Stylistic Design Engineering (SDE) to Conceptualize a New Seven-Seater Car

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Abstract

The present paper is about a family car project that starts from a study of the characteristics of the type of car taken into consideration and from an analysis of the environment carried out through an historical research on the models on the market from the 30s to the mid-90s, and their classification. The market analysis was carried out by answering six questions from the QFD and by developing the tables of relative importance and interrelation through which the most important and the most independent requirements to be attributed to the innovative family project were obtained. The competitor analysis was made through a research on the models currently on the market, the development of the benchmarking, and the what/how matrix from which the final requirements and project objectives were determined. The brand was selected, the budget was drawn up over a 12-month period and the car's product architecture was defined. The SDE was carried out through an aesthetic analysis of the existing models, the sketches for each type of style and the selection of the final sketches. The development of the product, instead, consisted in the prototyping of a 1:18 scale model of the car through 3D printing.

Keywords
SDE, QFD, CAD, Rendering, 3D Printing.

1. Introduction
1.1 Features and History
The family car bodywork is generally derived from a corresponding sedan model, from which it takes up the front and central part of the car body, while the rear is longer and increased in volume, joining the trunk with the passenger compartment, in order to create more space available to load luggage, goods or other. The first Station Wagons were built around 1910 in the United States and initially were born as commercial versions of the sedans dedicated to the world of work, also nicknamed "Carryall" as they offered a much larger and more spacious load compartment than the traditional torpedo body. Initially made with a wooden frame, they were then completely designed in steel and in 1929 Ford began to officially produce the Model T intended for the Wagon set-up. In 1935, however, General Motors launched its first Station Wagon intended for passenger transport: the Chevrolet Suburban (Figure 1). The Wagons were seen by the market as spacious and capacious cars intended not only for freight transport but also for family use. In Europe, the first cars with family bodywork were introduced in the 1930s and was the Citroen Traction Avant Familiare in 1935 (Figure 2), an elongated version of the Traction Avant with three windows and a third row of seats also available in a "commercial" version. In Italy the first family car was conceived by Mario Ravelli who designed the elongated version of the Fiat 1100 (Figure 3) after the Second World War.

Figure 1. Chevrolet Suburban

Figure 2. Citroen Tract. Avant

Figure 3. Fiat 1100

1.2 Car Models

Over the years many familiar cars have been produced. In almost all cases they derive from sedan models (Figure 4). Family cars became popular in USA around the seventies with the iconic minivans. The first family cars in Europe were released in the late seventies by Volkswagen, Volvo and Mercedes (to be released were Volkswagen Passat (Figure 5), Volvo 200 Series and Mercedes Benz W123) in the last years of the Seventies.
Later in the eighties, family cars became also popular in Europe where the major companies released new models of family car such as Audi 100 Avant, Volvo 700 Series and Mercedes Benz W124.
In Italy the first family car was released by the Lancia Company in 1986 which was Lancia Thema Wagon (Figure 6), the wagon version of the current Lancia Thema designed by Pininfarina.
In 1988 the Alfa Company introduced the idea of "sport family car" and proposed a new model: Alfa 33 Sport Wagon. In the first half of the nineties the family car had the greatest success in western Europe and Italy in particular going from 95.961 Station Wagon units sold in 1988 to 241.131 in 1994.

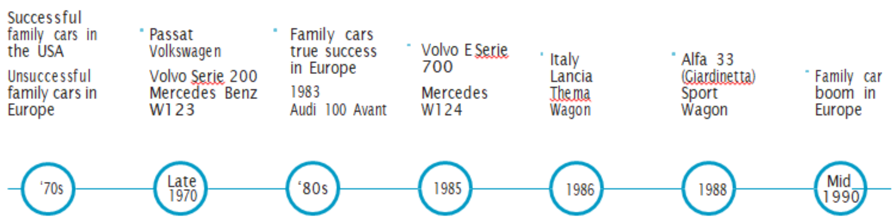


Figure 4 – Evolution of Family Car

Figure 5. Volkswagen Passat

Figure 6. Lancia Thema

1.3 Classification

Nowadays we have reached a large variety of companies and car models so we can decline the family car category in five subcategories which are: station wagon, suv, compact MPV, minivan, crossover. In Figure 7 it is possible to see a simplified classification of these kinds of vehicles. The aspects that must instead be optimized are the dimensions, which influence the practicality of driving the car, and consumption. In Figure 8 it is possible to read an analysis about the "PROS" and "CONS" linked to the adoption of a Family Car, by users.

