Colour, Material and Finish consistency for car design students

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This work aims to investigate the learning processes of the Colour, Material and Finish (aka CMF) design project by analysing the representation methods in the thesis of students of courses in Transportation Design. In car design, the eventual richness in students' representational abilities is crucial to express their ideas best. In the CMF design field, where the choice and combination of chromatic variables play a fundamental role, the representation richness is even more critical because of the need to express ethereal concepts such as emotional attributes. A first result described in this work identifies a recurring difficulty by students in the graphic restitution of the concepts, stated in the mood board of their projects, with style and quality consistent with the other parts of the project.

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Introduction

What is CMF design?

As Valtonen explains exhaustively in his work [1], the figure of the industrial designer has evolved over the years, assuming an increasingly strategic role within companies. Particularly in the last decades, with the increasing importance and demand for recognition of the concept of "brand", the designer has assumed the role of creator of experiences and then the generator of innovation. The user experience has taken a central role in the design and has made all those disciplines that deal with it more meaningful. The generic profession of the industrial designer has become increasingly specialised to meet the market's demands. Among these specialisations is CMF design.

Colour, Material and Finish design is an emerging professional discipline that runs parallel with the physical and technical industrial design process [2]. CMF design is adopted from the very first stages of the design process till the production phase. It focuses on designing colours, materials and finishes to highlight both functional and emotional attributes of products.

This work's features combine practical knowledge of material technologies' functional and technical properties (hard skills) with intangible human perceptions (soft skills). It means that the CMF designer will need to have broad skills: materials research (focusing on sustainability and the production cycle), colour theory, graphics, fashion, illustration, branding and advertising. Also critical is a sensibility to detect and articulate design languages and aesthetic trends, along with the ability to understand and translate consumers' aspirations into CMF solutions through engaging storytelling.

Throughout the design process, the CMF designer must also dialogue and collaborate with other professionals: engineering, marketing, legal, manufacturing, sales and purchasing.

Colour & Trim: CMF design in the car design field

Design-driven companies, such as car manufacturers are, usually have dedicated professional teams of CMF designers working in close collaboration with other departments. The department that deals with CMF design within the automotive companies is Colour & Trim.

In the car design context, the C&T department is often underestimated, but CMF design can really change the perception of a car. The Colour & Trim department is responsible for devising the perception of surfaces, textures and colours, both interior and exterior, that form a physically subtle but significant proportion of the vehicle's identity. In practice, it means researching, designing, and developing all interior and exterior colours and materials for all visible surface finishes. Thus, the trim lines for the future automobile are chosen from hundreds of samples and colours of fabric, leather, paint and plastic. Furthermore, sometimes, they are created entirely new from scratch.

CMF car designers work in close collaboration with exterior and even more with interior designers, as well as with marketing and product team, but also with ergonomists and with technical engineers, who work on the concept and industrialisation of the new vehicles. The main goal is to collect technical input and non-technical feelings from them and give a strong brand and product identity to the new project amplifying the aesthetics of products, maximising their performance and improving their functionality, as well as creating emotional connections using colours, materials, and finishes.

Indeed, as Becerra [3] explains very well, conveying positive emotions through a sensory experience can elevate the value of products. Most of the CMF designer's work is about the perceived value he or she creates for the end-users. Regardless of ethnicity, social status, education or gender, every user buys objects that satisfy emotional needs and intangible benefits such as status, beauty and belonging. Value creation through CMF design considers technical knowledge of production processes and cultural and emotional connections [4].

Because of all these interactions, the CMF designer acting in the car design world as a Colour & Trim car designer will have to be very good in visual representation techniques and materialise and communicate ideas. This professional should have a strong cultural, artistic, and technical background and a passion and a good understanding of the trends and lifestyle evolutions.

CMF design in car design didactic context

This work aims to investigate both the learning and the rendering processes of the CMF project by analysing the methods of representation in the thesis of students of specialisation courses in transportation design. For this purpose, the activities developed in the last years within the

specialisation master course in Transportation & Automobile Design of Politecnico di Milano have been considered.

Over the years, the educational path of this course has evolved significantly to improve the effectiveness of a curriculum aimed at professionalising students. The expected output profile is a junior professional with a broad vision of the many activities that contribute to the design process of a complex object such as cars and have representative skills consistent with this profile.

