GUIDELINES FOR A MATERIALS SELECTION SOURCE FOR INDUSTRIAL DESIGN ACTIVITY: A SURVEY ON THE EXPECTATIONS OF TURKISH DESIGNERS

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ABSTRACT

GUIDELINES FOR A MATERIALS SELECTION SOURCE
FOR INDUSTRIAL DESIGN ACTIVITY:
A SURVEY ON THE EXPECTATIONS OF TURKISH DESIGNERS

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This thesis focuses on the material selection process in industrial design activity and existing material selection sources particularly used by industrial designers. Therefore, in this study, the knowledge about materials the designers need, and materials selection sources and the methods they use are explored. The aim is, to propose guidelines for a materials selection source basing on the designers' needs and expectations from such a guide. The thesis consists of a critical review of the literature on existing materials sources and a field study conducted with 20 industrial designers practicing in Turkey.

Keywords: Material Selection, Industrial Design

ÖZ

ENDÜSTRİ ÜRÜNLERİ TASARIMI ALANI İÇİN ÖNERİLEN BİR MALZEME SEÇİM KAYNAĞI İÇİN KRİTERLER: TÜRK TASARIMCILARININ BEKLENTİLERİ ÜZERİNE BİR ARAŞTIRMA

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Yüksek Lisans, Endüstri Ürünleri Tasarımı
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Bu tez, Endüstri Ürünleri Tasarımı alanında malzeme seçim süreci ve tasarımcılar için özelleşmiş mevcut malzeme seçim kaynakları üzerinde yoğunlaşmıştır. Bu nedenle, bu çalışmada, tasarımcıların malzeme ile ilgili edinmek istediği bilgiler ve bu konuda kullandıkları malzeme seçim kaynakları ve metotlar incelenir. Amaç, tasarımcıların ihtiyaçlarına ve bir malzeme seçim kaynağından beklentilerine dayanarak, bu tür bir kaynak için kriterler önermektir. Tez, varolan malzeme seçim kaynakları ile ilgili literatürün eleştirel bir bakış açısı ile değerlendirilmesini ve Türkiye' de çalışan 20 tasarımcıya uygulanan bir alan çalışmasını içermektedir.

Anahtar Kelimeler: Malzeme Seçimi, Endüstri Ürünleri Tasarımı

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CHAPTER 1

INTRODUCTION

The story of materials constitutes a significant line in the history of civilization. In the history, the degree to which humans were able to exploit different materials has been taken as an indication of the pace of technological advance. The standards of living today have been largely determined by past discoveries of new materials, and the future prosperity of a country will mostly depend on the fruits of contemporary research into even newer materials and new materials' production processes.

In the 21st century, one of the hallmarks of modern industrialized society is the increasing use of materials. Not only are people consuming materials more rapidly, but also they are using an increasing diversity of materials. Indeed, it has been postulated that assuming current trends in world production and population growth, the materials requirements for the next decade and a half could equal all the materials used throughout the history up to date (Forester, 1988, 87).

This change in material consuming is both a product of advances in materials and a challenge to its future growth. It is obvious that the rising desire of materials expectations is not for the materials themselves, but for things which necessarily incorporate with these materials. In other words, the new materials technology could represent an entirely new ways of going about things, and such it will present a new major challenge not only to scientists and materials engineers but also to industrial designers and entrepreneurs.

Those improvements obtained together with the technology and the new materials, made the “material selection” important as product design parameters (McCardle, 2002). As like McCardle, Doordan states that (2002): “What something is made of and how the material is employed affects the form, function and the perception of the final design. The advent of new materials is generally treated as one of the distinctive and determining factors in modern design.”

The user interacts with materials through the products. The interaction involves lots of attitudes such as technical and aesthetic. The industrial designer is responsible for evaluating all those attitudes between materials and user. According to Ashby and Johnson (2002, 2):

> For technical designers, it is easy to access to information they need- handbook, selection software, advisory services from material suppliers- and to analysis and optimization codes for safe, economical design. However, at this point, industrial designers are disappointed with both print and interviews that they do not have equivalent support. In other words, there is no similar abundance of support for teaching of materials in industrial design.

Therefore, an industrial designer must have the efficiency on materials selection by evaluating several factors. A crucial question stems from this point: How?

The industrial designer needs the material data at every step of the design process. On the other hand, the content of the data differs at every stage. He/she uses some material selection sources and decide individually or not among the candidate materials.

While searching about the candidate materials, what kind of ‘*information*’ does an industrial designer *need* in the *design process*? For the aim of answering this question, the author found it valuable to concentrate on those following research questions.

1.1 RESEARCH QUESTIONS

- What are the effects of materials on industrial design?
- Why does the material selection process constitute an important problem for industrial designers?
- What kind of an 'information' do industrial designers need about 'materials' in the design process?
- How is the material selection process arranged in the design activity?
- What are the frequently used materials selection sources in the related literature and in Internet?
- What are the 'sources' used by practicing industrial designers in Turkey?
- How much do they know about the existing sources?
- What sort of information do they need to learn about materials?
- How do they prefer to access the information of materials?
- Do they have chance to select (suggest) new materials for their designs?
- What are the criteria to select a new material for their design?
- Do they follow the improvements and/or novelties in materials and manufacturing technologies?
- Do they find themselves qualified enough to select a material in the design process?
- What do they think about the ' techniques in design education' for materials?
- What is the most critical value for them while selecting a material?
- Do they use any emotional criterion while selecting materials for their designs?

1.2 STRUCTURE OF THE THESIS

After seeking the answers to those questions, the material selection process, the required data and the presentation techniques of the data on materials will be explored. Consequently, guidelines for a material selection source for industrial designers are aimed to be proposed.

