Stylistic Design Engineering (SDE) to Conceptualize a Futuristic Sports Car

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Abstract

The present work is a case study about the application of the methodology named Stylistic Design Engineering (SDE), that is an approach to develop car design projects in the industrial world. For attending this goal, it was chosen the S-segment car products, category that identifies the sport car as today's Lotus. The inspiration for the project started from the top model in the past years of the car manufacturer Audi, or the Audi Quattro (1980-1991). This model represented all the time the most advanced technology in the automotive world of the house, and the most important thing was the all-wheel drive, therefore with four-wheel drive. In the following pages will be illustrated the summary of the path that led to the final product following the "instructions" of SDE method.

Keywords (12 font)
Sportcar, SDE, QFD, 3D Printing.

1. Introduction
1.1 Stylistic Design Engineering
As already said before, Stylistic Design Engineering is one of the set up phase of the industrial project, and it is fundamental for the good success of a new product.
Normally, new industrial project structure is composed by three macro phases:
- Project Set up
- Project Development
- Start Up Production

Therefore, SDE is one of the steps that compose the first one, i.e. Project Set Up, being able to be performed also alone, without, initially, interfere with the other steps (that are Market and Competitors Analysis, Product Architecture, Budget and Scheduling) (Figure1).
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Figure 1. New Industrial Car Project Structure

Analyzing the structure of Stylistic Design Engineering (SDE) (Figure 2), the method is composed by the following phases:

1. Stylistic Trends Analysis
2. Sketches
3. 2D Drawings (Orthogonal Tables)
4. 3D CAD Models
5. Rendering
6. Solid Stylistic Model (Maquette)

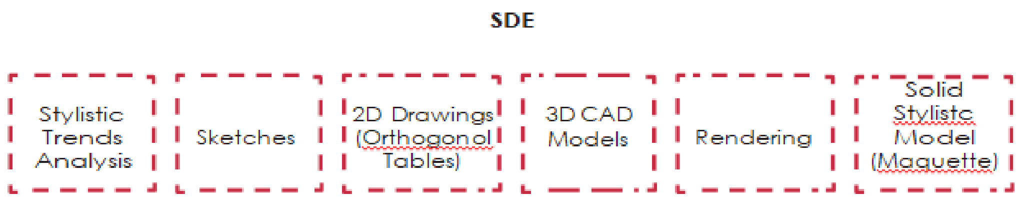


Figure 2. SDE – Stylistic Design Engineering Phases

1. **Stylistic Trends Analysis** is the phase in which Designer analyzes what kind of stylistic trends customers prefer to choose in the period. Nowadays, the main stylistic trends could be synthetized in: Advanced Design, Natural Design, Stone Design, Retrò Design. The above mentioned Trends could mix up each one with the others.
2. **Sketches**: Sketches are drawings free from dimensional and technical links. They are quite an artistic representation about the Design wants to imagine the new car. Materials employed for them are usually pencils.
3. **2D Drawings** (Orthogonal Tables): their characteristics are: Technical Transformations of the Sketches, Dimensional Representations, Verification of the Proportions. Designers named 2D drawings also «Blueprint» or «Canvas». Materials employed for them are substantially software for CAD 2D, as, for example, Autodesk Autocad.
4. **3D CAD Models**: starting from «Blueprint» (i.e. 2D Technical Drawings»), the 3D Models can be developed. Materials employed for them are substantially software for CAD 3D, as for examples, PTC Creo, Dassault Cathia, Siemens NX (or Solid Edge), Alias Autodesk, etc.
5. **Rendering**: it is a digital representation simulating the immersion of the new 3D model in a real environment. Materials employed for them are substantially software, as for example, V-red, 3D_ Studio Max, Cinema 4D, etc.
6. **Solid Stylistic Model (Maquette)**: it is normally the final result of an SDE Project and it is the «product» given to the engineers for starting the technical process of engineering and industrialization. Usually it is made by one or more of the following materials: Ureol, Polyurethan, Clay (synthetic argil).

It should be realized in scale 1:1, painted and updated with those items that helps the model to be more similar to the real one (for example, for a car, wheels, mirrors, colors of body)

