Study of Advanced Car Design for Vehicles of 2030 using Virtual Reality Technologies

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Abstract

The aim of this project is to give a practical demonstration of the most recent and revolutionary methods used at a professional level for the structure and design phases of developing a new car. Therefore, we need to clarify the steps that go from the birth of a new idea to its transformation into a virtual product. The result of the project is the design of a cutting-edge car that encompasses the technical, stylistic, and social needs of a potential user in the near future. A further purpose of the path was to demonstrate the main innovative technologies available, to date, in support of the design, which allows us to define the product at an extremely reduced time and cost. Subsequently, allowing feedback from the market in the first few stages of development and implementing a maximally customer-oriented design. In this project, for the first time, virtual reality has been combined with the classic 3D modeling methodologies. This allowed to have immediate feedback on the product without having to wait for the completion of the 3D screen modeling on a 2D screen. It is therefore a new criterion that allows for fast and reliable response, thanks to the clearer display given by virtual reality. We are therefore talking about a new design that, iteratively, allows you to test the product, modify it and improve it quickly and without wasting materials.

Keywords
Car Design, Virtual Reality, Quality Function Deployment, Stylistic Design Engineering, and Industrial Design Structure (IDeS).

1. Introduction
This project was born to solve certain problems related to the creation phase of new products and in particular to three-dimensional modeling. From the experience gained over time we have been able to ascertain that the three-dimensional representation of surfaces was a source of great loss of time and required very specific skills. This research started from this awareness, with the aim of identifying possible alternatives to traditional modeling and of giving a practical demonstration by applying them to the development of a new automobile. This research is important because it demonstrates the validity of a new technology, virtual reality, applied to three-dimensional modeling. In addition, the research provides information on what cars in 2030 will look like, what features they will have and what needs they will meet. This project can therefore be used as a guide for anyone wishing to study the development of a new product with a cutting-edge, innovative, and effective technology. The outcome of this process was a well-defined virtual product resulting from the use of a structured methodology for the development of new products (IDeS methodology) and the supporting design software (Creo Parametric, Autocad 2D, Alias Studio, Gravity Sketch, Rhino3D, Keyshot, Photoshop). By going through the various phases of the IDeS (Industrial Design Structure) method in succession, the various options currently available on the market were identified and compared in order to focus on the most successful products and on the needs of the market. The goal of IDeS applied to this project was to develop a car as close to the "ideal" car, i.e. the one defined by the Top-Flop analysis. In particular, the present study represented a further step forward of the IDeS method since it validated its efficiency in relation to a future-oriented project. Precisely, the design methods of which the IDeS is composed have been partially revisited in line with the time horizon of the project. Therefore, all phases of comparison with the current market are actually the result of a projection into the future of the car models currently available. In this way the project represents the validation of the robustness of the IDeS method not only for applications for products of different nature, but also related to different time perspectives.

This program has been organized, in line with IDeS, in two macro-phases: project setup and product development. In the first phase we focused on the market analysis and on a series of methodologies that allowed us to translate the data deriving from the market analysis into qualitative requirements and then into technical characteristics. In the second phase, once we understood the essence of the 2030 automobile, we focused on the methods to design it

1.1 Objectives

- To study the characteristics of the future automotive market and needs
- Provide a trace of the most innovative criteria at the service of the new product development process
- Finding a viable alternative to traditional 3D modeling
- Understanding the possibilities of Virtual Reality modeling
- Provide a trace of the most innovative criteria at the service of the new product development process
- Devising a technological solution for the challenge of vehicle electrification

2. Literature Review

The design process of research and development of a future car was supported by a tested methodology, IDeS, which was previously used not only in car design (Frizziero et al., 2022), but also in other fields, for example biomechanics (Frizziero et al., 2019). That shows that behind product design, there are common crucial aspects (Karana et al., 2008), firstly QFD, Quality Function Deployment, in which the analysis is carried out to improve the product design quality based on the customer's evaluation (Sivasankaran, 2021.). Secondly benchmarking, which is a process that allows organizations to improve upon existing ideas (Lankford, 2022). The conceptual design stage remained intensive in paper and pencil work, as Cad systems are too rigid to allow creative production of concepts (Alcaide-Marzal et al., 2013). In fact, designers still tend to use a combination of conventional and digital design tools. In addition, many of them are not familiar with the capabilities of some digital design tools and they are not exploiting digital sketching (Aldoy and Evans, 2015). Overall, design sketch is at the core of the product design process (Li et al. 2010) and sketching capabilities are needed in both engineering and design activities (Kudrowitz et al., 2012).

For what concerns the 2030 car, we could state that the future mobility will depend on the competition between coalitions of innovative actors who support alternative transport system (Marletto, 2014). But, in order to better control energy consumption of urban transports, it will be needed to better control consumption of urban transport, for example emphasizing eco-driving and applications of e-mobility (Sun et al., 2021). Also, successful climate change mitigation requires a timely shift to renewable sources of energy, such as sunlight and wind, but market pull alone is not enough (Jacobson and Delucchi, 2009).