In the master course program, the main didactical module is the Car Design Studio, in which students work in groups to develop their thesis projects that are concepts of complete vehicles. Due to this goal, the Car Design Studio has been structured to simulate what happens inside an Automotive Design Centre, to make the students' experience more consistent with the professional world: there are four teachers, three of them involved in teaching and reviewing a specific aspect of the car design process (exterior, interior, colour & trim); all of them are coordinated by the fourth teacher who corresponds to the design director.

CMF design is one of the subjects covered within the Car Design Studio and is one of the design aspects students develop within their final thesis project.

Methodology

The CMF design includes multiple processes based on very different practical activities, such as market research, colour experiments, tactile checks, and even relationships with suppliers. Mainly for these reasons, the teaching of CMF design is a well-known problem in the product design degree curricula, often managed on a theoretical basis because of the fragmentation of the several topics to be covered [5]. To prevent this problem, during the specialising master course in Transportation & Automobile Design, a double path for teaching CMF design has been set up. At first, lessons take place outside the Car Design Studio, as an introductory course mainly based on a theoretical approach, to build their knowledge. The second part of the course takes place inside the Car Design Studio and is mainly based on design review activities, according to Shön, Oxman and Cunliffe approach to cognitive processes [6-9]. They redefine the educational tasks on designer training, suggesting a shift from an orientation linked to a product achievement to a cognitive-constructive system.

For this reason, design reviews are the founding moment of all the teaching activities of the Car Design Studio; during reviews, the act of "reflection-in-action" allows to spend time exploring why students act in a certain way and how to improve their quality both in design and in representation. Indeed, the only way to describe the cognitive processes of design is to identify a set of representational techniques that can model visual and conceptual knowledge and its dialectical interaction with the "reflection-in-action" process. The cognitive characteristics of design thinking and its acquisition can be found in the content of the metacognitive and recursive approach to design education that involves "learning-to-learn". Moreover, moving from a cognitive to a practical approach, it can be observed that the specificity of the educational project is strongly linked to the relationship between visual and conceptual contents. In the CMF design field, where the choice and combination of chromatic variables play a fundamental role, the representation quality is essential because of the need to express ethereal concepts such as the emotional path linked to the user's experience.

From theory to practice

The CMF design course, organised in two phases, follows the "Double Diamond" model. Such is the name of a design process model popularised by the British Design Council in 2005 [10]. In this model,

the two diamonds represent the two successive processes of a broader or more profound exploration of a problem (divergent thinking) and subsequent focused action (convergent thinking). As illustrated in Figure 1, the four stages are: discover, define, develop, and deliver. The *challenge*, the starting point of the whole process, is the project brief.

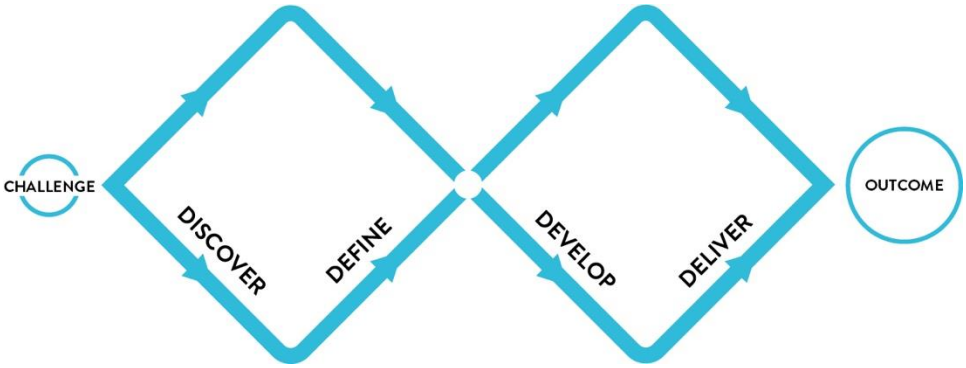

Figure 1: Visual description of the Double Diamond concept [11].

- **Discover**. The first Diamond helps people to understand, rather than assume, what the problem is. In CMF design, it is the research phase where divergent action leads to constructing at first a varied and then a well organised set of visual and physical materials.
- **Define**. The subsequent convergent phase leads to the systematisation and selection of the material obtained from the research. The result is a well-organised body of iconographic material and the first hypothesis of application.

The two first phases are carried out during the course first part in which tools to proceed with the research are provided. During the second phase, within the Car Design Studio, the CMF project is applied to the final thesis project, meanwhile taking shape in parallel.