1.2 Environmental Analysis

The definition of "sports car" refers to a type of car designed to achieve high speed and high performance. Among the relevant features we find particularly brilliant performance and driving behavior. Traditionally, sports cars were with manual transmission and rear-wheel drive. Already in the second half of the twentieth century, however, front-wheel drive sports cars with automatic or semi-automatic transmission appeared. The main factors to consider when designing a sports car are the powertrain and the position of the engine, they significantly influence the maneuverability of the car The front-engine and rear-wheel drive configuration is common in sports cars of all times , and has survived longer in this category of cars than common cars. More specifically, the engine in sports cars is generally positioned more backward than the traditional front-engine ones. This configuration is also called front-central and is adopted precisely to move the center of mass towards the central part of the vehicle. To increase maneuverability and improve weight distribution, other configurations are possible. The rear-central motor structure, that is, with the engine positioned centrally, behind the seats but in front of the rear axle, is generally a prerogative of the most "extreme" sports cars. Manufacturers that use this type of configuration are, for example, Ferrari and Lamborghini. Porsche is one of the few remaining car manufacturers that make their own cars with rear engine configuration and rear wheel drive. This leads to a weight distribution concentrated in the rear axle, where the rear wheels, unloading the mass on the ground, have considerable traction. However, some sports car models have the engine and front-wheel drive configuration. An example of a model with these characteristics is the Fiat Barchetta.
This configuration is advantageous for small, light and not very powerful sports cars, since it avoids the dissipation of energy in the transmission shaft typical of rear-wheel drive models. However, these vehicles have drawbacks,

such as understeer. This configuration is however common for compact sport cars, although for many drivers the best solution is still rear-wheel drive, especially for particularly powerful car models. For some time now there have been conflicting opinions between the experts and the enthusiasts. On the one hand we find a market that increasingly turns towards total anesthesia of driving pleasure, integrating front-wheel drive, understeer and autonomous guide. On the other we find the enthusiasts, who always put the thrill and involvement of the sports guide first. In order to get more information we decided to analyze the pros and cons of a sports car.

Pros

- One component that many enthusiasts don't often think about when buying a sports car is the story behind it. Sports car brands that sell all over the world usually have a track record of race wins, good looking classics and absolute performance.
- Performance, experience. No everyday driver could ever understand the feeling of the g forces pushing you into your place by a well- produced sports car. This experience can best be
- achieved on a track where the laws of the road do not apply and the car can really test its metal.
- Compared to a common sedan or SUV, sports cars retain their value, even if they are driven daily. That is to say, their value is obviously limited with the number of miles placed on the odometer, but has the potential to go up at any time.
- Status symbol. The purchase of a sports car can go beyond mere exhibitionism. For true fanatics, it is the opportunity to become part of a small circle of passionate people, who look at other aspects of cars such as aesthetics, history, and many others.

Cons

- The best circumstances for a high-end sports car to thrive will certainly not be in a place like the center of any city.
- Although the price is an obvious counter for this type of car, in recent years the market has gone against less well-off users, with cheaper models such as Mustang, Corvette, and others.
- Driving a sports car daily can cost a lot, unlike a typical Civic or Nissan, high-end sports cars have parts that exceed the cost of the normal version for the exact same thing. This is due to the advanced nature of the vehicle interior and the expensive materials used to manufacture it.
- Dimensions. A two-seater fireball may seem like a fabulous choice for a weekend walk along the coast, but if you have five children and you have your car always filled to the brim with boxes, school backpacks and sports equipment, the logistics of a sports car should be considered a little more.

After analyzing the environment, we went on to extrapolate the factors that, according to the team, best embodied the concept of a sports car.
Rear-wheel Drive greater involvement and driving fun;
Relationship weight - power easier handling and performance;
Communicative send information and feelings while driving, internal and external problems;
Handling instant response to the steering wheel.

2. Materials

Many materials were used to develop the present work. These materials can be divided into two main categories: Software and Machines.
Referring to the software 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. The 3D Printer utilized is an FDM (Fused Deposition Modeling).

3. Description of the Case Study

As it is illustrated in the present paragraphs, 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 sport car starting from the use of some innovative design methodologies.
The main methodology during the work is SDE – Stylistic Design Engineering, applied to determine the aesthetical and volumes characteristics of the new innovative sport car.
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.

3.1 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 3). Subsequently, the main open and unresolved issues were identified and reported in the Oil (Open Issue List) Plan with the respective priorities and deadlines (Fig.. 4)