For this aim, in the second chapter, the author concentrates on the effects of materials on a design product from the viewpoints of industrial designers, manufacturers and finally society. This chapter also includes the perceived values of the materials in a cultural context. In the third chapter, the author basically explores material selection in design activity. Therefore, first she defines the factors affecting the designers' choices in material selection then she evaluates the material selection process. Later in the same chapter, she evaluates the existing sources on materials selection and other research on the same topic.

The fourth chapter consists of the field study conducted with 20 industrial designers practicing in Istanbul, Ankara and Izmir. The chapter includes both the methodology of this research and the evaluation of the interviews and questionnaires applied to those designers. The author also makes comparisons of her own results with the findings of other research in this chapter. In the fifth chapter, gathering all the findings from the previous sections and guidelines are proposed for an appropriate material selection source. Finally, in the sixth chapter, she summarized all of her findings for this research and recommended a materials selection model for industrial designers in Turkey by listing the most significant criteria on materials selection activity.

1.3 AIM OF THE STUDY

The goal of this thesis is to evaluate the usefulness or otherwise of **existing materials information** for industrial design practice and **to suggest guidelines** to provide materials information input for the design process based on practicing designers' expectations from such an information guide.

1.4 DEFINITION OF TERMS

'**Material**' means that the thing needed for producing design object. The basic materials, which will be used in this research, are: woods, metals, glasses, ceramics, plastics and fabrics. The **material perception** is the mental grasp of the consumer towards these materials with the visual and the tactual information.

Materials selection: industrial design cannot be easily formulated as a method so its requirements are much more than creating an excellent product regarding to its function and usability; it requires creating a product personality. "Material Selection" is one of the most significant tools to create this personality for industrial designers.
Therefore, in this study, the term "**material selection**" is used for emphasizing the selection of appropriate materials for design products, by considering all the design requirements such as manufacturing, availability, target market, product personality, cultural aspects, cost, etc.

CHAPTER 2

EFFECTS OF MATERIALS ON INDUSTRIAL DESIGN

2.1 MATERIALS AND DESIGN

> Industrial design is a process of creation, invention and definition separated from the means of production, involving an eventual synthesis of contributory and often conflicting factors into a concept of three dimensional forms, and its material reality, capable of multiple reproduction by mechanical means. It is thus specifically linked to the development of industrialization and mechanization that began with the Industrial Revolution in Britain around 1770… (Heskett, 1980, 10)

The Industrial Revolution brought about an enormous increase in the use of natural resources. The impact of increasing scientific knowledge about the nature of materials provided considerable changes and developments in the techniques used in processing materials. These changes led development away from a trial and error approach, to a science based technology. By the end of nineteenth century, new methods were being used to work on traditional materials and to introduce the new ones. It resulted in new forms and designs for bridges, buildings and methods of transportation as well as new products in everyday use (Chapman & Peace, 1988). Therefore, the most of the contemporary design definitions from historians are associated with the industrial revolution, mass production manufacture, the modern movement in architecture, and the consumer society. Therefore, it was inevitable to begin a new term for manufacturer firms and society as well as designers.

2.1.1 Effects of Materials on Designed Products

The most obvious effect of Industrial Revolution on design was that: no longer was design thinking in terms of single components, but in units, in sub-assemblies processing different materials which affected the nature of a variety of goods-especially from the consumer's point of view.

Forester (1988) explains the topic with an example from automobile industry because he believes that the automobile industry can be a good example to explain the changes in designer attitudes towards the design activity because planning the production of a car involves complex computation of the relative merits of particular materials and production processes. According to him, changing consumers' preferences in durability (reduced corrosion), performance (improved aerodynamics), and style have created a further wave of materials innovation in the auto industry. In fact the combined impact of all these forces caused a dramatical change in the materials content of cars to the extend that many late 1980s cars bear little resemblance to late 1950s models (9).

Another sector, the American porcelain dinnerware industry virtually disappeared because it was not able to grow beyond traditional styles and it couldn't battle with newly produced materials. Designers have demonstrated that they could conceive new forms in new materials (Clemenshaw, 1989).

On the design and material relationship, plastics most probably have become the most versatile materials encouraging designers on creating new products. Katz (1978) argues, however, " Streamlining in plastics is an inherent characteristics of the material. Plastic objects are curved because polymers need to flow within the moulds and corners are difficult to produce.' In other words, she believes that, instead of inciting designer for creating new forms, plastics, because of their physical properties, force designers to create similar forms by removing the object from the mould. As like Katz, Sparke (1986) states that, “Perhaps more than any other single material it is plastics which have encouraged designers and the manufacturers to move towards aesthetic simplicity in the mass produced artefects.” (135)

Actually, it can be said that, a design in plastics is the result of many forces. Some are technological- someone had to design the resin and the process for shaping it; some are economic- capital investment and marketing considerations; some, including environmental and safety regulations and fashion, are purely social. For instance, Ashby (1992) uses this quotation from Misha Black, a Royal Designer for Industry (The Design Council, 1986): “We should approach each new problem on the base of practicality -how can it most economically be made, how will it function most effectively, how can maintenance be simplified, how can the use of scarce materials be minimized? An absolute concern with practicalities will produce new formal solutions as technology constantly develops; when alternatives present themselves during the design process, the aesthetic sensitivity of the designer will determine his selective design.” (237)

Besides, Ashby explores the evolution of the telephone as a designed object. According to him, the function of the telephone, and the manner of achieving it, has hardly changed since the days of Alexander Graham Bell (1847 -1916). However, new materials and manufacturing technologies affected its form evidently (Figure 2.1).

