated, seems to appear in the market without a brand, a marketing strategy, nor even an inventor. They are probably a direct evolution of Segway, a self-balanced scooter entered in the market in 2001 with a great clamor, but that actually never got full attention. Apparently a Hoverboard looks like a Segway without the steering column nor the handlebars. Despite this, not a single firm is responsible for having designed the Segway for the realization of the hoverboards, nor for having developed a technology of self-balancing, nor for having sold them. The most probable creator is Steve Chen, Portland's creator, which had a successful campaign on Kickstarter on May 2013 for what he called 'Hovertrax'. A dispute over patents arose and Chen's progress on bringing 'Hovertrax' on the market slowed down. In the mean time, the Hoverboard trend became viral..

1.4 Appearance on the market

The hoverboards, as mentioned before, seem to have arrived without a single brand, no orchestrated marketing drive and no inventor. They are probably an evolution of the Segway, the self-balanced scooter that arrived in 2001 with enormous clamor, but which never got the total acceptance. On the surface, the hoverboards look like Segways without the steering column and the dumbbells. But the redesign of the hoverboard or the development of technology cannot be credited to any company. The most likely creator is Steve Chen, inventor of Portland, who started a successful kickstarter campaign in May 2013 for a project called "Hovertrax". But a patent dispute has slowed Chen's progress in bringing the Hovertrax to market and, meanwhile, the hoverboard fashion has become viral. Some data on the Italian hoverboard market between 2016 and 2017: 40 thousand hoverboards/months; 50 thousand unity sold/month; 100 thousand micro-mobility tools; 1 million consumers.

2. Materials

The following materials were used to develop the present research project. Project materials are divided into two main categories: Software and Machines. About software, the ones used for the scope are: Autocad for 2D technical drawing, Creo Parametric for 3D solid modeling, Autodesk Alias for 3D surfaces modeling, Keyshot and V-red for rendering. Instead, referring to machines, a 3D Printer was employed to realize the 3D model for the verification of the project, in particular for testing the final aesthetic prototype. Then, the 3D Printer used for prototyping is an FDM type (Fused Deposition Modeling).

3. Methods

3.1 IDeS (Industrial Design Structure) Methodology

The methods adopted into the present research can be integrated in the main big methodology named Industrial Design Structure (IDeS), that is an industrial approach aiding companies to organize both the project and the structures of offices. For this reason it is normally used both by designers or engineers and human resources officers. IDeS follows the entire development of the industrial project, accompanying the birth of a new product, "from white sheet", to its production. It is composed by three main phases (Figure 1):

(1) Product Set Up - (2) Project Development - (3) Production Set Up

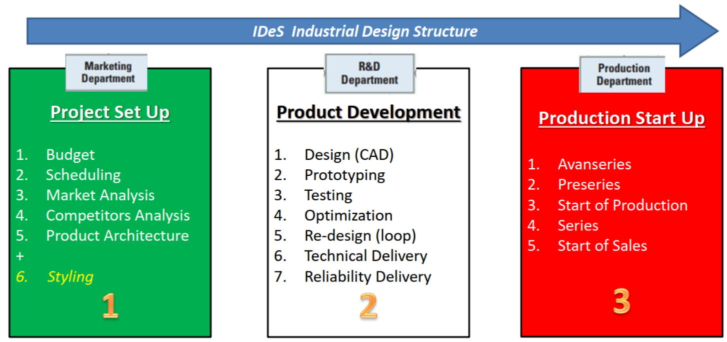


Figure 1 – IDES Structure (Frizziero et al. 2019)

3.1.1 Product Set Up

Introducing "Product Set Up" step, it can be affirmed that it is the moment in which the concept idea of a new product comes out. This new project is not only idealized, but it is also planned, it is also valued, it is also stylized, it is also architected, it is also compared with market and competitors.
So, it is possible to structure "Product Set Up" phase, composing it with the following steps:
(a) Planning – (b) Costing – (c) Market Analysis – (d) Competitors Analysis – (e) Product Architecture – (f) Styling

Planning creates a relation between the list of activities to be performed to complete the project (WBS – Work Breakdown Structure) and the times in which they must be performed-
Costing is the activity oriented to estimate the costs of all the materials, human performances and prototype equipment to be involved into the entire process of R&D activities, useful for completing the design project.
Market Analysis perceives what are the customers' requirements.
Competitors Analysis helps designers to know what products and technical solutions are already on the market.
Product Architecture achieves to reason where disposing the main functional components of the future product.
Styling give an appealing shape to the new product incoming.