However, the most challenging part was creating the 3d model. Thanks to a study we did, we found out that 3d models can be created and exported in virtual reality (Balzerkiewitz and Stechert, 2020) with advantages and disadvantages (Joundi et al., 2020) and we decided to challenge it. The most appreciable benefits we experienced is how VR (Virtual Reality) software improvements can support work in distributed teams (Abdelhameed, 2012) and extreme realism: "from virtual reality to real virtuality" (Chalmers and Ferko, 2010).

3. Methods

This study was conducted following the IDeS methodology (Industrial Design Structure) methodology, which allowed us to systematically address the various phases of the project. IDeS derives from the union of some of the most innovative and effective criteria used today and foresees the serial realization of: Environment analysis, Market analysis, Quality Function Deployment (QFD), Benchmarking (BM), Top-Flop Analysis (TFA), Product Architecture, , Stylistic Design Engineering (SDE), 2D and 3D modeling, testing, and rendering.

3.1 Environment Analysis

The environment analysis was useful for understanding the context in which the product we had to develop would fit. It represents a data collection of fundamental importance to identify, in the following phases, the most appropriate characteristics to assign to the product. The objective of the environmental analysis was to answer the following questions:
- Cars 2030: product or service?
- How is the company evolving?

- How will the city-periphery relationship change in 2030?
- What will the technological opportunities be in 2030?
- Autonomous driving: will it be part of the 2030 reality?
- What are the challenges today in the automotive world?
- What are the regulations that guide the development of new cars?
- What are the EU 2030 goals in terms of mobility?
- Study of propulsion: in which direction are we going? What does the transition to electric represent?
- What is the ecological impact of transport?

3.2 Market Analysis
The market analysis phase had the objective of framing the company that will experience the 2030 market and is, consequently, closely related to the analysis of the environment. The market analysis aimed to answer the questions:
- What is the role of the automobile in the future?
- Will the car, in 2030, be a simple people mover or something more?
- What will be the needs of a potential customer in 2030?
- Will the market be ready for new technologies?
- If autonomous driving is available, will the market be willing to convert?
- Will the car be a product or a service in 2030?

3.3 Quality function deployment (QFD)
The QFD methodology is used in IDeS to classify the results of market analyzes according to a scale of importance of the requirements that the new product will have to include. It therefore allows to carry out an optimized and maximally customer-oriented design. Thanks to QFD, in fact, the new product will be an agglomeration of all those requirements that had emerged in the initial phase of environmental study, in relation to their importance for the final customer.

In particular, the QFD consists of: 6W Matrix, Relative Importance Matrix, What-How Matrix

3.3.1 Benchmarking (BM) e Top-Flop Analysis (TFA)
Once the technical characteristics that the vehicle have have been identified, the IDeS methodology requires that products with similar qualities offered by potential competitors are identified on the market. In particular, IDeS suggests of creating a further matrix, called "benchmarking matrix", which highlights the technical characteristics of each of the rival products. The goal is to identify, for each characteristic, the competitor who has managed to do better. Finally, the most formidable competitor can be viewed in the Top-Flop matrix located downstream of the Benchmarking one.

3.4 Product Architecture
At the end of the benchmarking phase was carried out a study to design the architecture of the product, i.e. the structural apparatus at the base of the vehicle.
The design was created using Creo Parametric software and is representative of the structural part of the platform.

3.5 Stylistic Design Engineering (SDE)
Stylic design engineering (SDE) is a systematic procedure for new product design and was developed in three main phases:
1. Analysis and study of stylistic trends: stone, advanced, retro, natural
2. Stylistic study of the company or the reference segment
3. Sketch: front, side, back and three-quarter proposals

3.6 2D and 3D Modeling
The connection point between sketching, i.e. representation of the product concept, and the actual product, endowed with a shape punctuated by precise measurements, was the 2D representation of the vehicle. For the 2D survey of the vehicle, the AutoCad 2D software was used, thanks to which the orthogonal projections of the vehicle were defined.

For the modeling of the surfaces, the Alias3D and Rhino3D software were used, both mathematical CADs (Computer Aided Design) and Gravity Sketch, an innovative modeling software that allowed us to create surfaces in the three-dimensional space of virtual reality. In particular, Alias3D was needed to model the base surfaces, Gravity Sketch to correct and improve them, while Rhino3D to refine the model and close it for testing and prototyping.