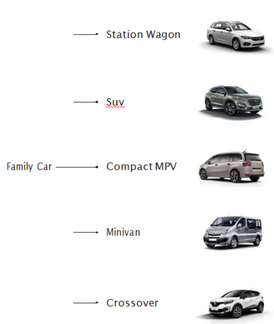


Figure 7 – Classification of Family Cars Types

Figure 8. – Pros/Cons of Family Car

The characteristics of the family car that we will maintain in the development of our product are an adequate boot capacity and total capacity, as well as the necessary safety during the transport of passengers.

2. Materials

Many materials were used to develop the present work. These materials can be divided into two main categories: Softwares and Machines.
Referring to the softwares employed for the research work, the one 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, speaking about machines, a 3D Printer was employed to realize the 3D model for the verification of the project, in particular for testing the styling maquette, that is the aesthetic prototype of the new concept car (Figure 9). The 3D Printer utilized is an FDM (Fused Deposition Modeling) machine, that can be schematized in Figure 10.

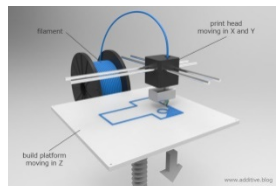


Fig. 9 – Styling Maquette

Fig. 10 – FDM Printer (https://www.additive.blog)

3. Methods

3.1 IDeS – Industrial Design Stucture

Methods employed in the present work are all integrated inside the main methodology, named Industrial Design Structure (IDeS). Industrial Design Structure is an industrial approach that helps companies to organize both the project and the structure of offices. So it is normally used both by designers or engineers and human resources officers. IDeS follows the whole 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, depicted and explained in Figure 11, as follows: (1) Product Set Up - (2) Project Development - (3) Production Set Up

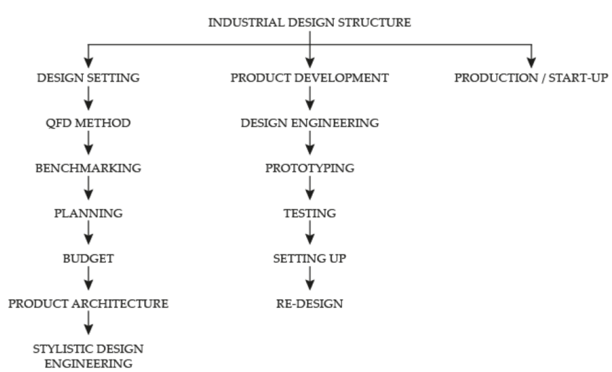


Fig. 11 – IdeS Structure (Frizziero et al. 2019)

3.1.1 Product Set Up

Introducing Product Set Up, it can be said that it is the phase of the industrial project in which the idea of a new product comes out. This new project is not only idealized, but it is also planned, it is also costified, 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. Description of the Case Study

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 a new and future family car, 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 family car 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 innovative family 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 Time Planning of the Case Study: the GANTT diagram

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 12). 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 13)