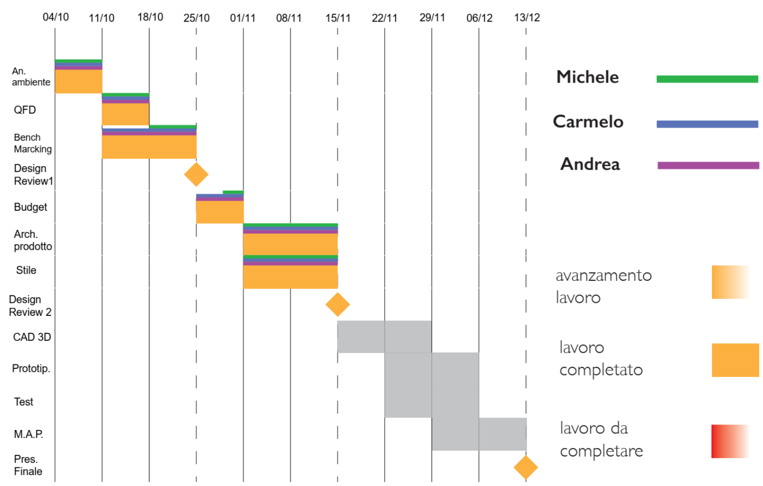


Figure 3 - Gant Diagram of the Case Study

The OIL table (Figure 4) 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

N°	Tipo di problema	Proposta risolutiva	Owner	Scadenza	Grado di priorità	Stato
I	Modello per stampa 3D	Perfezionare il modello 3D	A.Belsito C.Polito M.Sdruccioli	06/12/2019		Aperto
II	Conoscenza del software	Approfondire attraverso tutorial	A.Belsito C.Polito M.Sdruccioli	29/11/2019		Aperto
III	Dettagli modello	Studio dei programmi	A.Belsito C.Polito M.Sdruccioli	29/11/2019		Aperto
IV	Proposta progettuale	Studio dimensioni auto	A.Belsito C.Polito M.Sdruccioli	08/11/2019		Chiuso
V	Abilità sketching	Esercitarsi tramite libri e tutorial	A.Belsito C.Polito M.Sdruccioli	08/11/2019		Chiuso

Figure 4 - OIL Diagram of the Case Study

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

The calculation of the budget is used to understand how much will be spent, in terms of prototype, for the entire project. The *ad personam* price was also calculated for each job figure, thus giving an overall view of the cost of the project. Within the budget, the time it will take to develop the project must also be estimated, so as to be able to make a time / cost ratio, as well as experimentation, development and re-design. (Figure 5).

	Human Resurces	Introduction costs (€/h)	Time to spent to	Performance costs	Material costs	Prototype equipment costs
Design N° Sketch 4 CAD 2D 2 3D Model 1	2 Designers	80	234 h 390 h 936 h	124.800€	-	Photoshop 294 € Autocad 488 € Alias 2100 €
Prototyping	1 Designer 1 Workman sp.	75	240 h	18.000 €		
Experimentation	3 Workman7	51	30 h	9.750 €	Ureol 28-35€/kg	CNC 40-75€/h
Tuning	1 Engineer 1 Workman sp.	75	130 h	9.750 €	Clay 13-15€/kg	-
Re-design	2 Designers 1 Engineer	1201	20 h	14.400 €	2992€ Wheels 4000€ Mirrors 500-800€ Paint	-
Tot			2180 h (90 giorni)	176.700€	37.435 €	52.882 €

267.017€

Figure 5 – R&D Budget

3.3 Market Analysis applied to the Case Study through QFD

3.3.1 QFD (Quality Function Deployment)

Quality Function Deployment (QFD) is recognized as the most powerful decision support tool in contexts of product and service innovation. The QFD uses calculation matrices, interviews and brainstorming sessions to improve understanding of customer needs. Subsequently, it translates these needs into adequate internal company specifications at each stage of the product development cycle, starting with research through the design and engineering, production, distribution, installation and marketing, sales and technical assistance.

It develops a common language, graphical and mathematical, simplifying interactions within an organization. the QFD also tries to correlate non-homogeneous contexts, such as customer needs and product characteristics, defined in the design phase. To apply the method concretely, six essential questions are answered which will focus the product on the desired market segment.

3.3.1.1 Six Questions

In this research phase the following six questions were answered. From this procedure the concepts and terms to be included in the subsequent matrices will be extrapolated, the latter will be used to understand and find the ideal trajectory to follow in the development of the project.

WHO? A person who seeks and wants to rediscover an authentic, adrenaline driving experience.
WHERE? On extra-urban roads and on the track for maximum driving pleasure.
WHEN? Preferably it will be used in moments of pure free time, over the weekend
WHY? Authentic emotions linked to driving pleasure, with a return to a past perspective.
WHAT? The access key to be part of a real status symbol and a circle of enthusiasts.
HOW? A position comfortable that will maximize driving pleasure.

3.3.1.2 Matrix of relative importance

Following the QFD analysis, the relative importance matrix was compiled from which the four important characteristics on which to base the calculation of the Dependence / Independence matrices will be extrapolated.

The matrix will be compiled and composed of rows and columns on which will be found the characteristics which, in our case, denote the qualities that a sportcar should possess.

In the underlying matrix, the values will be assigned according to this logic:

0 = most important row in the column; 1 = row as important as the column; 2 = least important row in the column.