FIG 13.1 Telephones: (a) a wall telephone, circa 1900; (b) a "candlestick" or "tulip" telephone of 1920-1928; (c) the standard Ericsson telephone of 1928 – 1970; (d) a telephone of the period 1970 – 1980; (e) the telephone of 1982, making good use of polymers, but unappealing in its form, weight and proportion.

Figure 2.1 Evolution of telephone with new materials (Ashby, 1992, 235).

As it can be seen in Figure 2.1, plastics are amenable to a variety of processes: injection molding, casting, sheet molding, drawing filaments. Design in plastics is heavily influenced by what can be willingly cut in metal to make their moulds. Achievements in metal technology dictate what can be achieved in plastics. On the other hand, Clemenshaw (1989) explains this point from another perspective and says that the extreme malleability of plastics creates a demand for more creativity in shaping metals to work the plastic with. Therefore, the improvement of a specific material not only affects design objects produced by it, but also the objects with other materials ultimately.

Conversely, the tactile experience of plastic artifacts is generally unrewarding- plastics is smooth and lukewarm to the fingertips, not brilliant in its hardness like porcelain or steel. However, Dormer (1990) says that, product designers are working- although rarely in an imaginative way- to improve the range of tactile experiences, usually by designing in indentations or edges on those parts, which are to be handled by the user.

According to him, one of the commonest strategies adopted by designers seeking to enliven the plastics' surface has been to pattern it- often copying natural materials such as wood or marble (64). Using the plastics as surrogate materials by imitating natural materials has become the designers' approach to the new plastics products for a long time to make the society get used to this new unnatural material.

Another worthy analyze is made by Edwards and Endean (1990) on kettles, which will be considered deeply in the next chapter of material selection process in design activity. They explain that the early kettles were intended to be visually attractive, although they needed polishing regularly to maintain their bright finish and could be repaired if leaky, so they lasted forever. However, these kettles were complex to manufacture because of their complicated shapes but were regarded as something of a luxury item by the society. They therefore commanded a reasonably high price and people who owned them were willing and able to take the time to keep them polished and looking attractive. However, as expected, the general standard of living of the population increased through the 1950s and 1960s an electric kettle stopped to be seen as a luxury. The increased demand for them meant that they had to be made in larger numbers and would therefore be sold at a lower price. But they had to be easier to keep clean than the early copper products. *This required different materials and surface coatings*, stainless steel, chromium plating and so on, and designs, which could be manufactured cheaply in these new materials. (384)

Briefly, as Ashby and Johnson (2002) emphasize, the form of any design object has been strongly influenced by the nature of the material of which it is made. In other words, “ form follows material” (101).

2.1.2 Effects of Materials on Manufacturers

Manufacturing is a very broad activity used to convert materials into products. The manufacture of most products involves a number of individual processes, and the choice of a process for each stage involves estimating the features of competing processes, which can affect both the quality, and the cost of the product.

There is a close link between the shape of a product, the choice of a material and the choice of a process best fit to both. Therefore, a manufacturer, as like designers, is constantly trying to resolve the conflict between them. The product will require a set of properties from the material but a process capable of creating the necessary shapes may require a quite different set of properties related with the materials physical, mechanical and chemical properties. On the other hand, the material may be suited to certain processes, which generate new design possibilities in the product, which resulted with the appearance of some inclinations on designers towards some materials with ease of manufacture.

From the manufacturers' point of view, the tremendous expansion on materials world encouraged also producers to develop new end-products applications for the material they make and sell. Their marketing activities have necessarily included the development of a wide range of new consumer and industrial products and of the processes by which these products are made. Corey (1956) states that, an important element of competitive strength for these manufacturers has become the skill in design and they might therefore favor the use of a material, which offered the greatest possibilities for developing original and imaginative products (26).

Likewise, the marketing strategy of the producers has changed simultaneously with the new manufacturing approach on using new materials. According to Corey (1956), to establish an image of a new product converted from an old one with some of its superiorities in its appearance and cost has been likely to be the requirement of market success, which has brought up the selective demand with it. In the creation of selective demand, the promotion of the branded materials at the consumer level has been an important part of marketing strategy. Promotion of the material brand name is intended to enhance the reputation among consumers of end products made of these materials and hence to create among end product manufacturers a preference for the branded material over competing products, such as 'styron' in the polystyrene field (185).

2.1.3 Effects of Materials on Society and Their Attitudes on New Products

With the improvements in design and technology, the changes in societies' attitudes were inevitable. First of all, the new materials brought about changes on factory floor and commercial organizations, which created new opportunities for business in society (Forester, 1988, 113). Innovation in materials to a great extent determines the pace of technological advance in many key industries- especially the computer industry- that in turn greatly influences productivity, capital formation, the demand for labor, and the overall rate of economic growth.

Dormer (1990) explains the changes encouraged by the new technology and materials of the late 20th century with three cultural phenomena. Firstly, there appeared a move away from a heavy to lightweight and sometimes-invisible infrastructure. Secondly, the gap between the natural one and the manmade one has been narrowed. Finally the third trend, a retreat from non-renewable resources, is also the beginning of the research for re-usable materials, including a new generation of plastics in almost every industry. According to Dormer, these three trends influenced the nature of design as style and made sharper in the 1990s the arguments over " how designers can help people feel comfortable with new technology without having to disguise the new with a packaging from the past" (62). Moreover he emphasizes that, " materials science and information technology are delivering to us a culture in which our experiences become more complex, less substantial and, in the secular sense, more spiritual…" (62).

The values of some particularly used products have also changed gradually. The value and durability of kitchenware were associated with rigidity, weight and expense-ceramics, glass and iron for a long time by society. However, with tupper's[1] new products, by its very nature, simple modern shapes that were flexible, durable and eminently adaptable for refrigeration, storage and table use, just the opposite philosophy prevailed among the public (Clemenshaw, 1989).