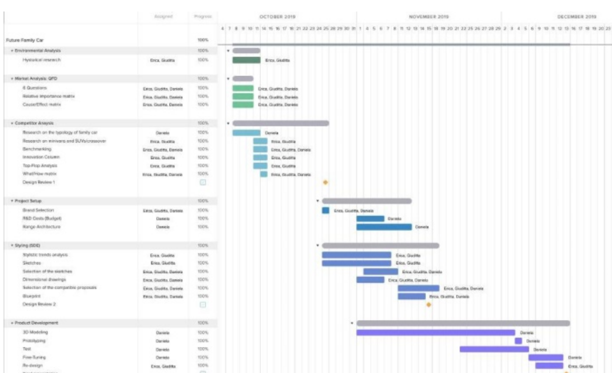


Figure 12 - Gant Diagram of the Case Study

Issues	Solution proposals	Owner	Deadline	State	Notes
Thesis	Writing, Translation of documents and tables	Giuditta, Erica, Daniela	11/01/19	Closed	
Final Presentation	Material updating and addition of the latest documents	Giuditta	12/12/19	Closed	
Style maquette	Paint the prototype	Giuditta, Erica	12/12/19	Closed	
Renderings	Do renderings with V-Red	Erica, Giuditta, Daniela	28/11/19	Closed	
Protoyping (3D printing)	Finish the 3D model, make an appointment at Bacci's laboratory	Daniela	9/12/19	Closed	
3D Modeling	3D Modeling with Alias	Daniela	03/12/19	Closed	
Budget	Research salary for designers and cost of prototype equipment	Daniela	8/11/19	Closed	
Range architecture	Research on the architecture of mechanical components, make a study on new seating arrangements	Daniela	8/11/19	Closed	
Stylistic trend analysis	Analysis of the aesthetics of family cars on the market	Erica, Giuditta	08/11/19	Closed	
Sketches	Based on the stylistic analyzes made	Erica, Giuditta	08/11/19	Closed	
Matrix for choosing the brand	Choose from brands that do not have a family car yet	Erica, Giuditta, Daniela	25/10/19	Closed	
Choice of the car name	Evolution of the brand name taken into consideration	Erica, Giuditta, Daniela	08/11/19	Chiuso	
Dimesional drawings	Dimesional drawings starting from the sketches	Giuditta, Daniela	08/11/19	Chiuso	

Figure 13 - 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

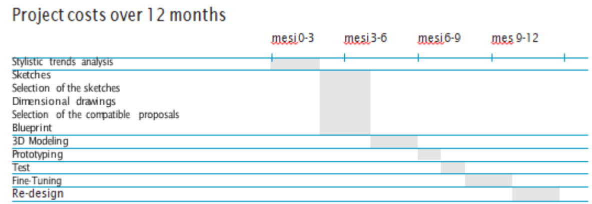
4.2 Costing applied to the Case Study through R&D Budget

The budget was calculated over a year by adding the personnel costs, for which was considered the work of three designers, two engineers and six workers, to the cost of the prototype equipment and that of the materials and tools necessary for the realization of style maquette.

The hourly wages of employees are 40 €/h for designers and engineers and 25 €/h for workers. The cost of prototype equipment includes the cost of using stereolithography, FDM, milling machine, press brake, 3D Waterjet laser for water cutting and the DEA three-dimensional system and portable measuring arm.
Wood and polyurethane (€ 29/kg), clay (€ 45.50/1.36 kg), window glass (€ 9100), rims and tires (€ 1954 per piece), mirrors (around € 100) and painting (around € 650) are instead included in the cost of the prototype materials (Fig. 14).

Personnel costs

	3 Designers	2 Engineers	6 Workers
Stylistic trends analysis	38.400	5000	
Sketches Selection of the sketches Dimensional drawings Selection of the compatible proposals Blueprint	38.400	5000	
3D Modeling	25.600	5000	
Prototyping		6400	24.000
Test		6400	24.000
Fine-Tuning		6400	24.000
Re-design	25.600	6400	24.000
Total cost	128.000	40.600	96.000



Cost of the prototype equipment

	Hours	€/h	Tot. equipment
Prototyping	480	65	31.200
Test	480	65	31.200
Fine-Tuning	960	65	62.400

Cost of materials

Style maquette	21.680

Total cost of the project

SDE	117.400
Prototyping	83.280
Test	61.600
Fine-tuning	148.800

Figure 14 – R&D Budget

4.3 Market Analysis applied to the Case Study through QFD

4.3.1 Environmental Analysis

We then move on to an analysis of the environment so that we can fully understand the theme of the future family car. It is immediately evident that the design of a family car requires, certainly, knowledges of cars, but also of taking into account the specific needs and characteristics of modern families.

4.3.1.1 Family

The target audience are families with one or more children. Families can be very diversified in terms of numbers, habits, preferences, etc. and will therefore have very different needs. As a starting point it can be observed that the family car must satisfy the needs of use of two categories of people: adults and children.
The decision to purchase a vehicle rather than another depends on the former. These are parents, often workers with the most disparate uses, who are looking for good performance and reliability but also driving pleasure. From the use by children and youngsters instead derive a whole series of needs related to safety, spaciousness and a series of regulations regarding the use of child seats, strollers, behaviors to keep etc. There are families who love fun, others contact with nature, others are more sedentary, so the versatility of the car becomes fundamental. The most current issue of interest to many is the eco-sustainability of the vehicle, perhaps electric. In addition there are large families that also require 7/8 places, therefore more space inside the vehicle.