3.7 Virtual Reality Validation and Re-Design
Having obtained the 3D model through the use of the previously mentioned software, it was decided to take an innovative approach to the model review stages, going to introduce Virtual Reality within the workflow. This new technology was implemented both in the machining steps, going to evaluate the proportions between the various parts and modifying the shapes where necessary, and a more advanced stage, going to evaluate the quality of the surfaces, fittings, and curvatures along the entire bodywork. The decision to adopt this type of technology was related to the great benefits that it was thought could be derived from it. First, through the use of special virtual reality viewers, it was possible to "immerse" oneself within the project, being able to visualize the in-progress design of the car in 1:1 scale. In this way, it was possible to evaluate in a decidedly intuitive way the quality of the modeled forms and any discrepancies. The technique of using a full-scale model is well known in the automotive field, where manufacturers have been going, for decades now, to clay models made by numerically controlled milling machines and then finished by hand. In fact, seeing a product in front of one's face in full size allows for entirely different and far more thorough and natural evaluations than just viewing it through a PC monitor. Through VR, it is possible to recreate this with enormously lower costs since budgets in the hundreds of thousands are used to create a clay style maquette. With VR viewers it was also possible to perform specific analyses on the bodywork, going to zebra stripes and curvature analysis.

Moreover, the possibilities offered by virtual reality do not stop at product representation alone. In fact, through the use of Gravity Sketch software it was possible to integrate design elements in real time into virtual reality, reviewing the design and modifying it, all with the model in front at 1:1 scale.

3.8 Testing and Rendering
In the final part of the project, we imported the 3D model on Keyshot to define materials and colors.
To conclude, we 3D-printed the prototype of the model at 1:20 scale, made of PLA (polylactic acid), an inexpensive material that allows for immediate physical tangibility at low cost.

4. Data Collection
From the scenarios analyzed, we could infer that, for many of us, the car of 2030 will be electric, in particular for those who only use their car in the city for a few km a day or for those who consider the car a simple means of transportation. On the other hand, the passionate car will remain thermal or available in a hybrid combination, especially for the supply chain of sports and racing cars of which Italy is the greatest exponent. The sale of internal combustion cars, in 2030, will not be eliminated, but limited to those few examples of cars purchased by those who really love engines. The key word for the near future, i.e. the one in 10 years, is multimodality: it is necessary to look at the user's point of view and analyze the different usage scenarios, from which specific design needs ensue. In particular, it is possible to identify three possible scenarios for using the car:

- Urban use

The 2030 Citycar will be electric, small in size and low in weight. In fact, the design will be revisited to allow greater use of renewable sources with maximum efficiency. They will not implement autonomous driving systems due to the still too high cost of the technology. The urban car of 2030 will also be shared. Integration models will be developed between different means of transport, including buses, trams, bicycles, electric scooters, and car sharing. In this way it will be possible to optimize the multimodal travel experience in a unique user experience that has the same comfort as a journey in your own car.

- Mixed use

The typical needs of this category of users are: range of about 500 km, speeds close to or greater than 100 km/h, load of about 350kg, safety, reliability, and reasonable costs. All requirements that, in ten years' time, will be abundantly satisfied by a battery-powered. For energy efficiency needs, it will be necessary to contain weight and dimensions.

- Extra-urban and long-range use

In this case, the propulsion system could be electric or plug-in hybrid to allow for greater autonomy. The market will be divided between sedans and SUVs, with particular attention, however, to the latter due to their weight and size.

In this paper we analyzed the second scenario, i.e. mixed use.

The user we have identified is in the medium-high range and young (30-55 years). He also uses the car on a daily basis and appreciates it not only as a service, but also as a product: the attention to detail, the aggressive and fashionable line, the quality, but above all the performance, all correlated to a reasonably studied price to satisfy moderately demanding users. The passenger compartment allows you to accommodate 2 people very comfortably, while in the rear seats space and comfort are compromised with the need for compactness. The trunk ensures a good load capacity. It is a car mainly used for single transport, as a couple and only occasionally with passengers on board. Emotional appeal, driving pleasure, safety, design, and personality are the reasons why it is purchased.