Usually, the instruments used in order to perform the above mentioned steps are:
(a) Gantt Diagram for Planning
(b) Budget for Costing
(c) Quality Function Deployment (QFD) for Market Analysis
(d) Benchmarking (BM) for Competitors Analysis
(e) Schematic Drawing for Product Architecture
(f) Stylistic Design Engineering (SDE) for styling

4. The Case Study: highlights

As it is illustrated in the present paragraph, about the case study description, the methods above will be applied. In particular, we are implementing the simulation of an industrial project applied to an innovative urban transportation means, like an hoverboard, as the product idea chosen, using the methodologies described in the previous paragraph.
The evolution of the industrial project is that described in the IDeS (Industrial Design Structure) methodology and consists into the main application area, i.e. the first macro-phase, Product Set up.
In the context of IDeS, this paper describes the design of a future urban means starting from the use of some innovative design methodologies. The main methodology used in the initial part of the work is the QFD - Quality Function Deployment, applied to determine the fundamental characteristics that a new urban means car should have.
Subsequently a typical method for product marketing is used, that is the decision-making process guided by the Benchmarking analysis, suitable for the organization of the competitive analysis and the choice of innovation objectives. Finally, the top flop analysis is implemented to improve benchmarking, identifying the brand on the market that is best suited to meet the requirements founded.

4.1 The GANTT diagram to Plan the Project: Case Study of an Hoverbaord

In order to start all the activities of the project, the relative time planning must be defined into an organization chart called the Gantt Diagram. In the column the main activities (WORK BREAKDOWIN STRUCTURE – WBS) are positioned and a series of rectangles mark the following phases based on the dates at the top and the colors of the roles of the team members have been attributed (Figure 2). Subsequently, the main open and unresolved issues were identified and reported in the Oil (Open Issue List) Plan with the respective priorities and deadlines (Figure 3)

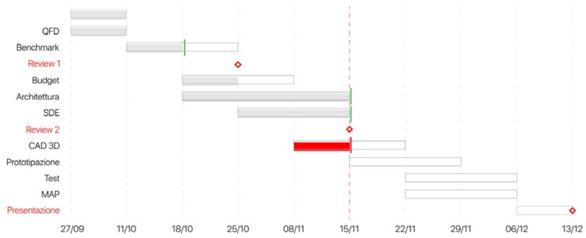


Figure 2 - Gant Diagram of the Case Study

	Problema	Proposta	Owner	Deadline	Priorità	Stato	Note
I	Sistemare matrice dip/ind	Invertire i risultati	Davide Bolzani	16/10	1	●	
II	Sistemare matrici benchmark	Riportarle su Ai	Davide Bolzani	16/10	1	●	
III	Finire presentazione	Unire materiale	Lorenzo Golinelli	17/10	1	●	
IV	Scegliere architettura per sketch	Matrice cosa/come e ricevimento	Tutti	29/10	1	●	
V	Iniziare sketches	Guardare ai trend	Tutti	25/10	1	●	

● Da completare ● Completare con urgenza ● In ritardo ● Completato

Figure 3 - OIL Diagram of the Case Study

The OIL table allows designers to monitor the problems that arise during the development of the project. To each problem corresponds a solution proposal, an owner, that is the person in charge of its resolution, a deadline, and the progress (open / closed) of the resolution activity

4.2 Costing applied to the Case Study through R&D Budget

As for the budget, we assumed the research and development process over the course of a year, divided into four phases: design, prototyping, testing and redesign (Figure 4). As can be seen from the Graph 1 (Figure 4) all stages, except for the design phase have a duration equal to 3 months. This happens because the first study models will be built in parallel with the design development phase. Subsequently we identified the professional figures necessary to achieve our goal: the designer, the engineer, the worker and various external consultants. Assuming an hourly wage of € 40 / hour for the designer and engineer, € 25 / hour for the worker and € 30 / hour for consultancy, the total cost of product development is € 256,080.00. Graphs 2 (Figure 4), on the other hand, show more detailed costs within each individual phase. It immediately stands out how all the phases with have more or less similar costs, except for the redesign phase. On the contrary, Graph 3 (Figure 4) refers to the materials to be used, during the 4 phases, for the realization of the final model. They are divided by "material" and "production", highlighting which components are currently available on the market and which will be produced from scratch.