4.3.1.2 Car

The car is a vehicle that usually moves on four wheels, driven by its own normally internal combustion engine, and designed primarily for the transport by road of a limited number of people. The space provided with seats that houses the driver and passengers is called the passenger compartment; any luggage is placed in a small boot. The number of seats can vary from a minimum of two to a maximum of nine, including the driver's seat. In some cases the seats are permanently anchored to the bodywork, in other cases they are removable. The movement of the seats makes it possible to more effectively harmonize the transport of people with the occasional need to transport goods.
The morphology of family cars is quite variable. The reference segment is the C/E of the Standards ISO 3833: 1977. In this discussion we will focus on the design of a car with more than 5 seats.

4.3.2 QFD (Quality Function Deployment)

4.3.2.1 Six Questions

In the market analysis phase, we clarified the project task by answering the 6 questions of the QFD: the present project car will be designed for families, it must be used in everyday life and when traveling, in the city and in suburban areas, with the necessary safety, comfort, practicality and space and without neglecting attention to consumption. The competition analysis starts from the six fundamental questions in reference to the new product. The basic requirements will be derived from the answers and will be included in the interrelation matrices in the next phase.

WHO? For families - WHERE? In cities, urban and suburban areas - WHEN? In everyday life, when traveling - WHY? Having the space and security needed to move the whole family - WHAT? Daily and occasional movement and transport - HOW? In safety, comfort and practicality.

4.3.2.2 Relative importance matrix

In this first matrix the requirements derived from the answers to the six questions are reported in line and in column. It then goes on to give a grade of 0, 1, 2 depending on whether: 0 the line is more important than the column; 1 the requirements are equivalent in terms of importance; 2 the line is less important than the column.
Adding the votes in the final line will obtain a chart that classifies from maximum to minimum, the most important requirements of the new project, related to the highest values (Table 1).

Table 1. Relative Importance Matrix

	Capacity	Economy	Dimensions	Practicality	Comfort	Safety	Aesthetic Form	Speed Power	Maintenance	Consumption	Optional	Capacity of Accessory	Sportiness	Durability
Capacity	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Economy	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dimensions	2	2	1	1	0	2	0	0	1	2	0	1	0	1
Practicality	1	1	1	1	0	1	0	0	1	2	0	1	0	1
Comfort	0	2	2	2	1	2	0	0	1	2	0	1	0	1
Safety	0	1	0	1	0	1	0	0	0	0	0	0	0	0
Aesthetic Form	2	2	2	2	2	2	1	1	2	2	1	2	0	2
Speed Power	2	2	2	2	2	2	1	1	2	2	1	2	2	2
Maintenance	1	1	1	1	1	2	0	0	1	2	0	1	0	1
Consumption	1	1	0	0	0	2	0	0	0	1	0	0	0	1
Optional	2	2	2	2	2	2	1	1	2	2	1	1	0	1
Capacity of Accessory Spaces	1	1	1	1	1	2	0	0	1	2	1	1	0	1
Sportiness	2	2	2	2	2	2	2	0	2	2	2	2	1	2
Durability	1	1	1	1	1	2	0	0	1	1	1	1	0	1
Total	17	**20**	17	**18**	14	**24**	7	5	16	**22**	9	15	5	16
%	8,29%	**9,75%**	8,29%	**8,78%**	6,83%	**11,71%**	3,41%	2,44%	7,80%	**10,73%**	4,39%	7,32%	2,44%	7,80%

So, the requirements resulting the most important are the following ones: SAFETY, CONSUMPTION, ECONOMY, PRACTICALITY.

4.3.2.3 Matrix of independence and dependence

In the second matrix the dependence and independence of the requirements is assessed by assigning a score of 0, 1, 3, 9: 0 if the line is totally independent of the column; 1 if the line is almost independent of the column; 3 if the line is very column dependent; 9 if the row is totally dependent on the column.

In the final row it is found a chart about the most independent requirements, ordered always from the maximum to the minimum; it is a good practice to choose the first four ones, having the highest score. (Table 2)