Through the arithmetic sum of the values in the columns, the highest numbers have been highlighted which will therefore represent the prevailing characteristics. (Figure 6)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1 maneuverability	1	1	2	2	0	1	0	1	0	1	2	1	1
2 involvement	1	1	2	0	0	1	1	2	0	1	2	1	2
3 performance	0	0	1	1	0	0	1	1	0	0	1	0	1
4 nimbleness	0	2	1	1	0	1	1	1	0	1	1	1	1
5 autonomy	2	2	2	2	1	2	2	2	0	2	2	1	2
6 comfort	1	1	2	1	0	1	1	1	0	2	2	2	2
7 smart	2	1	1	1	0	1	1	1	0	1	1	0	2
8 safety	1	0	1	1	0	2	1	1	0	1	2	0	2
9 capacity	2	2	2	2	2	0	2	2	1	2	2	1	2
10 custom	1	1	2	1	0	0	1	1	0	1	1	0	2
11 power/weight ratio	0	0	1	1	0	0	1	0	0	1	1	1	1
12 dimensions	0	1	2	1	1	0	0	2	1	2	1	1	1
13 weight distribution	1	0	1	1	0	0	2	0	0	0	1	1	1
	13	12	20	15	4	9	14	15	2	15	19	10	20

Figure 6 – Relative Importance Matrix

After making the various sums, the characteristics chosen are the following: PERFORMANCE, WEIGHT, DISTRIBTION, POWER/WEIGHT RATIO, SAFETY.

3.3.2.3 Matrix of dependence/independence

As specified above, we then moved on to the compilation of the Dependence / Independence matrix which has the same purpose as the matrix of relative importance, but a further skimming will be performed (Figure 7).

In fact, this time the criterion for scoring is the following:
0 = row totally independent of the column; 1 = row almost totally independent of the column; 3 = row very dependent on the column; 9 = row totally dependent on the column.

	1	2	3	4	5	6	7	8	9	10	11	12	13	
1 maneuverability		1	3	3	0	1	0	3	0	0	9	3	3	26
2 involvement	3		9	3	0	1	1	1	0	1	3	1	1	24
3 performance	1	9		3	9	1	0	0	1	0	9	3	9	45
4 nimbleness	3	0	9		3	0	0	0	0	1	9	9	3	37
5 autonomy	0	0	1	1		0	0	0	1	0	3	3	3	12
6 comfort	3	1	0	0	0		3	0	3	3	0	9	0	22
7 smart	1	3	0	0	0	9		9	0	0	0	0	0	22
8 safety	1	1	1	0	0	0	9		0	0	0	1	0	13
9 capacity	0	0	0	1	1	3	0	1		0	0	9	0	15
10 custom	3	3	1	0	0	3	0	1	0		0	0	0	11
11 power/weightratio	3	1	9	9	3	0	0	0	1	0		3	9	38
12 dimensions	1	0	3	9	3	3	0	1	9	0	9		1	39
13 weight distribution	9	1	9	3	1	0	0	0	0	0	9	1		33
	28	20	45	32	20	21	13	16	15	5	51	42	29	

Figure 7 - Matrix of independence and dependence

The characteristics analyzed this time, arranged both in column and in row, will see the sum of the values for the rows and for the columns with the resulting values, which will represent the 4 most independent values: POWER/WEIGHT RAT, PERFORMANCE, DIMENSIONS, NIMBLENESS.

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

3.4.1 Benchmarking (BM)

Benchmarking is a systemic and continuous process of measuring performance, products and services that is normally used in companies as a method for analyzing competition. This procedure allows you to: increase competitiveness, determine realistic goals, define a market strategy and predict failures.
In our specific case, we went to get all the features in the competitors' technical sheets in order to develop a "top-flop" analysis. In this phase, the best and worst characteristics are highlighted, in green and red respectively.
This method allows us, through the identification of the six chosen characteristics, to obtain the six minimum standards that can be respected during the design (Figure 8).