5. Results and Discussion

5.1 Numerical Results

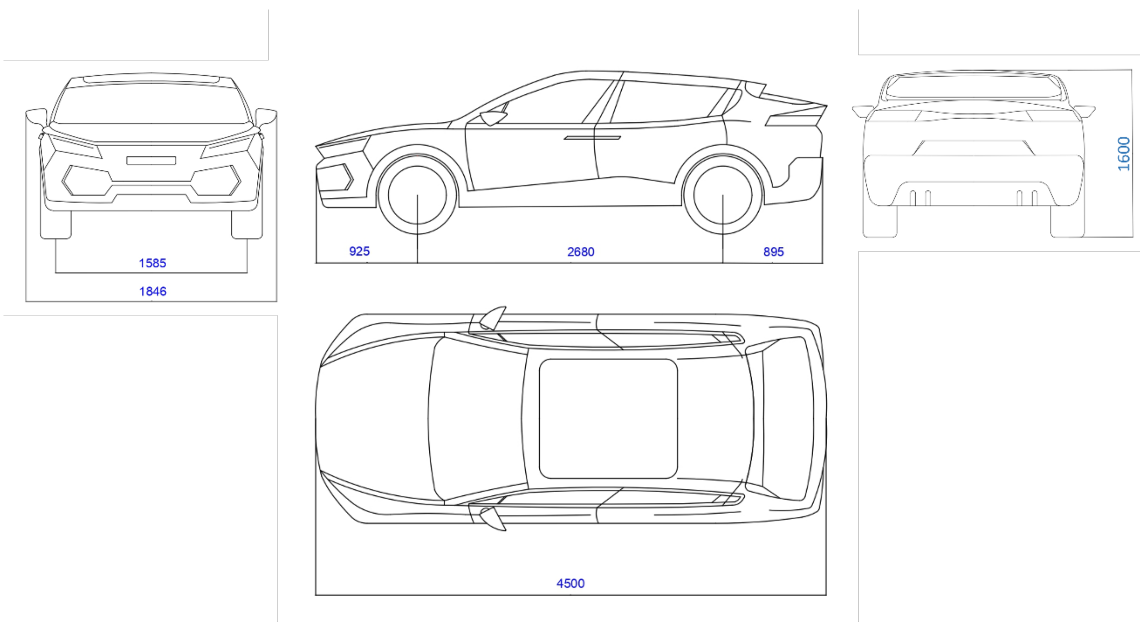

Figure 1. Blueprint with dimensions of the final model

The vehicle that responds to the characteristics obtained in the previous phases was found to be 4500mm long, 1846mm wide, 1600mm high and with a wheelbase of 2680mm (Figure 1). Furthermore, the architectural study showed that the 2030 car will be equipped with a modular battery pack, with the possibility of rapid charging up to 350 kW.

CATEGORIES	n°	€/h	PROJECT SETUP n° HOURS	PROJECT SETUP TOTAL [€]	SKETCHING n° HOURS	SKETCHING TOTAL [€]	CAD 2D AND 3D n° HOURS	CAD 2D AND 3D TOTAL [€]	PROTOTIPAZIONE n° HOURS	PROTOTIPAZIONE TOTAL [€]	TESTING n° HOURS	TESTING TOTAL [€]
Designer	1	40	180	7200	220	8800	400	16000				
Engineer	1	45					400	18000	220	9900	220	9900
Basic eployee	4	25							220	22000	220	22000
TOTAL [€]				7200		8800		34000		31900		31900

EQUIPEMENTS	n° hours	€/h	TOTAL [€]
Project Setup			0
Sketching			0
CAD 2D and 3D			15000
Prototyping	220	70	15400
Testing	220	70	15400

TOTAL COSTS	EQUIPMENT	STAFF	TOTAL [€]
Setup del progetto	0	7200	7200
Sketching	0	8800	8800
CAD 2D e 3D	15000	34000	49000
Prototipazione	15400	31900	47300
Testing	15400	31900	47300
	OVERALL PROJECT COST [€]:		159600

Figure 2. Budget cost analysis

In this work we have carried out a cost analysis taking into consideration: project setup costs, sketching, 2D and 3D modeling, prototyping, testing and equipment (Figure 2). It emerged that the total cost of the project is €159,600.00.

5.2 Graphical Results

Ranking		DESIGN	APPEAL	COMFORT	PRESTAZIONI	HABITABILITY	DRIVE EXPERIENCE	RELIABILITY	AUTONOMY	VERSATILITY	TECHNOLOGY	EASY TO USE	PRACTICALITY	TOTAL
2	DESIGN	1	1	1	1	2	1	0	1	0	1	1	1	11
4	APPEAL	0	1	1	0	2	0	0	1	1	1	1	1	9
7	COMFORT	0	0	1	0	1	0	0	0	0	0	1	1	4
5	PERFORMANCE	0	1	0	1	1	0	0	0	1	1	1	1	7
8	HABITABILITY	0	0	0	0	1	0	0	0	1	0	1	0	3
4	DRIVE EXPERIENCE	0	1	2	1	1	1	0	0	1	1	1	0	9
1	RELIABILITY	1	1	1	1	1	1	1	1	1	1	1	1	12
3	AUTONOMY	0	1	1	1	1	1	0	1	1	1	1	1	10
8	VERSATILITY	0	0	1	0	0	0	0	0	1	0	1	0	3
6	TECHNOLOGY	0	0	1	0	1	0	0	0	1	1	1	1	6
9	EASY TO USE	0	0	0	0	0	0	0	0	0	0	1	1	2
8	PRACTICALITY	0	0	0	0	1	1	0	0	0	0	0	1	3

Figure 3. Relative Importance Matrix

The relative importance matrix assumes the arrangement of the same qualitative characteristics both horizontally (in a row) and vertically (in a column) (Figure 3). Subsequently, each row is compared one by one with each column, assigning the score of 2 if the row clearly wins compared to the column, 1 if the row wins compared to the column, 0 if the row loses compared to the column. After the interpolation, the total column is drawn, which contains the score achieved by each characteristic. Thus, it is possible to obtain a ranking of the qualitative attributes, that in our study is: reliability, design, and autonomy.