Clemenshaw describes the Tupperware' s history as follow:

> In 1947 *House Beautiful* magazine commended the form of Tupperware products as being art objects, and compared their material to alabaster[2] and jade[3]. Other similar recognition came from their selection by the Museum of Modern Art for its Good Design Exhibitions in the 1950s. The public accepted these honors as being justly deserved recognition that precious materials and uniqueness were not the only criteria upon which esthetic value should be based and that even the humblest products could also have eternal cultural value (8).

On the other hand, while the new products with new materials were emerging like Tupperware products, the public was being bombarded by images of all times and places, the fantastic or exaggerated as well as the authentic with new materials (Meikle, 1995, 8). The boost in the diversities of those new products caused the appearance of a new name for public: the 'throwaway society'. They began to get used to the notion of: 'this is not worth repairing, it will be cheaper to buy a new radio/ iron/ vacuum cleaner.' (Dormer, 1990, 70)

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[1] Tupperware brand products made their debut in 1946. Tupperware now reaches nearly 100 markets around the world with its 'hygienic', colorful plastic products especially for kitchen wares (source: Tupperware website)

[2] Alabaster: a compact fine-textured usually white and translucent gypsum often carved into vases and ornaments (su mermeri, kaymak taşı)

[3] Jade: A stone, commonly of a pale to dark green color but sometimes whitish (yeşim). (kaynak: www.seslisozluk.com)

Actually, those kinds of shifts in societies and their attitudes towards new products did not go on for a long time. Schivelbusch (1979) explained that, " Only during a transitional period do new technologies evoke 'a sense of loss' in those who experience them. Soon people develop 'a new set of perceptions' and accept as 'natural', even desirable, events or objects formerly experienced as violations of their expectations of the world." (17-18). In other words, familiarity enhances acceptance, as acknowledged by a journalist, Wilson (1988), "children whose first experience of the world comes from Toys 'R' Us may be developing a different set of material values than adults who grew to maturity surrounded by wood stone, and metal."

In 1979, when the annual volume of plastics exceeded that of steel, especially the United States had entered the 'Plastic Age'. Plastics were in everywhere from computer housings and electronics components to automobile interiors and high-tech sports equipment. Bright artificial colors and textures of many plastic artifacts indicated acceptance of high-tech styling. The variety and fancy of their forms were proving the extraordinary degree of materials' possibilities. (Meikle, 1995)

The 'Plastic Age' was identified not only with plastic but also with 'information technologies'. That is; the prevalence of information reached to a satisfied degree with devices for recording, storing, reproducing, and manipulating sounds, words, and images. Though physically sheltered by the built environment, people found their emotions and thoughts ever more stimulated by immaterial experiences (Meikle, 1995, 8). Of course, the plastics were the main element of this information technology and facilitated these synthetic experiences by means of film, tapes, discs, and coatings receded from view and from consciousness (Larson et al., 1986).

As a result, everything becomes plastic day by day and this convert a culture to a different one with its new attitudes towards new products. For the aim of exploring the impacts of plastics on a specific culture, Cleminshaw in his book of *Design in Plastics* (1989), used a quotation from Kenji Ekuan, a famous Japanese industrial designer:

> The Japanese people have so entirely based their sensitivities upon the transience of time that they even include their own deaths in their natural calendar, and they keep transience in mind in everything they do. Thus they feel not only uncomfortable with, but they even hold a horror of this thing called plastic that denies death; that even when death of use/function finally comes does not show its death in a change of shape, that never undergoes any change. The way that plastic goes into their life as a substituted material, even though they appeared to be absorbed in the making imitations with plastics, caused an inveterate distrust of this new material in the hearts of the Japanese. (10-11)

2.2 EFFECTS OF NEW MATERIALS ON INDUSTRIAL DESIGN FROM A CULTURAL PERSPECTIVE

With all those changes in daily life with the effects of new materials as seen in the previous section, industrial designers began to consider some indefinable characteristics of materials for the purpose of creating different perceptional values such as emotions, associations, experiences and cultural differences among those for functional superiority.

According to Ljungberg and Edwards (2003), the material itself can have a certain metaphysical value. They explain this metaphysical value with different examples. One of them is the villa made of wood. Although they are quite popular in Scandinavia, in Middle Europe such houses are often met with skepticism. The enterprises of the Scandinavian villa producers to export the wooden villas to Germany did not work since German people normally think that wooden houses are inferior and simpler than houses built of stone or concrete. On the other hand, while in Mediterranean countries, wood is perceived more as a luxury material because it is quite rare and therefore an expensive material, in Scandinavian countries, since wood is very common, a house built of stone is typically perceived more expensive and prestigious than a wooden one.

Another example given by them is the kitchen worktops and sinks of different countries. For instance, in a country such as Turkey, kitchen worktops and sinks have traditionally been made of stone (e.g. marble), while in Sweden stainless steel has been used. The preferences on stainless steel may be correlated with the approaches to the Bang & Olufsen[4] products which are identified as prestigious, expressed to the customers by a unique design and the use of valued materials such as aluminum, which gives a cold and somewhat Nordic feel to the products. With those examples, there is little doubt that the metaphysical values created by the consumers have great impacts on perceiving an object as well as the real cost of the material. (Ljungberg and Edwards, 2003, 11)

Therefore, industrial designers are using those values wittingly or unwittingly. The quality of a product and its material is related with the consumer's experiences and the personal tastes. If a material or a product already exists, then this has an important effect on the decision by the consumer to purchase a new version of the product. In this situation, marketing people tend to give an impression that the older product is somewhat inferior to its replacement (Ljungberg and Edwards, 2003, 11).