	BMW i8 coupè	Ferrari Portofino	Audi R8	Porsche 911	Lexus LC	Maserati Granturi-smo	Mercedes AMG GT coupè	Nissan GTR	Aston Martin Vantage	Innovative Sport car
Lenght (cm)	469	459	443	452	477	492	454	471	447	443
Width (cm)	194	194	194	185	192	192	194	190	194	185
Height (cm)	129	132	124	130	135	135	129	137	127	135
Boot capacity (liter)	154	292	338	264	172	260	350	315	350	350
Urban cons. (km/l)	13	6,6	5,8	8,9	13,5	10,2	7,4	5,8	6,9	13,5
Extraurban cons. (km/l)	16	12,5	8,9	13	16,7	10,2	10,7	10	11,8	16,7
Highway cons. (km/l)	13,3	9,2	7,9	11,1	13,3	9,8	8,7	9	9,5	13,3
Cylinders capacity (cm3)	1500	3855	5200	2981	3456	4691	3982	3800	3982	1500
Supply	hybrid	gasoline	gasoline	gasoline	hybrid	gasoline	gasoline	gasoline	gasoline	hybrid
Power (CV)	362	600	570	385	359	460	510	570	510	600
Speed max (km/h)	250	321	324	293	250	299	310	315	314	324
Acceleration 0-100km/h (sec)	4,4	3,5	3,4	4,6	5	4,8	3,8	2,8	3,6	2,5
Couple max (Nm)	570	760	560	450	348	520	650	637	685	760
Seats number	4	4	2	4	4	4	2	4	2	4
Price	148.970	196.061	182.300	110.139	107.500	129.081	144.600	108.600	160.482	107.500
Blind spot angle	28°	11,35°	22°	16,25°	19,15°	17,30°	23,25°	20,55°	27,45°	11,35°
Rear visibility angle	27,5°	55°	41,35°	32,60°	42,85°	39,45°	43,20°	39,45°	26,95°	55°
N.Top	4	5	2	2	7	2	1	2	1	
N.Flop	5	3	8	2	1	2	3	2	4	
Top-Flop	-1	2	-6	0	6	0	-2	0	-3	≥6

Figure 8 – Benchmarking applied to case study (BM)

3.4.2 WHAT-HOW Matrix

In this matrix, the technical characteristics present in the benchmarking are compared with the results obtained from the matrix of relative importance and from the Matrix of Dependence / Independence. Considering that with benchmarking we have obtained a delta that is greater than or equal to six. This means that we will have to select only six or more requirements from the first two matrices, to be inserted in the what / how matrix.
Also in this case we have a relationship between the assigned characteristics of a different type that this time we will indicate with values equal to zero to ten (Figure 9).

0 = The column does not affect the row; 2 = The column slightly affects the row slightly; 4 = The column has little influence on the row; 6 = The column greatly affects the row; 8 = The column affects the line a lot; 10 = The column totally affects the row.

	dimensions	boot capacity	urban cons.	extraurban cons.	highway cons.	cylinders capacity	supply	power	speed max	acceleration	couple max	price	doors number	blind spot angle	rear visibility angle
Performance	2	0	0	0	0	6	8	10	10	8	8	6	0	0	0
Weight distribution	8	4	0	0	0	10	6	0	0	0	0	2	2	0	0
Power/weight ratio	8	0	0	0	0	8	2	10	2	2	6	6	0	0	0
Safety	8	0	0	0	0	10	2	8	6	8	4	8	2	8	8
Dimensions	10	8	0	0	0	6	0	0	0	0	0	4	8	2	4
Nimbleness	10	6	0	0	0	6	4	0	0	0	0	6	4	0	0
	46	18	0	0	0	46	22	28	18	18	18	32	16	10	12

Figure 9 – What-How Matrix

Making the sum by column, the following requirements are selected: DIMENSIONS, CYLINDERS CAPACITY, PRICE, POWER, CAR POWER SUPPLY, MAX SPEED, BOOT CAPACITY.

3.4.3 Choice of Brand

In the analysis of the brand, the car manufacturers chosen for benchmarking and the requirements obtained from the what / how matrix are compared, so as to choose the brand that most identifies the chosen philosophy. In this case the numerical classification is as follows (Figure 10):
0 = The column does not satisfy the row; 2 = The column satisfies the row slightly; 4 = The column does not satisfy the row very much; 6 = The column satisfies the row very much; 8 = The column satisfies the row very much; 10 = The column totally satisfies the row.

	Ferrari	Aston Martin	Maserati	Lexus	Porsche	Audi	Lamborghini	Lotus	Mercedes-Benz	McLaren
Dimensions	8	10	8	8	10	8	10	10	6	8
Boot capacity	10	6	8	6	6	6	4	2	6	8
Supply	6	2	0	10	8	8	6	2	6	8
Speed max	8	10	6	6	10	10	10	6	8	10
Cylinders capacity	8	8	6	4	6	10	10	6	8	10
Power	10	10	8	6	8	10	10	6	8	10
Price	2	4	6	8	6	6	2	10	6	2
	52	50	42	48	54	58	52	42	48	56

Figure 10 – Brand Choice

After obtaining Audi, as a result of our calculations, we delved into the history of the brand by examining the model that marked an innovation in terms of sportiness within the car manufacturer.

3.5 Product Architecture applied to the Case Study

3.5.1 Powertrain system

3.5.1.1 What is a mild hybrid?

'Hybrid car' used to mean a car that was driven by two distinct power sources: most commonly a petrol engine and electric motor. They could work separately or in tandem to drive the wheels and thus make the car move.
More recently, a new type of hybrid car has started to appear, as part of efforts by carmakers to get traditional internal-combustion petrol and diesel engines to be as efficient as possible. This new type is known as a 'mild hybrid'. What sets one of these apart from a regular hybrid is the fact that the electric part of the drivetrain never powers the car on its own. Instead, it serves to help the diesel or petrol engine in moving the car.