	TAPERED DESIGN	RAISED DESIGN	SPORTIVE DESIGN	5 DOORS	VARIABLE EQUIPMENTS	V2G	ON-BOARD TECHNOLOGY	TRACTION CHOICE	OPTIONAL
DESIGN	9	9	9	3	0	0	0	0	1
APPEAL	9	9	9	1	3	0	0	0	3
COMFORT	3	9	3	9	3	0	3	1	9
PERFORMANCE	3	3	3	1	0	9	1	9	1
HABITABILITY	3	9	3	3	3	0	1	0	9
DRIVE EXPERIENCE	9	9	9	1	3	0	9	9	9
RELIABILITY	0	0	0	0	0	3	1	0	1
AUTONOMY	1	1	1	0	0	9	1	3	1
VERSATILITY	0	3	3	1	1	9	3	9	3
TECHNOLOGY	0	0	0	0	0	9	9	3	3
EASY TO USE	1	3	1	3	1	3	9	1	3
PRACTICALITY	3	9	9	9	1	1	3	1	3
TOTAL	41	64	50	31	15	43	40	36	46
RAKING	5	1	2	8	9	4	6	7	3

Figure 4. What How Matrix

The next step was the What-How matrix (Figure 4), whose purpose was obtaining a scale of interdependencies between each qualitative attribute and a series of technical characteristics, also the result of the initial general study phase.

In particular, the qualitative attributes previously used are rearranged in columns, while the technical characteristics are positioned in rows. As in the previous case, the interpolation of rows and columns is repeated assigning to each comparison the value 0, if that quality and that characteristic are totally independent, 1 if they are scarcely dependent, 3 if they are quite dependent, 9 if they are very independent. The outcome of the WHAT-HOW analysis is a list of technical characteristics that the car must have, and which reflect the main qualitative attributes that emerged from the relative importance matrix: raised design, sportive design and optionals.

	CUPRA FORMENTOR	ALFA ROMEO TONALE	PEUGEUT 3008	VW TIGUAN	MAZDA MX30	LEXUS UX FE	NISSAN ARIYA	HYUNDAI IONIQ 5	INNOVATION	2030 CAR
LENGHT	4,45	4,53	4,45	4,51	4,4	4,5	4,6	4,63	4,5	**4,5**
WIDTH	1,84	1,84	1,84	1,84	1,8	1,84	1,85	1,89	1,85	**1,85**
HEIGHT	1,52	1,6	1,62	1,68	1,57	1,54	1,66	1,6	1,6	**1,6**
FULL ELECTRIC	NO	NO	NO	NO	YES	YES	YES	YES	YES	**YES**
HYBRID	YES	YES	YES	YES	-	-	-	-	NONE	**NONE**
HYBRID TYPE	PLUG-IN	PLUG-IN	PLUG-IN	PLUG-IN	-	-	-	-	-	-
BATTERY	12,8 KWH	15,5 KWH	13,2 KWH	13 KWH	35,5 KWH	54,3 KWH	63/87 KWH	58/72 KWH	72 KWH	**72 KWH**
AUTONOMY FULL ELECTRIC [KM]	52	70	60	40	200	305	360/500	400/500	500	**1000**
RECHARGING TIME 100%	5 HOURS AT 2,3 KW	2 HOURS AT 7,4 KW	1H45M AT 7,4 KW	4 HOURS AT 3,6KW	40MIN AY 50KW	50MIN AT 50KW	45 MIN AT 50KW	50/65MIN AT 50KW	50/65 MIN AT 50KW	**20 MIN AT 200KW**
ENGINE	4 CYLINDRES	4 CYLINDRES	4 CYLINDRES	NT	-	-	-	-	-	-
DISPLACEMENT	1395	1300	1600	1395	-	-	-	-	-	-
POWER	245 CV	275 CV	224 CV	150 CV	145CV	204 CV	217/242 CV	170/305 CV	245 CV	**245CV**
TORQUE	250/400 Nm	-	300 Nm	350 Nm	271Nm	300Nm	300Nm	350/605 Nm	300 Nm	**300Nm**
MAX SPEED[KM/H]	205/210 KM/H	-	235	205 KM/H	140 KM/H	160 KM/H	160 KM/H	185 KM/H	185 KM/H	**200 KM/H**
0-100 KM/H	7 s	6,2 s	8,7 s	7,5 s	9,7 s	7,5 S	7,5/6,9 S	8,5/5,2S	6,5 s	**6,5 s**
TRACTION	FRONT WHEEL	FOUR-WHEEL Q4	FOUR-WHEEL	FRONT WHEEL	FRONT WHEEL	FRONT WHEEL	FRONT WHEEL	FRONT WHEEL	FOUR-WHEEL	FOUR-WHEEL
CONSUMPTION	1,4 l/100 KM	-	1,3 l/100km	2 L/100 KM	0	0	0	0	0	**0**
CO2 EMISSIONS	38 G/KM	-	35 G/KM	38 G/KM	0	0	0	0	0	**0**
CARGO VOLUME	450 LITRES	ND	395 LITRES	615 LITRES	350 LITRES	367 LITRES	468 LITRES	527 LITRES	400 LITRES	**400 LITRES**
WEIGHT [KG]	1704	-	1840	1811	1660	1860	2775	2370/2540	2150	**1950**
OPZ. MANUAL TRANSMISSION	6 GEARS	NO	NO	6 GEARS	-	-	-	-	NO	**NO**
PRICE [€]	45050	36000/	44930	43400	34358	57000	45000	44000/60250	47000	**45000**
TOP	6	8	6	6	9	10	11	13		
FLOP	9	7	9	9	6	5	4	2		
DELTA	**-3**	**1**	**-3**	**-3**	**3**	**5**	**7**	**11**		