[4] Bang & Olufsen, a firm creating high quality, distinctive, home entertainment products in Denmark, is known throughout the world for its distinctive range of consumer electronic products, which are sold in over 40 different countries worldwide for over 70 years (Source: Web Site).

This can be considered as an explanation of why plastics have had a poor public image over the years, because it was originally intended as a cheaper substitute for other materials (Walker, 1989, 102). In other words, it has been seen as standing in for more traditional materials, especially metals. For example, metal containers are acceptable to us through custom. Since it is widely known how a metal container is produced, it can be estimated that metal is resistant to fire and so it is suitable for cooking; but not plastics. A plastic cooking pot contradicts the common understanding of what plastics are and how it performs: one fears that the pot will melt under around the food (Dormer, 1990, 62).

Like Dormer, Soentgen (1997) claims that, people prefer the traditional materials for their every day use objects because they find plastics not linked to the earth. That is; only very few know exactly how it is manufactured. There is no characteristic of plastics, which attests to its relation to earth. The origin of the plastics is not known, whereas everybody can say the origin of wood. Therefore, the more the people know about the material- its origin and manufacturing techniques, the more confident they feel with the help of having control of that material (49).

For these reasons, plastics have been well suited to its role as a replacement material since its acceptation as a unique material of a design object by the society (Clemenshaw, 1989, 10). Similar kinds of attitudes towards different materials have been built up in time. Wood, for example, as a natural material, has been perceived warmer and softer, and associated with characteristic sounds and smells. It has a tradition; that is, it carries associations of craftsmanship. It acquires additional character with time; so, the wooden objects are valued more highly when they are old. As like wood, ceramics or glass have also long tradition (Greek pottery, Roman glass). Ashby and Johnson (2002) state that, they are the materials of great crafts-based industries. Although today ceramic or glass objects are produced by advanced technology, they still carry the fingerprints of older craftsmen, which make them perceived as highly valued traditional materials.

Ashby and Johnson also emphasize that: " There is a character hidden in a material even before it has been made into recognizable form- a sort of embedded personality, a shy one, not always visible, easily concealed or disguised, but one that, when appropriately manipulated, can contribute to good design..." (75)

To sum up, people see, touch, sample and in the end recognize the materials, which they frequently see all around. In other words, they attribute on the basis of their experiences. There are lots of products around which make people create stereotypes and associate some products with specific materials. These associations give the materials cultural weight and solidity. On the other hand, since the ranges of products are boosting every day, the names of materials associated with those products seem to be charged with broader meanings. For this reason, people do no longer make classifications of materials according to their properties and intrinsic cultural meanings. Instead, they use the materials' levels of performance and evocative images generated as integrating parts of manufactured products (Manzini, 1986, 31).

CHAPTER 3

MATERIALS SELECTION IN INDUSTRIAL DESIGN ACTIVITY

As already mentioned in the previous chapter, different materials made a great influence on industrial design and manufactured products. Today, a good design exploits the special properties of materials; and a good designer must have a good understanding of all materials and manufacturing processes available, in order to have confidence that the proposed material and manufacturing process is the most economical and appropriate one. Therefore, an industrial designer whether acting alone or on a design team is responsible for selecting appropriate materials and manufacturing techniques for design products.

The industrial designer can achieve this through a systematic materials selection process in the design activity. Therefore, in this chapter the author aims to answer following questions: What is the place of materials selection process in design activity? What are the factors that affect materials selection decisions? What kinds of sources used by industrial designers in the design process and how do they present the materials data? What are the findings of other research on materials selection in industrial design?

3.1 FACTORS EFFECTIVE IN MATERIALS SELECTION PROCESS

The selection of a material for a specific application is a thorough, lengthy and expensive process. Almost always more than one material is suited to the application, and the final selection is a compromise that brings some advantages as well as disadvantages.

There are many factors or constraints to be considered in selecting materials. There are of course some situations that the certain criteria for a material are defined at the beginning of the design project. Although at such situations the required criteria dominate the selection process, most of the time the designer selects one material among a range of materials depending on some factors.

At different sources, the factors that affect the materials selection are grouped under various subtitles. For this section, eight sources on materials selection were examined, five of which were engineering based and the others were industrial design based. For example, Patton (1968) states that, when a designer selects a material, he must consider fulfilling the three basic requirements: 1.Service requirements, 2.Fabrication requirements and 3.Economic requirements. According to him, the service requirements are supreme. The material *must* stand up to service demands which commonly include dimensional stability, corrosion resistance, adequate strength, hardness, toughness, heat resistance. In addition to any such basic requirements, other properties may be required, such as low electrical resistance, high or low heat conductivity, fatigue resistance, or others. These properties are all under the title of 'service requirements'. The material must be possible to shape and join to other materials. Patton puts those properties of materials under 'fabrication requirements'.

Finally, he states that, the objective of a designer is to *minimize overall cost* of the product and manufacturing, and this objective is sometimes attained only by increasing one or more of the cost components. For example, a more expensive free-machining metal may be substituted for a standard metal, since the savings in machining cost may overweigh the increased cost of the more expensive metal. Again, the substitution of a light metal, such as aluminum, for a heavier metal such as steel, increases the raw material cost. Therefore, Patton (1968) defines these as economic requirements (10). He adds that, although they are placed last for reasons of organization, they are ultimately the most important ones. To him, indeed, all material characteristics are economic characteristics. The excellent specific resistance of pure copper has only a limited economic value; if copper were the double in price, probably most electrical conductors would be made of aluminum (420).

