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Development and evaluation of a methodology to integrate technical and sensorial properties in materials selection

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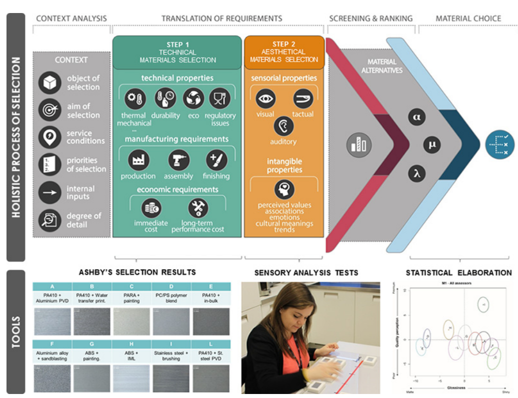
HIGHLIGHTS

- A new approach to material selection that integrates technical and aesthetic decisions is proposed in a two-step framework.
- Sensory Analysis is integrated within the traditional Ashby's selection process.
- A case study on aesthetic components describes the applicability of the method in the New Product Development process.
- The reconciliation of material languages among designers and engineers helps reaching a mutual appreciation of diverse material properties.

GRAPHICAL ABSTRACT



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ABSTRACT

In the materials selection process, the use of different tools, languages and perspectives frequently causes disagreement between engineers and industrial designers.

The aim of the paper is to define an integrated method for materials selection that provides industrial designers with measurable data to support and explain aesthetic decisions on materials.

A new method for materials selection consisting of multiple tools structured in a two-step framework is presented. The method is tested through a case study of professional kitchen appliances where metal components are replaced with polymers. The first step involved the application of an established technique to identify polymeric bulk solutions, based on their technical properties. The second step employed a sensory analysis test to choose suitable finishes. Thirty-seven individuals performed the test: the subjects highlighted their main perceptions of metal and metal-look polymer finishes.

The research demonstrates that the proposed method is suitable for the evaluation of both technical and sensorial properties of materials. In particular, Mapping test represents a rapid, low cost and effective tool to help industrial designers justify Colour Materials and Finish (CMF) choices with quantifiable information.

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1. Introduction

Materials selection plays a central role in defining the design and aesthetics of products [1]. In new product development [2,3], materials selection is the result of a multidisciplinary decision-making process that typically involves several departments of a company, particularly the design and product engineering departments [4,5]. Moreover, material and finishing choices are determined by a considerable number of variables related to aesthetics and design including: the product's technical configuration, manufacturing constraints, operating conditions and environment stresses, designers' expertise and sensitivity to certain styles, colour and material trends, usability issues, and brand identity [6–14].

For this reason, materials selection is usually a complex and iterative process of design formalisation, which starts from the first phases of concept development. Fig. 1, elaborated from a typical model [15], describes the main stages of the product development process, highlighting the company departments generally involved and the decisions to be made in the steps of "Screening" and "Design", in which the activity of materials and finishes selection is predominantly performed.

As illustrated in Fig. 1, different professionals are involved in the materials evaluation process, according to their know-how. Engineers and technicians (i.e. Product Engineering) typically deliberate on technical decisions based on quantitative data, namely technical properties, and manufacturing and economic requirements [11,12]. In the last fifty years, several methods and tools have been developed to guide "engineering" materials selection [16,17]. Among them, Ashby's method [10,12,13,18–20] is widely implemented in the industry [21–24], providing a useful support (i.e. material indexes and properties charts) to compare different material properties since early stages of product design. From the perspective of evaluating material performance in technical applications, materials selection can, therefore, be considered a mature discipline [25].