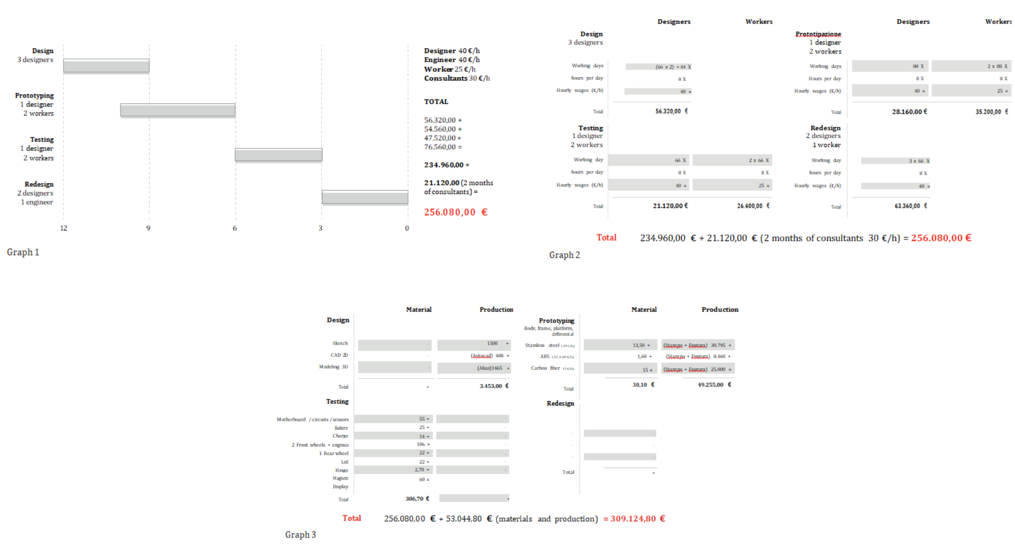


Figure 4 – R&D Budget

4.3 Market Analysis applied to the Case Study through QFD

4.3.1 Quality Function Deployment

Quality function deployment (QFD) is a state-of-the art method on the approaches on quality management. With QFD firms' attention on quality is moved from the production process back to the initial projection. It has the task to satisfy the needs and the wants of the buyer, directly in the projection of the product/service.

The QFD we carried out consists of 3 phases: an initial group brainstorming in which we asked ourselves six fundamental questions for the analysis and understanding of the product that we had to develop, the interrelation matrix of relative importance in which we inserted and voted the fundamental characteristics identified in the first phase and the matrix of dependence/independence interrelation, also composed of the same properties of the first matrix, to which we have, however, given a different type of evaluation.

4.3.2 Six Questions

The questions we asked ourselves in the initial phase that we tried to answer in the most open and farsighted way possible are: Who? When? Why? What? How? Where?

These questions have allowed us to analyze and fully understand the most important features for the realization of our project. With a brainstorming we collectively decided what the characteristics we wanted our product to be.

After this analysis, fourteen product features emerged which we thus inserted into the two matrices of relative importance and successively dependence/independence.

The characteristics emerged are: stability, ergonomics, cost, lightness, portability, durability, cleanability, speed, dimensions, adaptability, resistance, driveability, immediacy, safety.

WHO? 14/70 years old.
WHERE? Cities, parks, factories.
WHEN? Daily 2/4 times
WHY? Practicality and comfort.
WHAT? Ease / time to move.
HOW? Use of the body.

4.3.3 Matrix of relative importance

The matrix of relative importance was built based on the characteristics that emerged from the brainstorming and from the six questions of Quality Function Development.

The characteristics have been reported in the columns and rows to be compared in relation to the importance of each other. The comparison method is based on assigning a value between 0 and 2 following the scheme of the importance of the rows with respect to the columns.

Value 0: assigned if the characteristic present in the analyzed line is more important than that in the column.
Value 1: assigned if the value analyzed in the row has the same importance as that in the column.
Value 2: if the characteristic analyzed in the row is less important than that present in the column (Figure5)