Table 2. Matrix of independence and dependence

	Capacity	Economy	Dimensions	Practicality	Comfort	Safety	Aesthetic Form	Speed Power	Maintenance	Consumption	Optional	Capacity of Accessory	Sportiness	Durability
Capacity		9	1	0	3	0	0	0	0	0	0	1	1	0
Economy	3		3	1	3	9	9	3	3	9	9	3	3	9
Dimensions	9	1		9	0	1	9	3	0	0	1	9	3	0
Practicality	3	0	9		9	0	0	1	0	3	9	3	3	1
Comfort	1	3	9	3		0	1	0	0	0	9	3	1	0
Safety	0	3	1	1	0		0	0	9	0	9	0	0	0
Aesthetic Form	3	3	3	9	1	0		3	0	0	1	9	9	0
Speed Power	3	3	3	1	0	0	3		3	0	0	1	9	0
Maintenance	1	1	0	0	1	3	0	1		1	1	0	1	0
Consumption	3	3	3	0	0	0	1	9	9		0	0	3	0
Optional	1	1	0	0	0	0	0	0	0	0		0	0	0
Capacity of Accessory Spaces	3	1	3	0	1	0	3	0	0	0	1		0	0
Sportiness	1	1	1	1	0	0	1	3	0	0	1	1		0
Durability	1	3	0	0	0	0	0	0	9	0	0	0	0	
Total	29	23	**35**	25	15	13	27	23	**33**	13	**41**	29	**32**	10

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

4.4 Competitors Analysis applied to the Case Study through Benchmarking and What-How Matrix

4.4.1 Benchmarking (BM)

The fourth step aims to analyze the competition using the Top-Flop analysis tool. At the top there are ten models of the most significant competitive cars; in the column instead the most relevant technical features. Through research tools we complete the matrix and then highlight the most advantageous (top) and most disadvantageous (flop) solutions in terms of our product (Frizziero et al., 2019; Donnici et al. 2019; Liverani et al. 2018). In the final column you will have the innovation column with all the best requirements. To understand how many of these introduce in our project we calculate the delta between the tops and the flops of each product. Then add one (or more) features to this number (Figure 15). So, a series of seven-seats family cars on the market were analyzed through a list of parameters. This analysis led us to the definition of the product innovation column, while thanks to the top-flop analysis, has been determined a delta of requirements greater than or equal to three.

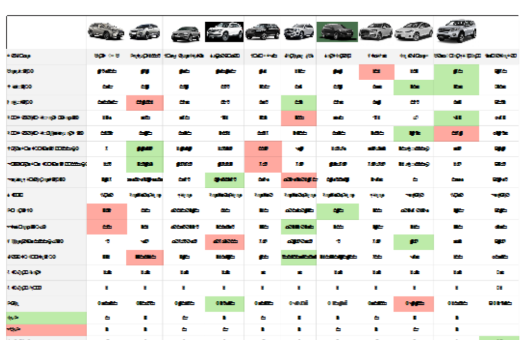


Fig. 15 – Benchmarking applied to case study (BM)

4.4.2 WHAT-HOW Matrix

The what-how matrix relates the requirements and the innovative features found by the previous matrices. It is valued with values 0,2,4,6,8,10 what are the most influential characteristics from a customer perspective. Designers can have indication about what technical characteristics to be chosen in order to satisfy customers (Table 3).

Table 3 – What-How Matrix

	Length	Width	Height	Trunk capacity with seats up	Trunk capacity with seats down	Urban Consumptions	Extra-urban Consumptions	Autonomy	Power	Speed	Acceleration	Torque Max	Seats Number	Doors Number	Price
Safety	0	0	0	4	4	4	4	6	4	0	4	4	6	6	8
Consumptions	6	6	6	4	4	10	10	10	4	10	4	4	6	6	4
Economy	0	0	0	6	6	10	10	10	2	10	2	2	6	4	4
Practicality	10	10	10	10	10	10	10	10	10	10	10	10	10	10	8
Optional	4	4	4	10	10	6	6	6	6	6	6	6	10	10	10
Dimensions	10	10	10	10	10	6	6	6	2	6	2	2	10	10	10
Maintenance	4	4	4	2	2	4	4	4	4	4	2	2	4	4	4
Sportiness	10	10	10	4	4	10	10	10	10	10	10	10	4	2	4
Total	44	44	42	50	50	**60**	**60**	**62**	42	**56**	40	40	**56**	52	52

So, the following technical characteristics resulted the ones asked by customers: POWER SOURCE, CONSUMPTIONS, NUMBER OF SEATS, SPEED

4.4.3 Choice of Brand

To decide which brand was the most suitable for a family car with our characteristics there were compared the main brands through a specific QFD (Figure 16). The car brand was selected by evaluating a series of brands through analysis matrices. Finally, Polestar was selected because, being a brand of recent birth, it is more open to innovations in style as well in technology, driving safety and consumption.