On the other hand, industrial designers (i.e. Industrial Design) mainly focus on Colour, Material and Finish (CMF) selection to characterise the identity, perception and aesthetic appearance of products [26–29]. In describing aesthetic decisions about materials, finishes and textures, industrial designers generally use qualitative criteria, expressed as intangible and sensorial characteristics [30–34] by descriptors or adjectives [16,31,35–37]. Mood boards [38] and physical material collections, inspired by product and material trends, are non-verbal qualitative tools used to express a specific aesthetic and expressive effect on a product's surface. The need for integrating expressive-sensorial characteristics of materials has gained increasing attention in the last thirty years, especially in the academic field. Theoretical design-based methods [14,31,39,40] and practical tools have been developed [36–38,41–43]. Among them, the Expressive-Sensorial Atlas [43], a collection of sensorial maps that link technical properties of materials with the sensorial ones in a linear scale, can be recognised as one of the first tools focused on visual and tactile properties with a design educational perspective. From a general observation of the approaches for materials selection currently employed by industrial designers, emerges the intention of quantifying aesthetic attributes of materials correlating sensorial and physical properties [31,36,41,43,44], by involving evaluators. Moreover, they provide a large set of materials aesthetic and perceived attributes that are generally used among designers [37,39,45,46]. However, there is no evidence to indicate that such design-based methods fit with real industrial needs. In addition, these approaches are not correlated with any standard procedure, which are established in the industrial field. Standards, indeed, provide step-by-step instructions, accessible to different users, to select the appropriate experimental design and panel of assessors, and to analyse data based on appropriate statistics.

Engineering and design approaches to materials selection differ in terms of tools, languages and perspectives [16]. Different ways of interpreting and communicating material surface properties often cause discontinuity and disagreement along the materials selection process [47]. The epistemology contrasts among engineers, who tend towards propositional knowledge, and designers, who are more familiar with experiential learning (empirical knowledge), has been investigated in depth in the materials teaching context [49,50]. In the manufacturing industry, engineering rationale is generally considered more robust and reliable than the design one. This because engineering rationale is based on propositional knowledge, funded on analysis and investigation to satisfy "the truth of what is believed and the justification of what is believed" [51]. Compared with engineering, we can envision design epistemology as a method for subjective expression and materials manipulation [52]. Even if it is not possible to fully rationalise aesthetic decisions, industrial designers are increasingly called to justify their materials choices [53]: a possible way is to qualify aesthetic attributes with

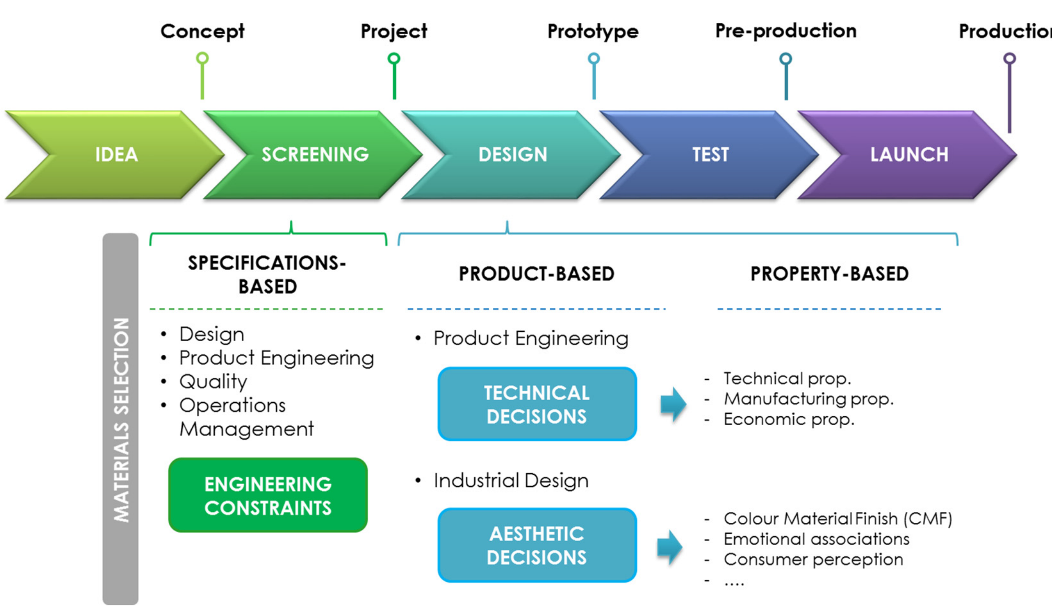

Fig. 1. Materials selection in new product development (NPD) (2-column).