Mild hybrids come in several different configurations, but most commonly they feature a larger battery pack that works with the conventional 12V battery found in every combustion-engined car. Often, this is a 48V system that features an integrated starter-generator, which acts as both a starter motor and a power bank to assist the engine.
Some 48V systems use a lithium-ion battery, while some make do with lead-acid batteries. Either way, instead of replacing the 12V unit, the 48V unit works with the regular battery. It’s connected to a hybrid motor and an electric supercharger, and takes over from the 12V unit duties such as powering the air-conditioning, catalytic converter and engine fan. The 48V unit also supplies power to the hybrid motor and supercharger, allowing the car to accelerate slightly more quickly and smoothly. In some models, such as the latest high-end Audis, the 48V system can turn off the car’s engine for up to 40 seconds when coasting. (Figure 11).

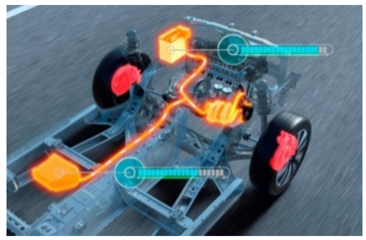


Figure 11 – Mild Hybrid Architecture

3.5.1.2 Benefits of a 48V mild-hybrid system

One of the key benefits mild-hybrid systems offer is improved fuel efficiency and reduced pollution. Engineering firm Delphi, which has developed a 48V mild-hybrid system, says that it can offer a 25% increase in low-end torque, a 10-15% boost in fuel efficiency and a 25% reduction in CO2 emissions when compared to a traditional 12V system. There are further benefits to a mild-hybrid system. Tyre and automotive technology company Continental has been working on ‘super-diesel technology’ that uses a 48V system to cut nitrogen oxide (NOx) emissions from diesel cars by 60%. Continental has developed an electrically heated catalytic converter that relies on the 48V battery to rapidly heat it to maximum operating temperature. Normally, a catalytic converter relies on the engine to bring it up to temperature and it only works properly once this has happened. Using an engine to heat it up takes time, but thanks to the 48V system, this can now be done faster, which reduces tailpipe emissions.

3.5.1.3 Does a mild hybrid feel different than a normal car?

Not drastically. Most systems improve the car’s start-stop feature, meaning you may coast to a stop with no engine power, rather than have the engine cut out at the last minute. The internal- combustion engine still does all driving, although in some cars the battery may provide additional assistance when accelerating. You might also feel a slight difference when braking, as some systems use regenerative braking to recharge the mild-hybrid batteries. This means when you lift off the throttle, for example, the car can slow down as if brake pressure has already been applied (Figure 12).

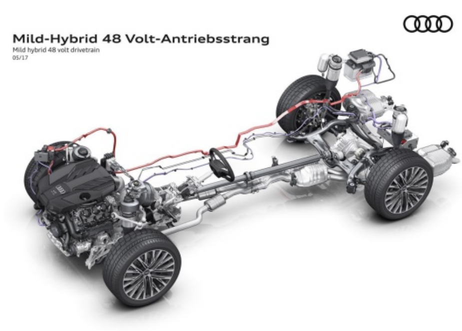


Figure 12 – Innovative mild hybrid system by AUDI

3.5.1.4 Supreme power package: the engine

The 4.0 TFSI in the new Audi RS-tron delivers 600HP and 800 Nm of torque, which is maintained at this high level between 2,050 and 4,500 rpm. In just 3.6 seconds the high-performance Avant sprints from zero to 100 km/h. And in a mere 12 seconds the Audi RS-tron reaches 200 km/h. Top speed is electronically governed at 250 km/h.

Thanks to the 48 volt main electrical system the twin-turbo V8 combines maximum performance with high efficiency. A belt alternator starter lies at the heart of the mild hybrid system (MHEV). Up to 12 kW of power can be recovered during light deceleration and stored in a separate lithium-ion battery.
The standard eight-speed tiptronic with optimized shift times and a new Launch Control function transmits the power of the 4.0 TFSI to the quattro permanent all-wheel drive.
The drive forces are distributed to the front and rear axle in a ratio of 40:60 via the all-mechanical centre differential. If one wheel slips, more drive torque automatically goes to the axle with the better traction. Up to 70 percent can flow to the front wheels and up to 85 percent to the rear wheels.
We decided to equip our car with all-wheel drive because we wanted to create a historical link with the old Audi Quattro from the early eighties, which also had all-wheel drive..