Figure 5. Benchmarking and Top-Flop Analysis

Once the technical characteristics that the vehicle were identified, the IDeS methodology requires that products with similar qualities offered by potential competitors are identified on the market. In particular, IDeS suggests of creating a benchmarking matrix which highlights the technical characteristics of each of the rival products (Figure 5). The goal is to identify, for each characteristic, the competitor who has managed to do better. The result is twofold: on the one hand, thanks to this analysis it is possible to identify the most formidable competitor, on the other, the so-called "ideal product" can be identified, i.e. a product consisting of a set of the best characteristics considered by the competitors as a whole. As regards the most formidable competitor, it can be deduced from the Top-Flop analysis, an extension of benchmarking which is created by analyzing rival car models one by one and assigning a score of 1 (Top) if the single feature is winning, -1 if the single feature is losing (Flop). The performance of each competitor is therefore evaluated by subtracting the Top score from that of the Flops. Secondly, to define the characteristics of the ideal car, it was sufficient to identify the best performing competitor for each attribute. The set of winning characteristics can be viewed in the two right-hand columns, which define the properties of the ideal car. At the design level, the ideal product is what the new car must aim for in order to be successful. In particular, the benchmarking phase of this project has been revisited to make it possible to obtain, as an output, the "ideal" car available on the market not now, but in 2030. In fact, as it is possible to recognize in the diagram in the figure, the characteristics of the ideal car 2022 have been projected into 2030 (see last right column). For this purpose, together with the study of the environment and the market, the evolutionary process of the last 10 years in the automotive sector has been analyzed, to be able to identify a growth trend that has made it possible to project current cars into the future. This project, therefore, represents a further evolution of the IDeS methodology and demonstrates its adaptability to different time horizons.