	Sta	Erg	Cos	Lig	Por	Dur	Cle	Spe	Dim	Ada	Res	Dri	Imm	Saf
Stability	1	1	0	0	1	0	0	0	0	0	0	1	1	1
Ergonomics	1	1	0	1	2	1	0	0	1	0	0	2	2	1
Cost	2	2	1	2	2	2	0	0	2	2	2	2	2	1
Lightness	2	1	0	1	1	0	0	0	1	0	1	1	2	2
Portability	1	1	0	1	1	0	0	0	1	0	1	2	2	1
Durability	2	2	0	2	2	1	0	0	2	0	1	2	2	2
Cleanability	2	2	2	2	2	2	1	2	2	2	2	2	2	2
Speed	2	2	2	2	2	2	0	1	2	2	2	2	2	2
Dimensions	2	1	0	1	1	0	0	0	1	0	1	1	2	2
Adaptability	2	2	0	2	2	2	0	0	2	1	1	2	2	2
Resistance	2	2	0	1	1	1	0	0	1	1	1	2	2	2
Driveability	1	0	0	1	0	0	0	0	1	0	0	1	1	1
Immediacy	1	0	0	0	0	0	0	0	1	0	0	1	1	1
Safety	1	1	1	0	1	0	0	0	0	0	0	1	1	1
Total	22	18	6	16	18	11	1	3	17	8	12	22	24	21

Fig. 5 – Relative Importance Matrix

So, the following requirements resulted the most important: IMMEDIACY, DRIVEABILITY, STABILITY, SAFETY.

4.3.4 Matrix of dependency / independency

The dependency - independence matrix was constructed to analyze how much each of the fourteen characteristics depends on the other (Figure 6).

Specifically, the reading of the matrix is based on the question "how much the characteristic of the row depends on that in the column", based on the following values to be assigned.

Value 0: if the characteristic is totally independent from that in the column.
Value 1: if the characteristic in the row is almost independent of that in the column.
Value 3: if the characteristic in the row is highly dependent on that in the column.
Value 9: if the characteristic in the row is totally dependent on that in the column..

	Sta	Erg	Cos	Lig	Por	Dur	Cle	Spe	Dim	Ada	Res	Dri	Imm	Saf	Tot
Stability	/	9	0	3	0	0	0	9	3	1	0	9	9	0	43
Ergonomics	3	/	0	0	0	0	0	0	9	0	0	3	9	3	27
Cost	0	0	/	9	9	9	0	3	1	3	9	0	0	0	43
Lightness	3	0	9	/	9	0	0	9	9	3	9	1	1	0	53
Portability	0	3	3	9	/	0	0	0	9	0	1	0	0	0	25
Durability	0	0	9	0	0	/	3	0	0	3	9	0	0	0	24
Cleanability	0	9	1	0	0	3	/	0	3	9	9	0	0	0	34
Speed	9	9	3	3	0	3	0	/	3	1	3	9	9	1	53
Dimensions	3	9	3	9	9	0	9	3	/	0	0	0	3	0	48
Adaptability	9	3	3	0	0	1	1	0	0	/	9	9	9	3	47
Resistance	0	0	3	0	0	9	1	0	1	1	/	9	0	0	24
Driveability	9	9	3	0	0	0	0	9	3	0	9	/	0	0	42
Immediacy	9	9	0	1	0	0	0	9	3	0	0	9	/	9	49
Safety	0	9	0	0	0	0	0	0	3	0	0	0	9	/	21
	45	69	37	34	27	25	14	42	47	21	49	49	49	16	

Figure 6 - Matrix of independence and dependence

So, the following requirements resulted the most independent: OPTIONAL, DIMENSIONS, MAINTENANCE, SPORTINESS.

4.4 Competitors Analysis applied to the Case Study

4.4.1 Benchmarking (BM)

Benchmarking is a process of measuring the performance of a company's products, services, or processes against those of another business considered to be the best in the industry, aka "best in class" (Figure 7).

Thanks to this method-tool we have chosen to analyze the production competition of the selected hoverboards the products currently on the market and defining which characteristics to analyze to compare them.

The TOP-FLOP estimate was then calculated, thus highlighting the hoverboards that having the best characteristics emerged. In red the worst values for each characteristic have been highlighted, while in green the best of each characteristic.