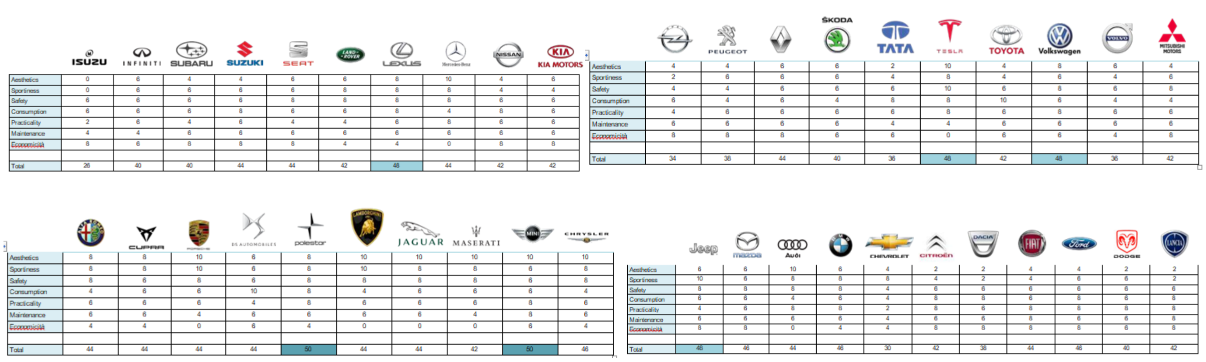


Figure 16 – Brand Choice

The project objectives deriving from market and competition analysis are safety, attention to consumption, sportiness and a new arrangement of seats that allows an optimization of spaces, dimensions and therefore the practicality of the car.

4.5 Product Architecture applied to the Case Study through Schematic Drawing

In order to understand the best functioning and the main components of a vehicle, a product architectural analysis has been carried out. Then it was identified the most suitable features for our family car (Figure 17). Following the philosophy of the Polestar brand, it has been decided to equip Polestar 4 with an electrical supply, in order to look forward to a sustainable future for the automotive industry. Polestar 4 would be provided with two electric motors, one collocated in the anterior axle and the other in the posterior axle. Both motors have a power of 400kW, a maximum torque of 700 Nm, and guarantee 600 km of autonomy (WLTP). The batteries have a power of 80kWh put in 27 moduli. Polestar 4 reaches 100 km/h in 4,7 seconds. Polestar 4 gives a new image to the family car with five doors and seven seats by a re-arrange the seats. The seats are put in two lines: three in the anterior line and four in the posterior line ensuring a wide space to the trunk. The three anterior seats have a width of 520 mm, the two posterior seats in the middle have a width of 360 mm and the two posterior seats on the side measures 480 mm (Figures 18, 19, 20).

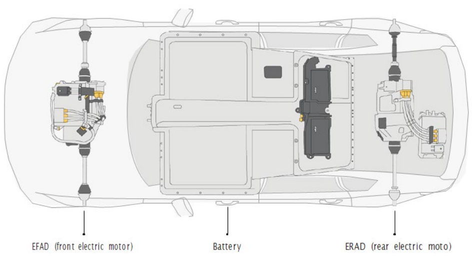
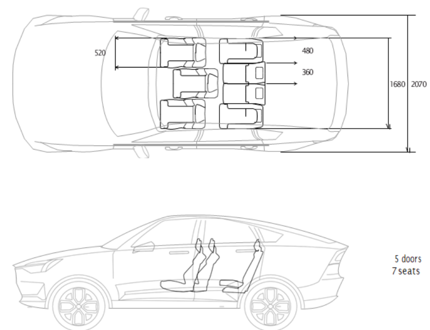


Figure 17 – Car Architecture



Figs. 18 – Innovative lay out of the 7 seats

Figures 19 – Innovative lay out of the 7 seats

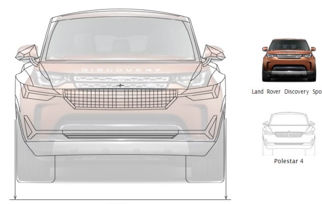


Figure 20 - Polestar 4 vs Land Rover Discovery

The width of the car measures 2070 mm and it has been compared to the Land Rover Discovery Sport which also measures 2070 mm (Figure 20).