In another book named *'Materials' (1967)*, the factors, which affect the decision-making on material selection, '*mechanical properties'* of materials and '*cost'* are defined as two basic requirements for designers. The authors explain that, to understand the basis of the mechanical properties of materials have provided the development of material science and encourage designers to explore new usage areas of new materials for new products; because properties of materials define their usage and environment. They list the most important requirements achieved with the mechanical properties as strength and rigidity, quality and durability of the surface. The last requirement, that is the durability of the surface, may be met by a number of accessory materials or treatments, so that it is not usually a critical element in the choice of the primary material. Strength remains as the property most sought. Consequently, industrial designers select materials depending on their mechanical properties to fulfill those requirements (14).

To the cost of the material, the authors of the *Materials* (1967) book mention the cost of fabrication and incorporation in the final product. They believe that, it is not important how the selected material is appropriate for the idea unless it is reasonable for the final cost of production (192).

Similarly, according to Lindbeck (1995) a number of factors affect material selection. He lists those factors as: requirements related with *physical properties* as a material's melting point, density, moisture content, porosity, and surface texture; *chemical properties* related to resistance to corrosion and dissolution; *thermal properties* which are measures of the effects of temperature on materials; *electrical properties* determining materials' conductivity and resistance to electrical charges and *acoustical properties* indicate reactions to sound, and optical properties reactions to light (104). He says that, *mechanical properties* are especially important because they are indicators of strength, productibility, and durability. For example, tension is a force that tends to stretch a material; compression is a force that applies squeeze pressure; torsion is a twisting or torque force; and shear involves two opposing forces tending to fracture a material, as in shearing a piece of paper or metal. Knowledge of such forces, and the ways in which materials react to them, is valuable in determining which material to use in a specific application. (105)

Among those factors, Lindbeck mentions another issue, which he calls as '*indefinable characteristics of materials'*. He defines it as appearance, odor, feel, and general impression that result from special uses and combinations of materials for aesthetic purposes (105). These are directly related with the emotional approaches of the consumers and can easily be affected by the marketing strategies. Patton (1968) also mentions this issue and says that:

> Interesting to note the high value at which the market rates some properties and the low value applied to others. Relatively little economic value is attached to a high modulus of elasticity, for example…the attractive appearance of the plastics vastly overweighs their poor dimensional stability. The predominant market importance of appearance is best illustrated by the use of whitewall tires on cars; such tires contribute no useful function whatever to the automobile and have only two characteristics to recommend them: they are more expensive and people buy them. The latter characteristic

> of market acceptance cannot be safely ignored merely because it satisfies no scientific or engineering criteria. Even scientists who feel that marketing considerations are no part of their lofty calling have bought whitewall tires. (420)

Budinski in his book of '*engineering materials: properties and selection*' (1996), uses a chart to classify the basic requirements for material selection (Figure 3.1). As it can be seen in figure 3.1, Budinski divides the factors to be considered in material selection into four major categories: *Chemical properties, Physical properties, Mechanical properties and Dimensional properties.* As being different from other sources, he uses 'dimensional properties' as an individual title. To him, this category is not listed in property handbooks, and it is not even a legitimate category by most standards. However, he adds that, the available size, shape, finish, and tolerances on materials are often the most important selection factors. So, it can be established with that category of properties relating to the shape of a material and its surface characteristics. Surface roughness is a dimensional property. It is measurable and important for many applications (21).

Another different term used by Budinski (1996) is 'business issues'. To him, in the U.S. and some European countries, environmental and regulatory issues, which he calls the business issues because business must deal with them, can be of equal importance with, or even of more importance than, economic factors. Because, it may not be possible to use a particular material (no matter how appropriate it is), unless it is on the approved list of some regulatory agency. For example, in the U.S., the Food and Drug Administration regulates the materials of construction that can be used for medical instruments (605).