	Glyboard Lamborghini	LZZ Hoverboard	Nilox DOC 2	NINEBOT Segway	NINEBOT Segway MiniLITE	TEKK Neo	Twodots Glyboard Evo	TOEU	BEBK	Valori innovativi per il nuovo hoverboard
Speed (km / h)	20	16	10	24	16	12	10	12	12	> 24
Autonomy (km)	20	25	12	30	18	20	15	30	20	> 30
Charging time (h)	2,5	2,5	2,5	3	3	3	3	1,5	1,5	< 1,5
Max driver weight (kg)	100	100	100	120	80	150	100	120	100	> 150
Hoverboard weight (kg)	10	15	11	11,4	12,5	13	12	12,5	9,5	< 9,5
Length (cm)	66	67	58,5	42	55	61	58	59	58	< 42
Width (cm)	24	27	18	18	26	25	18	18	18	< 18
Height (cm)	22	28	18	45	59	23	19	18	18	< 18
Foldable (yes / no)	no	si	no	no	no	no	no	no	no	si
Max power (Watt)	400	500	360	500	700	600	700	400	700	> 700
Num engines	2	1	2	1	2	2	2	2	2	1
Led lighting (yes / no)	si	si	si	no	si	si	si	si	si	si
Display (yes / no)	no	no	no	no	no	no	no	no	no	si
Uphill degrees (°)	15	30	15	15	10	15	15	15	30	> 30°
Bluetooth (yes / no)	no	si	si	si	si	si	no	si	no	si
Price (€)	399	680	171	550	335	180	100	120	140	< 100
TOP	1	6	4	6	3	3	4	6	7	
FLOP	4	5	6	4	7	4	6	3	4	
DELTA Δ	-3	1	-2	2	-4	-1	-2	3	3	> 3

Figure 7 – Benchmarking applied to case study (BM)

4.4.2 TOP / FLOP Analysis

We came to identify the best product on the market, in the case of the same score with Δ = 3, the TOEU hoverboard and the BEBK hoverboard were placed. This indicates that the product we will develop, in order to be competitive and successful on the market, will have 4 or more features among those present in the benchmarking (Figure 8).

Best product Δ = 3 ; New product Δ > 3

Figure 8 – Top-Flop Anlysis

4.4.3 WHAT-HOW Matrix

The features emerged as fundamental from the matrices of relative importance and dependence-independence, with the characteristics used to analyze the competitors in the benchmarking matrix, were included in the what-how matrix. The expected result was to identify what were the fundamental characteristics for us to improve the best products already on the market and therefore obtain a Δ > 3 . (Figure 9).

	Spe km/h	Battery life	Charge time	Heavy weight	Weight	Length	Width	Height	Max power	Num engine	LED	Display	uphill degrees	Bluetooth	Price
Stability	10	0	0	6	6	10	10	10	0	0	0	0	10	0	4
Driveability	8	0	0	6	8	10	10	10	6	0	6	4	8	0	4
Immediacy	0	0	0	0	2	6	6	6	0	0	6	10	0	0	4
Safety	10	6	0	4	2	6	6	6	8	0	6	6	6	0	4
Ergonomics	0	0	0	6	6	10	10	10	0	0	4	2	4	0	0
Resistance	2	0	0	8	8	2	2	2	0	0	0	0	0	0	6
Totale	30	6	0	30	32	44	44	44	14	0	22	22	28	0	22

The result has been **Δ** = **7**.

Fig. 9 – What-How Matrix

So, the following technical characteristics resulted the ones asked by customers: SPEED, HEAVY/WEIGHT, DIMENSIONS, LED, DISPLAY, UPHILL DEGREES.

4.5 Product Architecture applied to the Case Study
4.5.1. Choice of the Architecture

Based on the requirements that our hoverboard must possess, it was hypothesized numerous innovative product architectures. We then compared them using the what-like matrix (Figure 10) and drawing up a list of possible pros and cons (Figure 11) of each. From these analyzes, the product architecture number 3 emerged as the winner. The central frame, placed between the two platforms, and the wheels one front and one rear allow this architecture to have excellent stability, greater balance and to be immediate to the use. (Figure 10).

Stabilità	6	6	8	4	10	6	8	8	4	2
Guidabilità	6	4	8	6	8	6	6	6	8	2
Immediatezza	4	8	8	4	4	4	6	6	6	4
Sicurezza	6	4	6	4	8	6	6	8	2	2
Ergonomia	8	4	4	4	6	4	8	4	6	2
Innovazione	8	2	8	2	8	8	8	4	2	2
Totale	38	28	42	24	44	34	42	36	28	14

Figure 10 – what-hoe matrix for architecture choice

Architecture	Pros	Cons
Ipothesis 1	Ergonomica e innovativa	Stabilità
Ipothesis 2	Maggiore stabilità	Non innovativa
Ipothesis 3	Maggiore stabilità e innovativa	Poco ergonomica
Ipothesis 4	Guidabilità semplifcata	Non innovativa e poco stabile
Ipothesis 5	Stabilità elevata e innovativa	Non immediata
Ipothesis 6	Innovativa	Poco stabile
Ipothesis 7	Innovativa e stabile	Poco sicura
Ipothesis 8	Stabile	Poco innovativa
Ipothesis 9	Guidabilità	Poco stabile e sicura
Ipothesis 10	/	Tutto