- **Develop**. The new divergent phase leads the designer to apply the first hypothesised solutions and fix them within the project. This phase is again divergent because it encourages people to give different answers to the clearly defined problem, seeking inspiration from elsewhere and co-designing with a range of professionals (i.e., professors, exterior consultants, other students).
- **Deliver**. The hand-over phase within the Master's programme corresponds to the phases of the final presentation through the showcase. Within the Master's programme, it is only partly possible to finalise this phase, which involves testing different solutions on a small scale, rejecting those that do not work and improving those that do.

The first diamond

The starting point of the CMF course is the same project brief that is given to students to develop the car design. The two processes, CMF design and body design, initially proceed independently and in parallel.

During the early stages of the CMF course, students learn the basics of colour theory and its history, the most important typologies of materials used in making cars, some tips on environmentally friendly materials, and new generation and experimental materials. Research is always carried out with the

design brief and the hypothesised target brand, the needs of the personas and the user experience in mind.

At the same time, students are involved in a more practical activity focusing on making reports on the most crucial design exhibitions to highlight the new trends in the sector. That means doing research either the most famous *Motor Shows*, like Geneva, Tokyo, Paris, but also exhibitions not directly focused on vehicles, like CES (Consumer Electronics Show in Los Angeles), *Salone del Mobile di Milano*, or *Lineapelle* (in Milano, New York and London).

This assignment is carried out individually and is completed with a survey in materials libraries and web platforms specialised in colour and lifestyle trends [12-13]. The last part of the preparatory activities is a simulation of a CMF project for a piece of a car (for example, the door panel). The project is described using a mood board with references to at least three different materials and a colour palette (Figure 2). The colour definition is always requested in one coded colour palette (mainly RAL, NCS, Pantone) to keep more consistent information. In the end, students are ready to implement the same process in their thesis projects, developed in the Car Design Studio, with reviews by the same teacher.

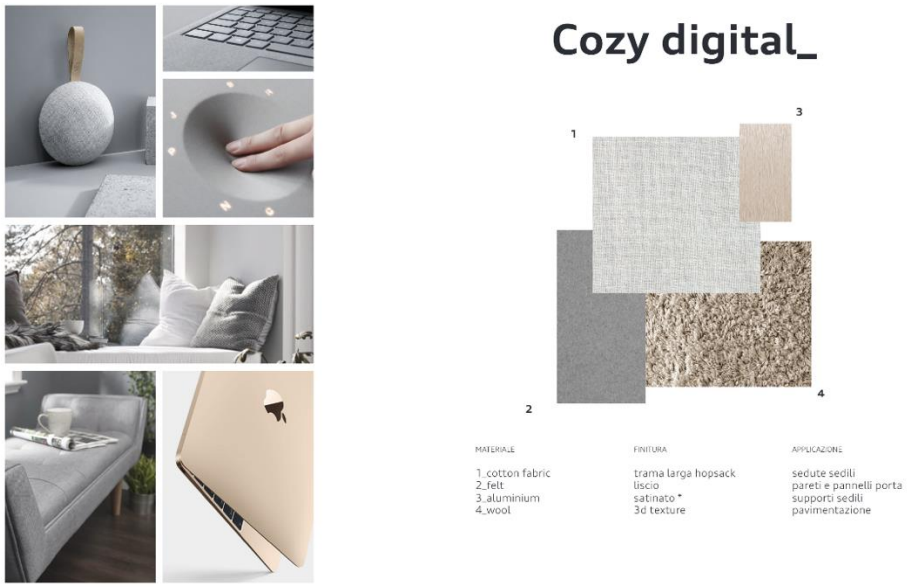

Figure 2: Mood board "Cozy Digital" by Marco Quamori Tanzi. On the left is the mood board to describe materials, finishes and sensations; on the right is the CMF proposal for the interior of a vehicle.

The second diamond

The concept created at the end of the first convergent phase finds, within the Car Design Studio, a new opening given by the possibility of co-design with the other components of the project group: the technical and the design components above all.

The comparison with the other components of the project can give rise to new hypotheses, and the mood board evolve, the images corpus created and organised expands, and materials & finishes are catalogued.

The colour and material variations created at the end of the first phase are simplified as a triad of colours (the primary colour: 60%; the secondary one: 30%; and the accent: 10%) to allow students to manage a complexity that, by its nature, must also consider the geometry of the project as well as materials, finishes, textures, and patterns [14-18]. The final materials selection happens gradually with the final definition of the interior shapes, going deeper into the project details via graphical proposals.

Two alternative CMF projects are developed for each project, the main one and a secondary one: the main will be used in the presentation images and models.