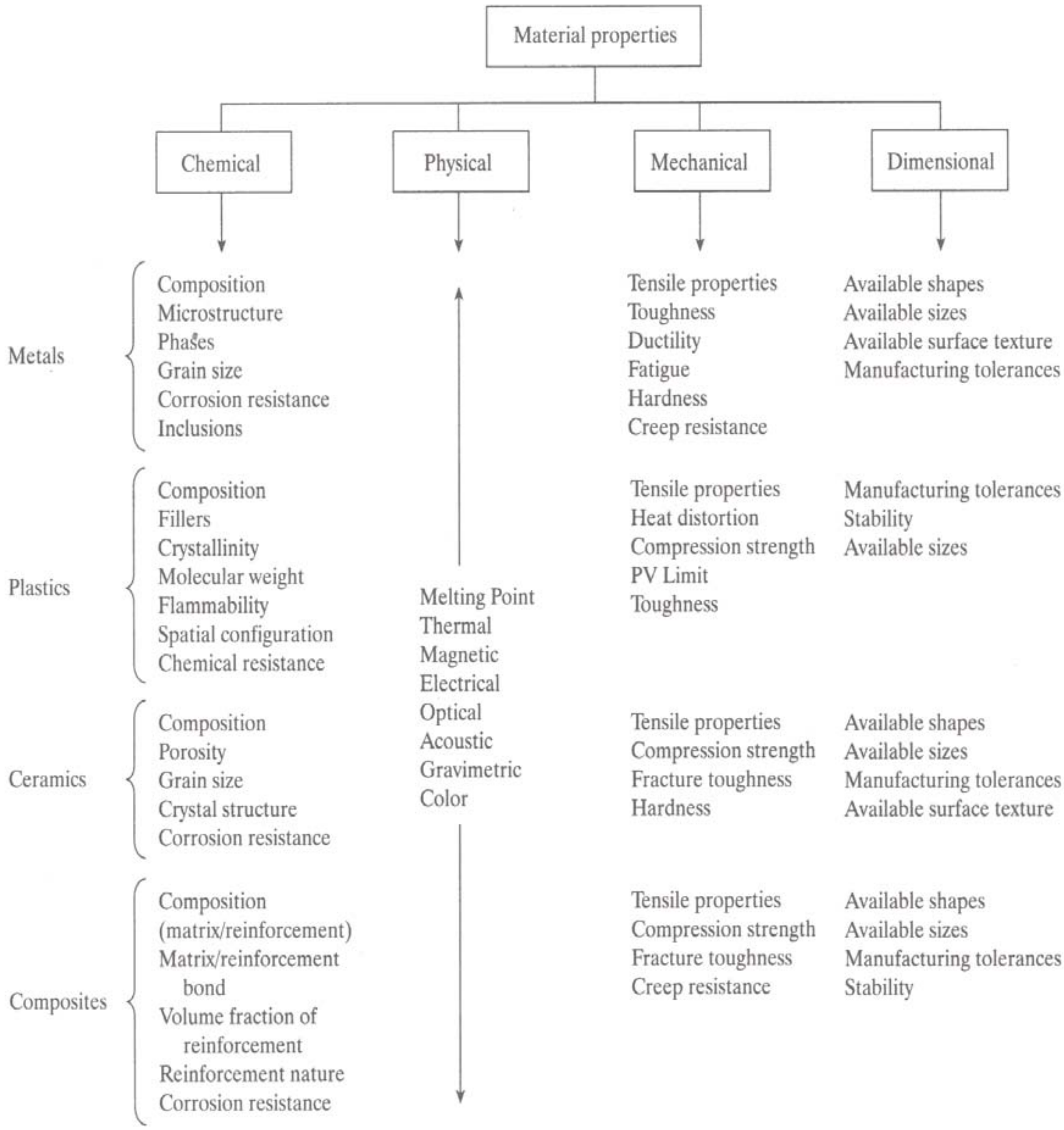

Figure 3.1 The factors to be considered in material selection (Budinski, 1996, 21).

Budinski also emphasizes the significance of the ‘availability’ factor. According to him, one of the first things that many designers ask when initially considering the use of a particular material is whether the material is on hand. A "no" answer will provoke a second question: Can we get it in one week? Two weeks? And so on. If this answer is acceptable, the next question is, do we have to order a minimum quantity? He adds that, there are more than 15,000 plastics that are commercially available, but only a dozen or so are available in standard shapes from warehouses. Since it is the designer's responsibility to establish a time line for procurement of materials, and if a desired material cannot be obtained within the constraints of this schedule, another material will have to be substituted or he recommends selecting materials that are known to be readily available (605).

In another source (Esin, 1980) factors are grouped as (1) production requirements, (2) economic requirements, and (3) maintenance requirements. The author of the source explains that, a material, which has been selected on the basis of its functional merits, must also be *capably produced*. This involves the designer in a consideration of a much wider range of properties such as the ability of the material to be machined, shaped, formed, cast, welded, hardened etc. For most situations, the designer has to make some sort of comparative assessment to select the most favorable material. Like Patton, he believes that the greatest limitation to any material is the final *cost of the product* manufactured from it. The cost of a product is composed of the raw material and the production costs, baring the overheads. He adds that, it must be remembered the cost of any product can be only as high as the potential costumers are prepared to pay for it. Therefore, when a compromise is required, it is usually the compromise between the cost of the finished product and the level of satisfaction of the functional requirements.

Finally, Esin (1980) states that, the designer must also consider the *maintenance requirements*; whether replacement or repair is envisaged will depend upon the size of the part, extent of possible damage, maintenance and repair faci1ities of the potential costumers and the acceptable level of replacement or repair costs (164).

On the other hand, while Esin divides the factors under those categories, he emphasizes that, for most of the design purposes, the properties of materials can be categorized as the 'general_properties' and the 'special properties'. The general properties are the mechanical and physical properties, which are commonly employed in most applications. The special properties may be of secondary importance, or the primary reason for choosing a particular material, such as the electrical or thermal conductivity, resistance to high temperature or chemical attack, etc. In fact, when the functional demands are mainly on special properties, the number of suitable materials relatively facilitates a designer's selection (171).

The 'availability' keyword appears one more time at Esin' s thesis. As like Budinski (1996), he emphasizes that, as far as the material considerations are concerned, the foremost economic consideration is the availability. If a certain material is not available and if the properties of that material are essential to fulfill the functional requirements either the design project cannot be realized or it does not achieve the envisaged performance (171).

Mangonon (1999), a well-known design engineer, defines six factors having influence on material selection: *Physical Factors, Mechanical Factors, Processing and Fabricability, Life of Component factors, Cost and Availability and Codes, Statutory, and Other Factors.* Being called under a different title, here the *Life of Component factors* relate to the length of time the materials perform their intended function in the environment to which they are exposed. The properties in this group are the *corrosion, oxidation, and wear resistance, creep, and the fatigue or corrosion fatigue life properties in dynamic loading.* The performance of a material based on these properties is the hardest to predict during the design stage. As it is seen, he combines '*cost'* and *'availability'* criteria, and explains that, in a market-driven economy, these two factors are inseparable. In addition, he says that, *quantity and standardization* are related to cost and even if the materials are readily available it matters whether orders are made in tonnages or in pounds or grams. The customer also pays a cost-penalty when orders are nonstandard items requiring special processing or are non-stocked items due to very little demand from other customers.