Figure 11 – Pros/Cons Graph

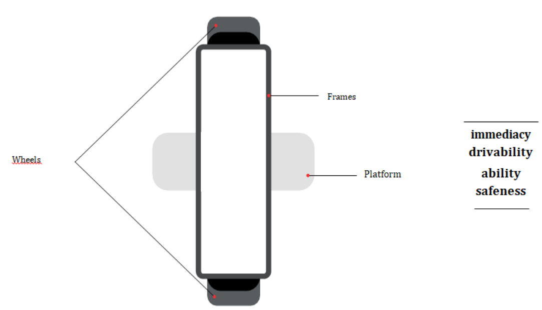


Figure 12 – Product Architecture

4.5.2. Handle extension mechanism
Useful length to position the 360mm handlebar; Telescopic mechanism to extract the handlebar; The last section is independent and contains the handles; The handles are extracted by a rotational movement: Extraction of the handlebar from the special housing in the body; Self-locking of each hinge once opened in position (Figure 13).

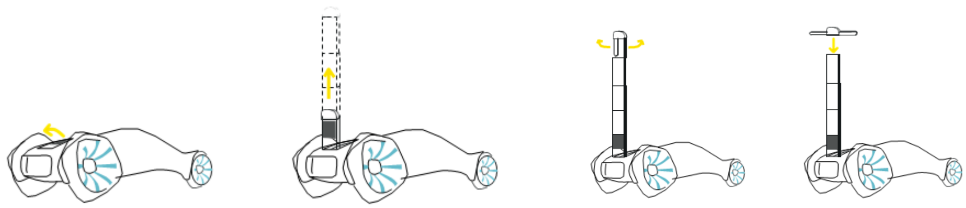


Figure 13 - Handle extension mechanism

4.5.3. Transport and closing mechanism
Thanks to a hinge that allows a rotation of 180 degrees, the rear part of the hoverboard can fold and go to fit into the central belly where a special housing has been designed and where, thanks to a neodymium magnet, it is blocked (Figure 14).

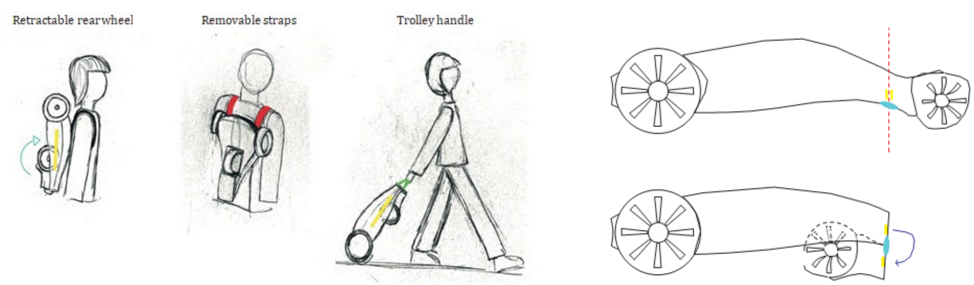


Figure 14 - Transport and closing mechanism

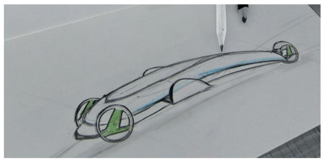
4.6 SDE (Stylistic Design Engineering) applied to the Case Study
4.6.1 Stylistic Design Engineering Method
In this phase we proceed using the tool of the SDE which consists in:

- the analysis of the current stylistic tendencies
- the elaboration of sketches of each of them (Figures 15-16, 17-18, 19-20, 21-21)
- the elaboration of 2D drawing (Figures 22)
- the modeling of 3D CAD concept (Figures 23, 24, 25)
- the rendering of the new product (Figure 26)
- the prototyping of the 3D model (Figures 27, 28, 29, 30, 31)

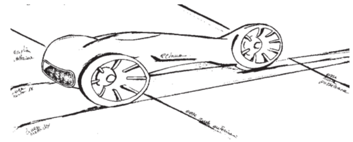
The main current stylistic trends are: ADVANCED, NATURAL, RETRO‘ and STONE. Here below the proposals of the ***present*** project will be shown in order to satisfy these tendencies.

4.6.1.1 Stylistic Tendencies Analysis and Sketches Proposals
Four sketches concept and orthogonal projections has been proposed, each one for one of the four styles of the SDE method: advanced, natural, stone, retrò.

a) Advanced Style
The advanced sketch concept shows the futuristic and aerodynamic features of an hoverboard that looks forward and gives the idea of power, speed and future (Figs 15 and 16).