Results

In a ten-year-long list of exhibitions made to highlight the final thesis projects developed by the Transportation & Automobile Design course students, the exhibited materials are changed, evolving towards a more complete and professional way to describe a car design work.

Currently, the most comprehensive exhibition was made in the summer of 2019. The subsequent ones have been greatly influenced by the covid-19 pandemic scenario and by the related constraints. For these reasons, the 2019 one will be described as the actual state of the art reference to analyse the strengths and weaknesses in showing the CMF part of the projects. In the 2019 exhibition, each project has been shown using a layout characterised by:

- a 2 × 1,4 m board containing a graphical description of the global project;
- an aesthetic model of the exterior shape in 1:4 scale created with a CNC machine and painted [19];
- a 1:10 scale FDM 3D printed model of the interior, unpainted;
- a 1:18 scale FDM 3D printed model expressing a secondary feature of the project, unpainted;
- two panels with the two alternative CMF proposals.

About the exterior part of the vehicles, the proposed colours were represented by a few ad hoc produced samples (3 or 4 depending on the project) intending to highlight the behaviour of light on concave, convex surfaces and small and large radii of curvature (Figure 3). The prominent colours combination proposal has been used to paint the 1:4 scale model (Figure 4). Materials chosen for interiors are represented by some samples in the CMF panel and the renderings of the mainboard. The model of the vehicle's interior, built in 1:10 scale, does not show any material characterisation, describing only the layout and the main shapes.

Figure 3: CMF project panel for Audi Crisalis by F. Batavia, J.P. Bruni, E. Trabattoni, P.E. Tranchellini (June 2019). In the upper part, the primary colour (blue), the secondary one (grey) and the accent (yellow).

Figure 4: 1:4 scale model created with a CNC machine and painted with the first CMF proposal represented in Figure 3. Audi Crisalis by F. Batavia, J.P. Bruni, E. Trabattoni, P.E. Tranchellini (June 2019).

Of course, the last two years editions (which ended in July 2020 and July 2021, respectively) were inevitably influenced by the covid-19 pandemic. The projects of the 2020 edition were highlighted exclusively online (on a webinar, on the Master's website, on a YouTube channel): this meant that digital images became the absolute protagonist replacing the physical component of the models and samples. The development of virtual models and, from them, the creation of 3D digital render images capable of expressing the material component at its best was therefore fundamental (Figure 5).

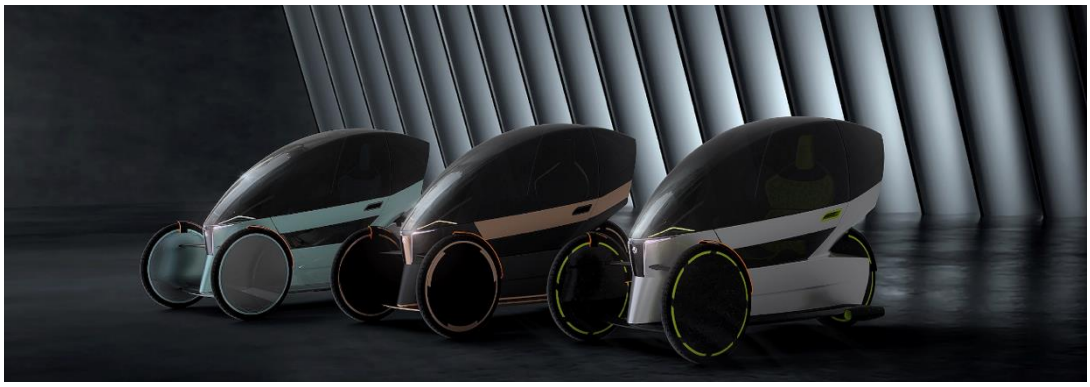

Figure 5: BMW Hyla by S. Armento, F. Errera, J. Gussoni, A. Lanzalotta, P. Vitale (July 2020). The image was digitally rendered from a 3D digital model to describe three CMF proposals.

In the 2019-20 edition, the students completed the course online after the outbreak of the pandemic scenario, while in the 2020-21 edition, students had to attend the most significant part of the course from home. This matter allowed a hybrid approach to the traditional final exhibition, being back to a physical one in a lighter mode than usual but in which the projects were exhibited again. The presentation models were created in Additive Manufacturing (FDM and SLA) on a 1:10 scale, starting from the digital NURBS models done by the students and painted. Of course, the exhibition was smaller in size than in the past (Figure 6), but large enough to keep the presentation models, a table with a graphical description of the project, and a secondary 1:20 scale model unpainted to tell the alternative function that was in every project (the projects brief requested it).