3.5.2 Digital matrix LED headlights

With the digital matrix LED headlights as top-of-the range equipment, Audi presents a worldwide first in a production vehicle: Broken down into minute pixels, their light can illuminate the road in high resolution. The design is based on a technology abbreviated as DMD (digital micro-mirror device) and is also used in many video projectors. At its heart is a small chip containing one million micro-mirrors, each of whose edge length measures just a few hundredths of a millimeter. With the help of electrostatic fields, each individual micro-mirror can be tilted up to 5,000 times per second. Depending on the setting, the LED light is either directed via the lenses onto the road or is absorbed in order to mask out areas of the light beam.
In the Audi RS-tron, the digital light performs multiple tasks. It can generate dynamic leaving- and coming-home animations that appear as projections on a wall or on the ground.
This presentation transforms the area in front of the car into a carefully illuminated stage. Not only does the digital light system deliver cornering, city, and highway lighting as versions of the low-beam light with exceptional precision, it also supplements the high-beam light by masking out other road users with even greater accuracy. Above all, however, it offers innovative functions such as lane light and orientation light.
On freeways, the lane light creates a carpet of light that illuminates the driver's own lane brightly and adjusts dynamically when he or she changes lane. In this way, it improves the driver's awareness of the relevant lane and contributes to improved road safety.
In addition, the orientation light uses darkened areas masked out from the light beam to predictively show the vehicle's position in the lane, thereby supporting—especially on narrow roads or in highway construction zones—the safe lane centering assist.
The marking light function is also used in conjunction with the optional night vision assist. The light automatically draws attention to any pedestrians it detects, thereby reducing the danger of overlooking pedestrians in the immediate vicinity of the lane (Figures 13 and14).

Figures 13– Digital matrix LED headlights

Figures 14 – Digital matrix LED illumination

3.6 SDE (Stylistic Design Engineering) applied to the Case Study

3.6.1 Stylistic Design Engineering Method

In this phase we go on using the tools 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)
- the elaboration of 2D drawing (Figure 20)

- the modeling of 3D CAD concept (Figure 31)
- the rendering of the new product (Figures 32, 33, 34, 35)
- the prototyping of the 3D model (Figures 36, 37)

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. It was tried to create 4 different proposals for the four different stylistic trends: Retrò, Stone, Advance and Natural, focusing on the historical Audi models of the past. The basic idea was to take the Audi Quattro produced between 1980-1991 to present it in a modern version following the four stylistic trends. The result was to explicitly take the front headlights with the iconic mask of the model and modernize it with new shapes and new trends

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.

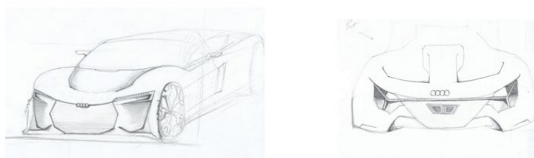


Figure 15 – Sketches of Advanced proposal

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.

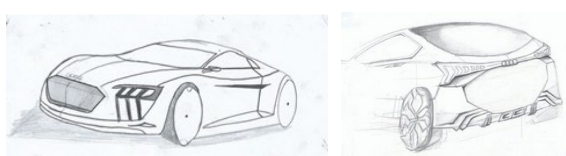


Figure 16 – Sketches of Natural proposal

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

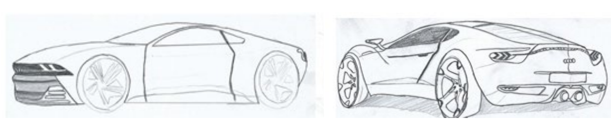


Figure 17 – Sketches of Stone proposal

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 18 – Sketches of Retrò proposal

4.6.1.2 Final Proposal and CAD 2D drawings

In this second phase all the best characteristics of the four proposals were merged. Then it was sketched the final model. They were made some aesthetic changes where necessary. The choice of the style model fell on the retro proposal updated with the Advance style components in particular the rear lights and the rear bumper. Then, the 2D Cad drawings were performed, respecting the dimensions of the car segment and the proportions proposed by the sketches (Figures 19 and 20).