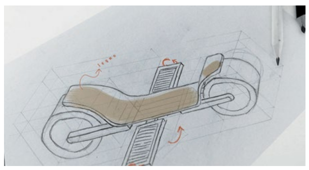
Figures 15 – Handmade Sketches of Advanced proposal



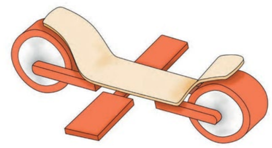
Figures 16 – B/W Sketches of Advanced proposal

b) Natural

The natural sketch concept represents an hoverboard with sinuous, delicate and feminine features which matches perfectly with the powerful aim of the means (Figures 15 and 16).



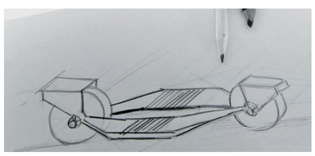
Figures 17 – Handmade Sketches of Natural proposal



Figures 18 – Colored Sketches of Natural proposal

c) Stone

The stone sketch concept proposes a strong and powerful idea of a new safe and solid hoverboard (Figures. 17 and 18).

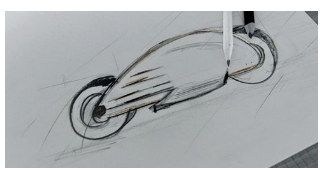


Figures 19 – Handmade Sketches of Stone proposal

Figures 20 – Colored Sketches of Stone proposal

d) Retrò

The retrò sketch concept reclaims sharp-cornered features and simple volumes (Figs.19 and 20).



Figures 21 – Handmade Sketches of Retrò proposal

Figures 22 – Colored Sketches of Retrò proposal

4.6.1.2 CAD 2D

Here are presented the orthogonal projections of the chosen proposal (Figure 23)

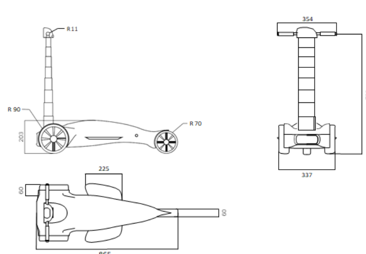
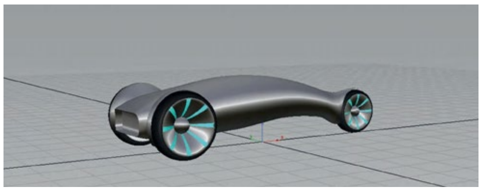
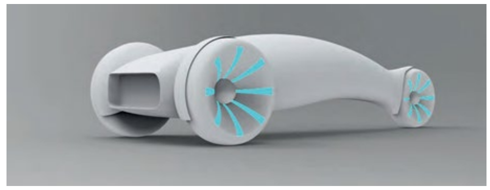


Fig. 23 – 2D drawings of Chosen proposal

4.6.1.3 CAD 3D and Digital Prototype

The digital model of the hoverboard was created with the Autodesk Alias software using surface modeling. Below are images of the steps of the modeling phase up to the finished model. In order to model the hoverboard, it was started with the construction of the main "driving lines", derived from the 2D CAD (i.e. canvas or blueprint). From here the body was built. Then it was moved on to modeling details (Figures 24, 25, 26).





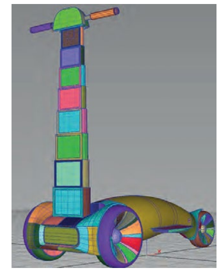


Figure 24 – 3D Modeling   Figures 25 – 3D Modeling   Figure 26 – 3D Modeling

Using the rendering tools it was created the digital prototype. Prototyping has the function of giving a realistic view of the hoverboard and of the various colors and textures. Below there are some views (Figure 27).

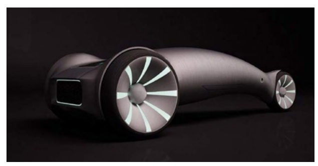


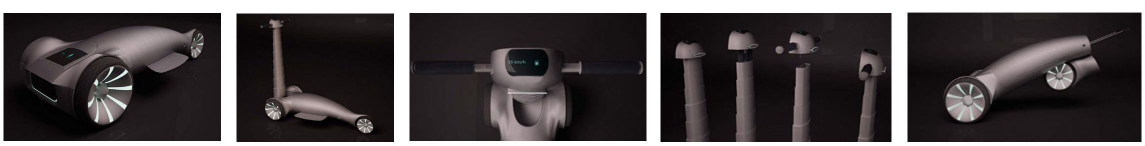
Figure 27 – 3D Models rendered

4.6.1.5 Rendering

In computer graphics, rendering (lit. "graphic restitution") identifies the process of rendering, that is, generating an image from a mathematical description of a three-dimensional scene, interpreted by algorithms that define the color of each point of the digital image.