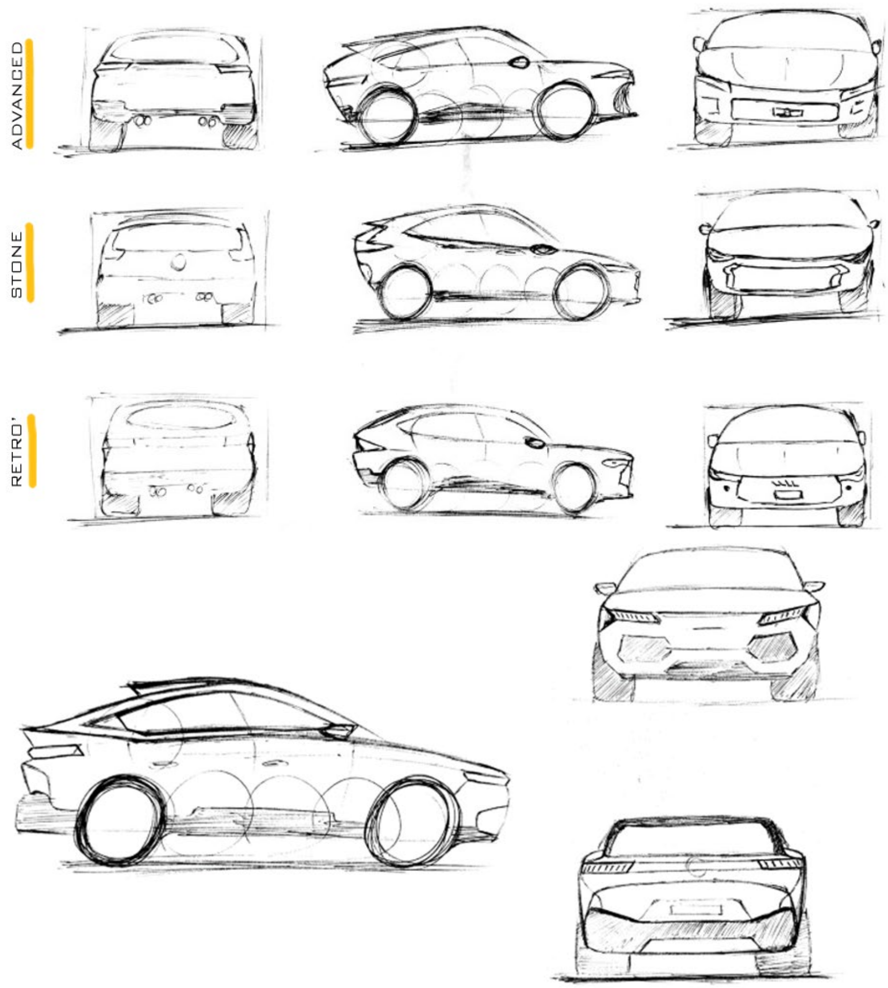

Figure 6. Sketching phase

Afterwards we thought about the design of our car. In order to do that, we followed SDE methodology, that includes the realization of many sketches for different design trends, Stone, Retrò and Advanced and then merge them to obtain the final outcome (Figure 6).

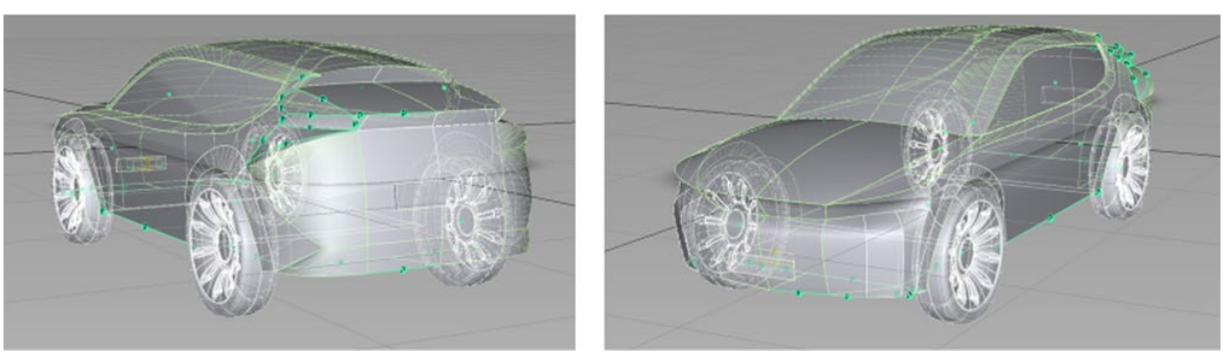

Figure 7. 3D Modeling

The next round of development involved reworking and turning the sketches into exacting 2D renderings. In contrast to the sketches, it was therefore feasible to get a comprehensive perspective of the various concepts, making it simpler to identify any potential flaws.

In the final part of the project, with the aim of modeling the surfaces, the Alias3D and Rhino3D software were used (Figure 7), both mathematical CADs and Gravity Sketch, an innovative modeling software that allowed us to create surfaces in the three-dimensional space of virtual reality. In particular, Alias3D was needed to model the base surfaces, Gravity Sketch to correct and improve them, while Rhino3D to refine the model and close it in view of testing and prototyping. For what concerns the virtual reality, this was the most innovative point of the project. In fact, it was one of the first applications of virtual reality at the service of 3D modeling done by the Department at the University.

The key benefit of this new technology for us was the ability to communicate clearly and immediately about any changes that were suggested while interacting in virtual reality with various designers. Thanks to this step, we were able to understand the power of Virtual Reality at the service of 3D modeling. Working inside a complete immersive reality gave us the chance to have a different perspective compared to what traditional modeling is. Indeed, thanks to virtual reality we could work on a 1:1 scale model, walking around it and overall feeling the essence of what we were building. The opportunity to design a model with our hands by moving them in the tridimensional space is a big step forward compared to the same work done on a workstation with buttons and clicks.

5.3 Proposed Improvements

Possible improvements are related to the extension of the use of virtual reality to the whole project, starting from three-dimensional modeling, up to rendering. Also displaying different configurations to a possible customer could be interesting as an improvement, as well as conducting ergonomics studies inside the virtual space with dynamic features.