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 23, 24, 25, 26), the elaboration of 2D drawing (Figures 27, 28, 29, 30), the modeling of 3D CAD concept (Figures 31, 32, 33, 34), the rendering of the new product (Figures 35, 36, 37, 38), the prototyping of the 3D model (Figures 39, 40).
The main current stylistic trends are: ADVANCED, NATURAL, RETRO‘ and STONE. Here below the proposals of the ***present*** project will be shown n 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 a car that looks forward and gives the idea of power, speed and future (Figure 21).

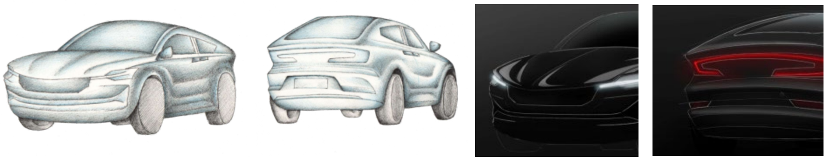


Figure 21 – Sketches of Advanced proposal

b) Natural
The natural sketch concept represents a car with sinuous, delicate and feminine features which matches perfectly with the powerful aim of the car (Figure 22).

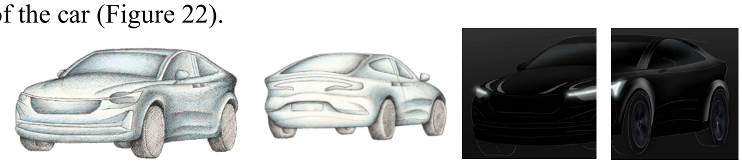


Figure 22 – Sketches of Natural proposal

c) Stone
The stone sketch concept proposes a strong and powerful idea of a new safe and solid family car (Figure 23).

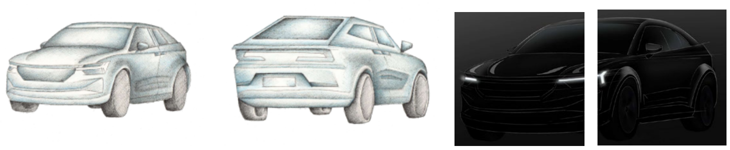


Figure 23 – Sketches of Stone proposal

d) Retrò
The retrò sketch concept looks to the previous car models of the Volvo brand, of which Polestar is a branch, and reclames sharp-cornered features and simple volumes (Figure 24).

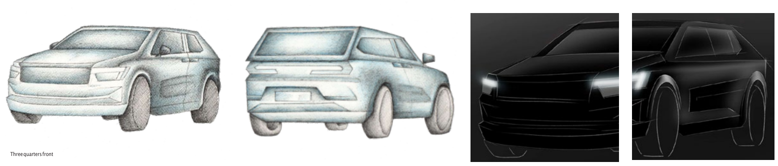


Figure 24 – Sketches of Retrò proposal

4.6.1.2 CAD 2D
Advanced, Natural, Stone, Retrò

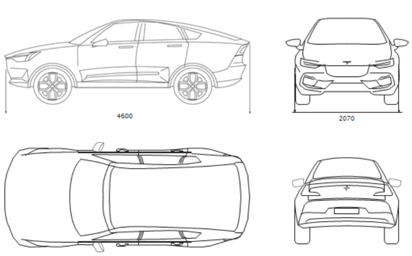


Figure 25 – 2D drawings of Advanced proposal

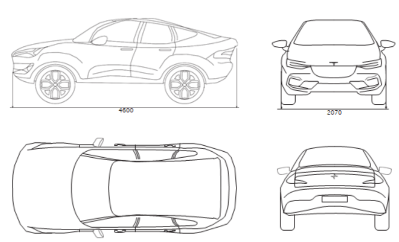


Figure 26 – 2D drawings of Natural proposal

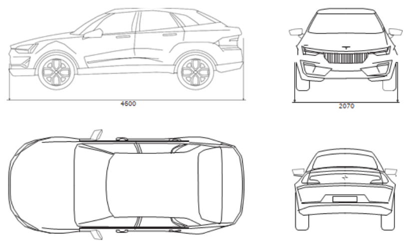


Figure 27 – 2D drawings of Stone proposal

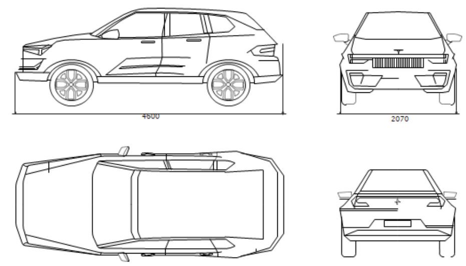


Figure 28 – 2D drawings of Retrò proposal

The drawings above show the 2D orthogonal projections about the four stylistic proposals: Advanced (Figure 25), Natural (Figure 26), Stone (Figure 27), Retrò (Figure 28).