In a broad sense (in the drawing), it indicates an operation capable of producing a quality representation of an object or an architecture (designed or detected) (Figures 28).

With the Autodesk Vred software, renderings of the digital model were created in studio settings and in realistic settings by inserting HDR images showing details of the car and its overall view in the realistic context.



Figures 28– Various Rendering of the 3D Model

4.6.1.6 Physical Prototype and 3d Printing

The 1:18 scale prototype was made with the 3D printer. Its main function is to verify the volume and visual of the car (Figures 29).

Figure 29 – 3D Printed Model – Styling Maquette

Thanks to digital prototypes and to the physical model it has been possible to make some considerations and modifications regarding aesthetic checks, verification of proportions and volumetric checks.

5. Future Developments and Conclusions

As already presented and said in other works at IEOM Plzen Conferences 2019 and 2020 by Frizziero et al. and Donnici et al., future developments of IDeS and SDE methods should be oriented to the implementation of the emerging technologies (derived from Industry 4.0) instead of the techniques nowadays used for SDE. In particular, two aspects can be mostly put under the attention:

1) Pencil Sketches can be evolved into Digital Sketches
2) Physical Model can be substituted by Digital Model (for example using A.R. or V.R.)

In conclusion, it can be affirmed that in the present work, a new innovative urban innovative means project was developed using the method and the technologies illustrated.
In particular, through Stylistic Design Engineering applications, sketches, 2D drawings, 3D models and Physical Prototype were realized, in order to help the design process to be performed.

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Biographies

Leonardo Frizziero is a Senior Assistant Professor of the Department of Industrial Engineering, at Alma Mater Studiorum University of Bologna. He promotes the scientific issues related to the Mechanical Design and Industrial Design Methods (CAD 2D, 3D, Advanced Design, QFD, TRIZ, DFSS, DFD, DFA, ecc.). In 2005, he was recruited by Ferrari Spa, as project manager of new Ferrari cars projects. In 2009 he came back to University, obtained the Ph.D. degree and started collaborating with the Design and Methods Research Group of Industrial Engineering becoming Junior Assistant Professor in February 2013 at DIN of AMS University of Bologna. He teaches and follows researches in the design fields, participating at various competitive regional, national and international research projects. Since 2018 he has been a Senior Assistant Professor. Since 2017 he is qualified Associate Professor of Design and Methods of Industrial Engineering (ING-IND/15). Prior to the role of university professor, he held relevant positions for some industrial companies.

Giampiero Donnici is a Ph.D. Resercher and Fellow of the Department of Industrial Engineering, at Alma Mater Studiorum University of Bologna. Giampiero Donnici worked as a mechanical designer in agricultural machinery companies and machine companies. As a consultant he has worked in numerous companies producing automatic machines and PLM and PDM systems. He is now a tutor and adjunct professor at the aforementioned university.

Alfredo Liverani is a Full Professor and Chief of Mechanical Engineering Degree Course at the Department of Industrial Engineering of Alma Mater Studiorum University of Bologna. Prof. Alfredo Liverani is a member of CbEM (Computer-based Engineering Methodologies) research group and he is involved in several activities related to Computer Aided Design (CAD), Computer Graphics, Virtual and Augmented Reality. In detail he focuses on real-time visualization and interaction with particular attention to mechanical, aeronautical applications and also Industrial Design. Surface modelling, reverse engineering, mesh generation (FEM) and manipulation, virtual prototyping and live simulations are fields investigated in the several publications available at http://diem1.ing.unibo.it/personale/liverani.

Giampiero Donnici is a Ph.D. Student of the Department of Industrial Engineering, at Alma Mater Studiorum University of Bologna. Gian Maria is involved in Augmented Reality and 3D Printing applications and studies. He is now a tutor at the aforementioned university.

Davide Bolzani, Lorenzo Golinelli Federica Marchi are students of the course “Advaced Design-Design and Methods of Industrial Engineering”, held by Prof. Leonardo Frizziero at Alma Mater Studiorum University of Bologna**.**