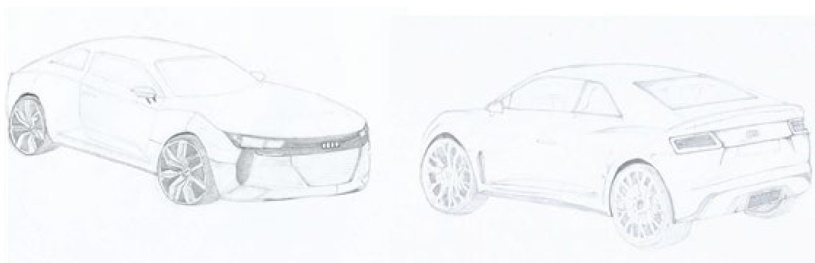


Figure 19 – Sketches of the Final Proposal

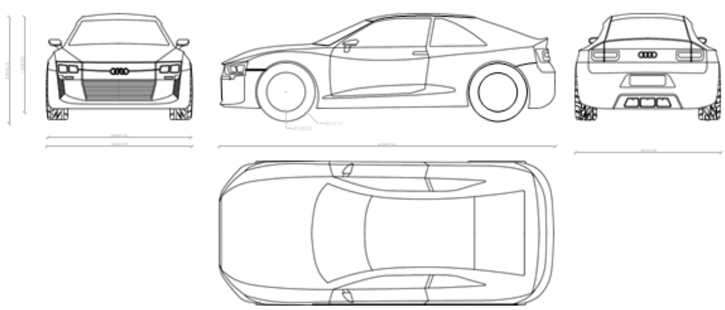


Figure 20 – 2D drawings of Stone proposal

4.6.1.3 CAD 3D and Digital Prototype

Proceeding with putting the model on the table, starting from the sketch, they were created the four views necessary to continue with the design: Front, back, side and the view from above. Therefore realized the 4 different views queed, it was possible to switch to 3D modeling with the software of Autodesk, or Alias. Then were imported all the views into the work plan, starting to work to create surfaces to be modeled based on the proportions decided. It was started from the rear bumper, continuing with the roof, the front bumper and finally the side panels, which was initially idealized as the only body in which the hatch was integrated, but then subsequently it was changed idea by inserting some miniskirts and an internal rounded to make more sinuous the car. (Figure 21).

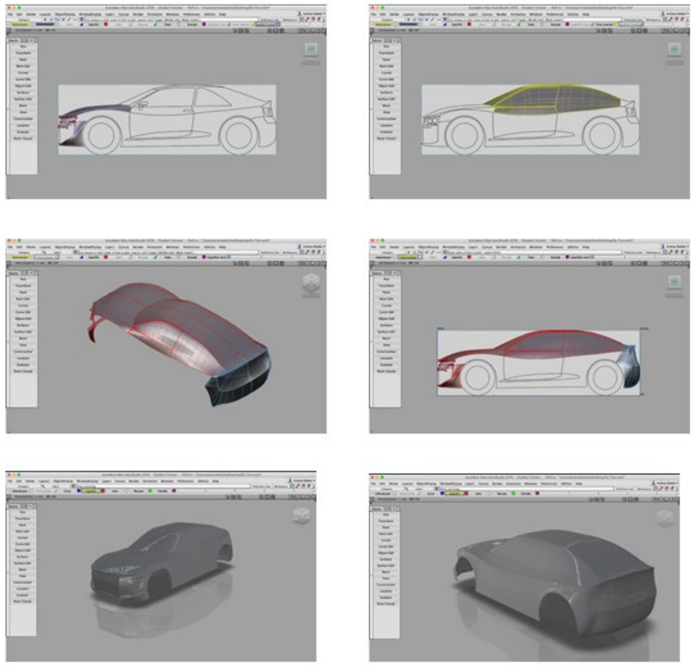


Figure 21 – Evolution of 3D Modeling

Using the rendering tools it was created the digital prototype. Prototyping has the function of giving a realistic view of the sport car and of the various colors and textures. Below there are some views (Figures 22).

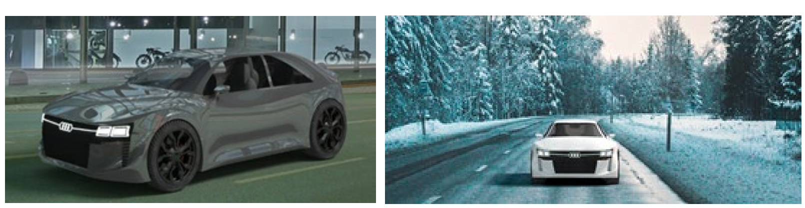
Figures 22 – 3D Models rendered

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 23).

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 24).



Figures 23– Rendering of the 3D Model

Figures 24 – Other Rendering: particulars and customization

4.6.1.6 Physical Prototype and 3d Printing

Once the model on the “Alias” software was completed, it was decided to print the 3D model in 1:18 scale with the division between the main body and the wheels. This subdivision of printing in two moments was designed because it seemed more appropriate, in qualitative terms, to print the 4 wheels separately from the qualitatively speaking body, the result obtained is better even though they have to be supplemented manually, once printed, on the model. The 1:18 scale prototype was made with the 3D printer. Its main function is to verify the volume and visual of the car (Figure 25).

Figure 25 – 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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