4.6.1.3 Summary of the characteristics chosen

After an analysis of the emerged models it is decided to merge some features to arrive at the final proposal.
The final proposal is a match of the advanced and the stone sketch concepts: the front is taken from the stone one to give more character to the car and the rest of the features are the ones of the advanced sketch concept. (Figure 29).

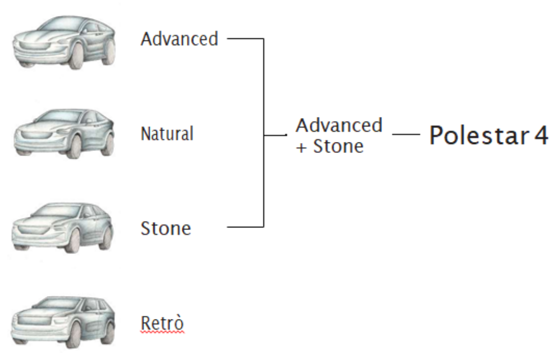


Figure 29 – characteristics chosen road map

4.6.1.4 Final Proposal

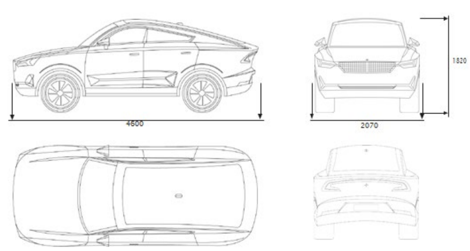


Figure 30 – 2D drawings of the final proposal

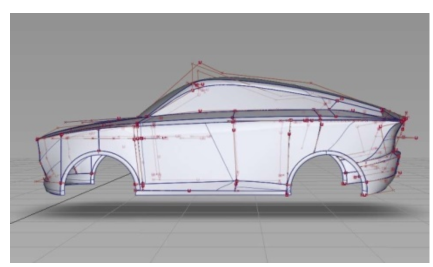


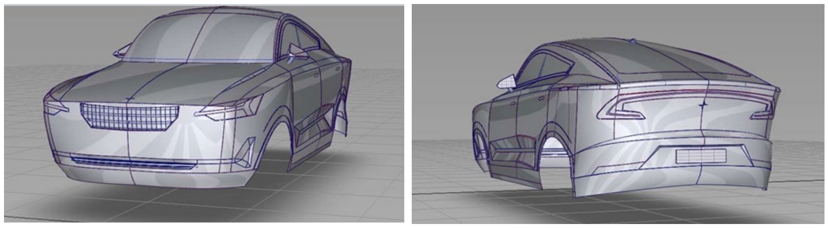
Figure 31 – 3D Drawing of final proposal

Here above the final solution reported in 2D drawings and 3D model (Figures 31 and 31).

4.6.1.4 CAD 3D and Digital Prototype

The digital model of the car 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 family car, it was started with the construction of a “skeleton” of the main lines, derived from the 2D CAD. From here the body was built. Then it was moved on to modeling details: headlights, handles, glass, doors, mirrors, etc. These have been customized to best suit our vehicle (Figures 32).



Figures 32 – 3D Modeling

Using the rendering tools it was created the digital prototype. Prototyping has the function of giving a realistic view of the family car and of the various colors and textures. Below there are some views (Figure 33).

Figure 33 – 3D Models rendered

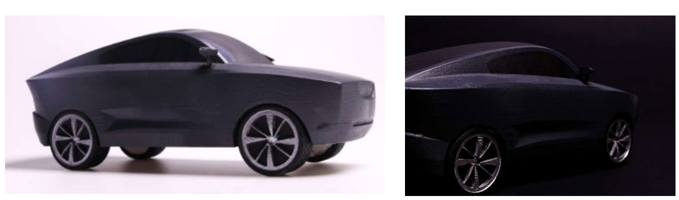
4.6.1.5 Rendering

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) (Figure 34).
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.

Figure 34 – 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 35).



Figures 35 – 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 in 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 car 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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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.

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Erica Bugli Giuditta Contini and Daniela Harsan 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**.**