5.4 Validation

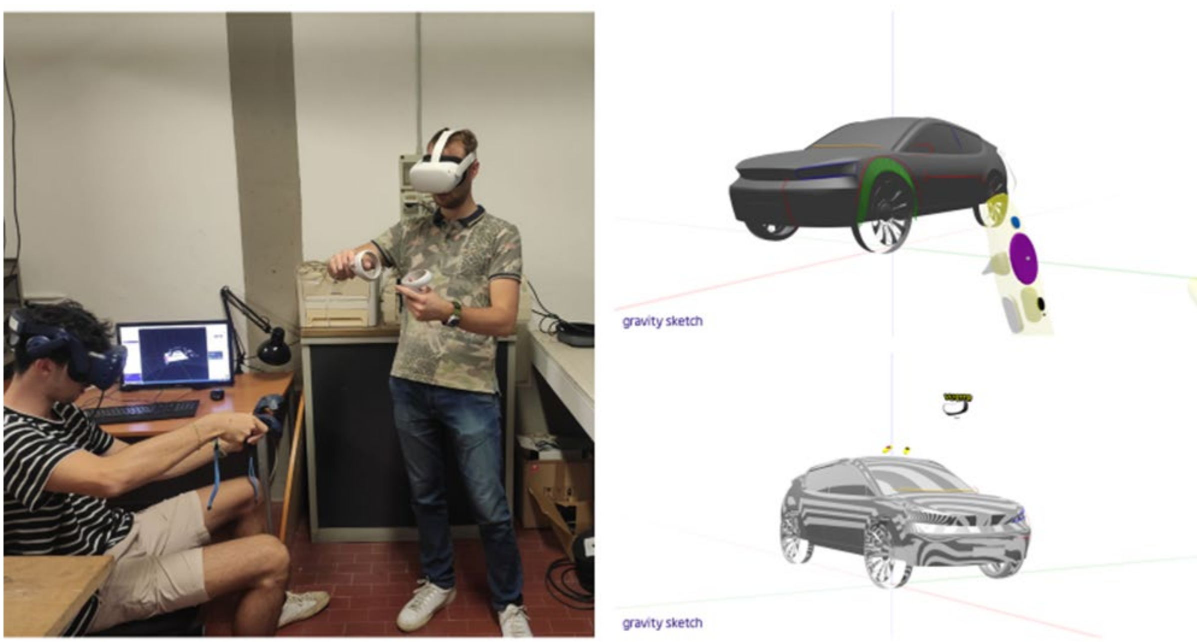

Figure 8. 3D Validation of the model using Virtual Reality

Thanks to the realism offered by virtual reality, we were able to test the model directly inside this ambient (Figure 8). In addition to that, we 3D-printed the model (Figure 9) and realized some rendering using Keyshot software (Figure 10).

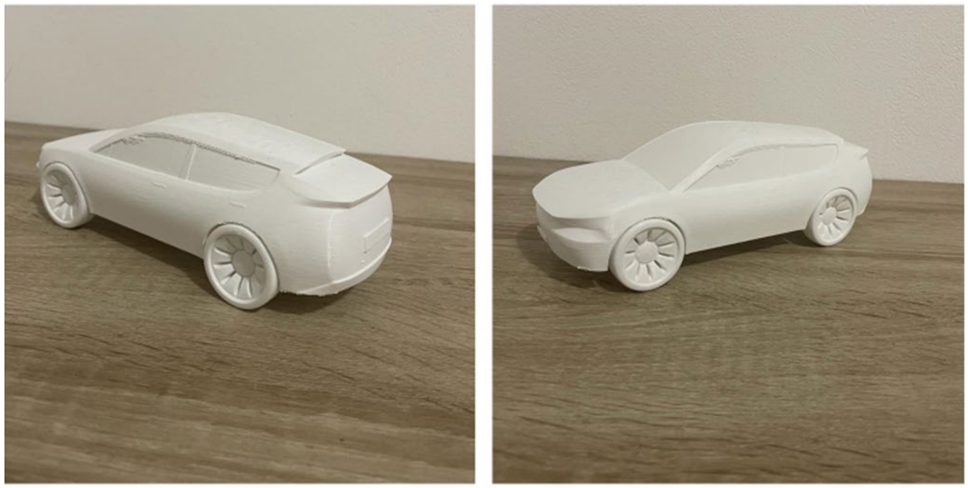

Figure 9. 3D Print of the Model

Figure 10. 3D Rendering of the Model

6. Conclusion

The development project for the 2030 car was the result of a structured and systematic process, the one indicated by the IDeS methodology, which allowed us, in about 8 months, to understand the car of the future, what characteristics it should have, what needs it satisfy and to generate a well-defined virtual model. The "Auto 2030" program, in addition to representing a further validation of the IDeS methodology, demonstrates how to apply the most modern technologies available to design support to arrive at a digital product in a very short time and at low cost. In particular, the implementation of augmented reality as a project system is a new and outstanding method which has made it possible to combine the classic 3D modeling with a virtual three-dimensional space thanks to which, directly in the design phase, some corrections have been made directly under construction. This made it possible to have immediate feedback on the product without having to wait for the completion of the 3D modeling on the classic flat screen. It is therefore a new criterion that allows for fast and reliable feedback thanks to the clearer feedback given by virtual reality. We are therefore talking about a new design which, iteratively, allows the product to be tested, modified, and improved quickly and without wasting material. The result is a fully electric urban SUV capable of meeting future urban and extra-urban mobility needs, thanks to the union of the various and innumerable technical and qualitative requirements that have been condensed inside.

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