Because of the still alive difficulties in getting in touch with textile suppliers for experiencing a real tactile experience, the CMF project was still illustrated using prints and video. Once again, the digital model function and, even more, the quality of its rendering was fundamental, especially for materials' renderings proposed for the projects.

Figure 6: GoPro Chios by E. Campinotti, R. Gallo, R. Nagaraj, S. Toninato (July 2021). Project showcase.

Discussion

The different approach that the pandemic has forced us to take in the last showcases (2019, 2020 and 2021) has allowed us to reflect on the representation methods related to the final CMF design.

The 2019 showcase was the most comprehensive in terms of the amount of material on display as far as CMF is concerned. This exhibition made it possible to narrate two CMF proposals per project but left this narration relegated to almost two-dimensional material panels (Figure 3). The scale model, the real focal point of the exhibition, was painted with the colours and finishes chosen as the first choice for CMF's project. Indeed, the presentation model can capture the eyes and give the perception that the colours and finishes of the exteriors are those, and only those, visible on the model itself. Despite this, 2019 was the first year that managed to match the main CMF design of the virtual and physical exteriors, mainly thanks to reviews with suppliers, particularly with the workshop that took care of finishing painting the models.

The pandemic meant that the physical exhibition could not be finalised, postponing all the work to the digital presentation of videos and static images during the following year. The presentation of CMF's projects was notably lacking in material rendering and surface finish. Projects took into account almost only the choice of colour, overshadowing what was impossible to find due to the pandemic: materials. The lack of physical references did not help generate renderings to make up for this deficiency. In addition, the students did not have the hardware available in the university classrooms. The quality of the videos was not of a satisfactory standard in terms of rendering materials.

Finally, the 2021 showcase returned to face-to-face teaching, albeit to a lesser extent due to the period's uncertainty. Teaching throughout the studies took place almost exclusively online. The problems of finding materials were the same as in 2020, resulting in the lack of panels describing CMF's proposals on the showcase, particularly concerning interiors. The proposals were only presented during the graduation day discussion through static images in the presentation. Only one CMF choice per project was therefore presented in the exhibition. The painted scale model was significantly impacted: the pupils were involved in revisions with the 3D printing workshop and the paint workshop during its creation. The students did the models for both printing and painting and realised the choices and

compromises a designer has to make during his work. The quality of the models was very high, and although they told only one version of the CMF design, they rendered it very faithfully.

Conclusions

Of course, it is possible to work for better consistency of colour management between physical objects and their digital representation (Figure 7). Still, it could probably be better to teach students that different representation systems could tell other things, highlighting different information about the CMF project [20].

Figure 7: GoPro Chios by E. Campinotti, R. Gallo, R. Nagaraj, S. Toninato (July 2021). On the left is the physical model in the 1:10 scale, on the right is a rendered image: both representations are from a 3D digital model done by students.

Besides that, there are two main areas to improve the general quality of the course's current process. The first significant improvement in communicating the CMF project could be to close the gap in perception of CMF for interior and exteriors. To reach this goal could be helpful to have both a panel with CMF samples for interior and exterior, as it was in the 2019 exhibition, and a meaningful part of the interior model as a presentation model with its relative CMF choices applied. This is much more challenging than the presentation model for the exterior because it is not a matter of paints and finishes only: it is also involved materials to cover the hard model. Still, it could probably be a significant jump in the perceived quality of the CMF representation.

A second improvement could be reached with a closer relationship with external suppliers, but this is mainly a management topic rather than a technical issue.

The relationship with external suppliers was shared with the students in the last showcase in the educational field. This connection brought a greater awareness of the learners in the complexity of the quality of representation they wanted to achieve.

Videos to present CMF's proposals have not yet reached a sufficient level for two reasons. The first is that the purpose of the video, in the case of CMF description, must focus on the aesthetics of the materials more than other topics (i.e., the handling of certain parts of the car). The second reason is that CMF, as an experiential project, rightly remains linked to the sense of touch, as well as of sight.

The design of a complex vehicle as a car is, because of its double side (the exterior one and the interior one) and the several ways to interact with it, highlights there are still some issues to be improved in the way CMF project and its presentation could be managed. An entire digital process is still not doable

successfully, and a full physical one is costly in time to be suited at its best in a relatively short course as the analysed 15 months long specialising master course is.

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