For the last category of *Codes, Statutory, and Other Factors*, which were called as 'business issues' by Budinski (1996), Mangonon states that, *Codes* are sets of technical requirements that are imposed on the material or the component. These are usually set by the customer, or are based from those of technical organizations such as the ASME, ASTM, SAE[1]. *Statutory* factors relate to local, state, and federal regulations about the materials and processes used or the disposal of the material. These relate to health, safety, and environmental requirements (433).

Interestingly, at most of the sources, the environmental issues are placed at the bottom of the listed requirements for industrial designers, although the current design issues give great importance to them. Most of the time, unless the environmental requirement is given as the specific criteria for the project, the designers do not consider it with a significant care. This point will be mentioned in detail in chapter 4, at the section of evaluations of the interviews with industrial designers.

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[1] These organizations will be explained in section 3.3.1 and 3.3.2.

On the other hand, Mangonon (1999) makes a different classification for the current design engineers, and organizes the factors under three topics: property profile, processing profile, and environmental profile. According to him, selection based on the environmental profile relates to the impact of the material, its manufacture, its use and reuse, and its disposal on the environment. He adds, designers and companies feel that if the costs of incorporating them in design are prohibitive, the environmental aspects are usually laid aside, unless law mandates it. However, to Mangonon, in spite of the added cost, designing for the environment is a good strategy because it can be a good marketing tool for environment-conscious consumers (435).

Walker (1989) is another author who mentions the environmental issues and foresees about the nature of the society related with the environmental issues. He believes that, the enlarged consumption of materials means that the society shall have to cope increasingly with natural resource and supply problems- and also with energy problems, for the extraction, processing, creation, or recycling of materials requires enormous consumption of increasingly scarce energy resources (86,87).

Johnson and Ashby (2002) define for materials two overlapping roles as: providing technical functionality and creating product personality. Accordingly, they add some emotional factors affecting the designer's selection in their requirements list. To them, the requested design requirements by selecting appropriate material are: technical, economic, sustainability (related with environmental issues), aesthetic, perceptions and intentions. In the next section, which explores material selection process, the contents of those requirements will be evaluated more comprehensively.

3.2 MATERIALS SELECTION PROCESS

Up to this section, the author has been concentrated on the impacts of materials on industrial design and the various interrelated factors that are considered in the material selection process. Obviously, the varied requirements demanded of any material cannot be treated in the right perspective without understanding the fundamental aspects of the design procedure (Esin, 1980, 149). As explained at the introduction section, the aim of the thesis is to develop 'guidelines' for material selection in industrial design. Therefore, the following section is devoted to a brief survey of the fundamental aspects of the design procedure as regards the material selection and use.

Every design effort, as it is widely known, starts with a need or some form of a problem statement that needs to be solved. This need may come from a client or a customer when an industrial designer works independently or for a consulting firm, or it may come from the company who employs the designer. Depending upon the nature of the design, it is sometimes the functional requirements, and sometimes the design limitations that dictate the properties that have been sought. Since the author is interested in the use of materials, the need is usually a tangible product that may be a component or a structure. The product may be completely new or may be a redesign of an older component because of size or performance limitations.

According to the defined needs, a designer determines the essential and desirable features of the design. As it is impossible for a design to satisfy all of the requirements to the same degree, in order to be able to identify the areas of compromise, the requirements are then arranged in the order of importance. The next step in design work is to define the boundaries within which the solutions must be achieved. Esin (1980) states that, no designer is at liberty to bring a solution purely of his own accord and therefore a design has to be in compliance with certain inevitable limitations.

According to Ashby (1992), design is an iterative process. The starting point is a market need or an idea; the end point is a product that fills the need or embodies the idea. Between lie a set of stages: the stages of *conceptual design, embodiment design* and *detailed design.* He briefly explains these stages: at *the conceptual design stage* all options are open, that is, the designer considers the alternative working principles or schemes for the functions which make up the system, the ways in which sub functions are separated or combined, and the implications of each scheme for performance and cost. *Embodiment design* takes a function structure and seeks to analyze its operation at an approximate level, sizing the components and selecting materials, which will perform properly in the ranges of stress, temperature and environment suggested by the analysis. The embodiment stage ends with a feasible layout, which is passed to *the detailed design stage.* Here specifications for each component are drawn up; critical components may be subjected to precise mechanical or thermal analysis using finite element methods; optimization methods are applied to components and groups of components to maximize performance; materials are chosen, the production route is analyzed and the design is costed. The stage ends with detailed production specifications (6).

While Ashby divides the design process into three stages, Mangonon (1999) believes that two more stages should be evaluated separately. So, he defines five stages in design process as: (1) clarification of the need, (2) conceptual design, (3) embodiment design, (4) detail design, and (5) manufacture/assembly. Like Ashby, he also says that the design process is an iterative process; that means that the designer has to constantly weigh the results of each phase against the constraints and requirements (430).

a) Material selection process in design activity

Once the designer has firmed up in his or her mind the requirements of each part, it is time to make detail drawings. According to Budinski (1996), material selection is a key part of this step in the design process. A set of drawings must be produced that shows the shape, dimensions, material of construction, and applicable treatments or special sequences. Figure 3.2 schematizes the design activity pointing out the materials selection process in that activity. Esin (1980) used a similar diagram explaining design process within the material selection (Figure 3.3).

NEED	
⇓	
FUNCTIONAL REQUIREMENT	(Order of importance, level of satisfaction or failure criteria}
⇓	
DESIGN LIMITATIONS	(Production requirements Economic requirement Maintenance requirements)
⇓	
DEFINITION OF THE PROBLEM	(Material selection)
⇓	
MATERIAL ALTERNATIVES	(Storehouse of knowledge, Experience)
⇓	
FINAL CHOICE	(Merits, limitations)

Figure 3.3 A simple flow diagram of design thinking for material selection (Esin, 1980, 151).

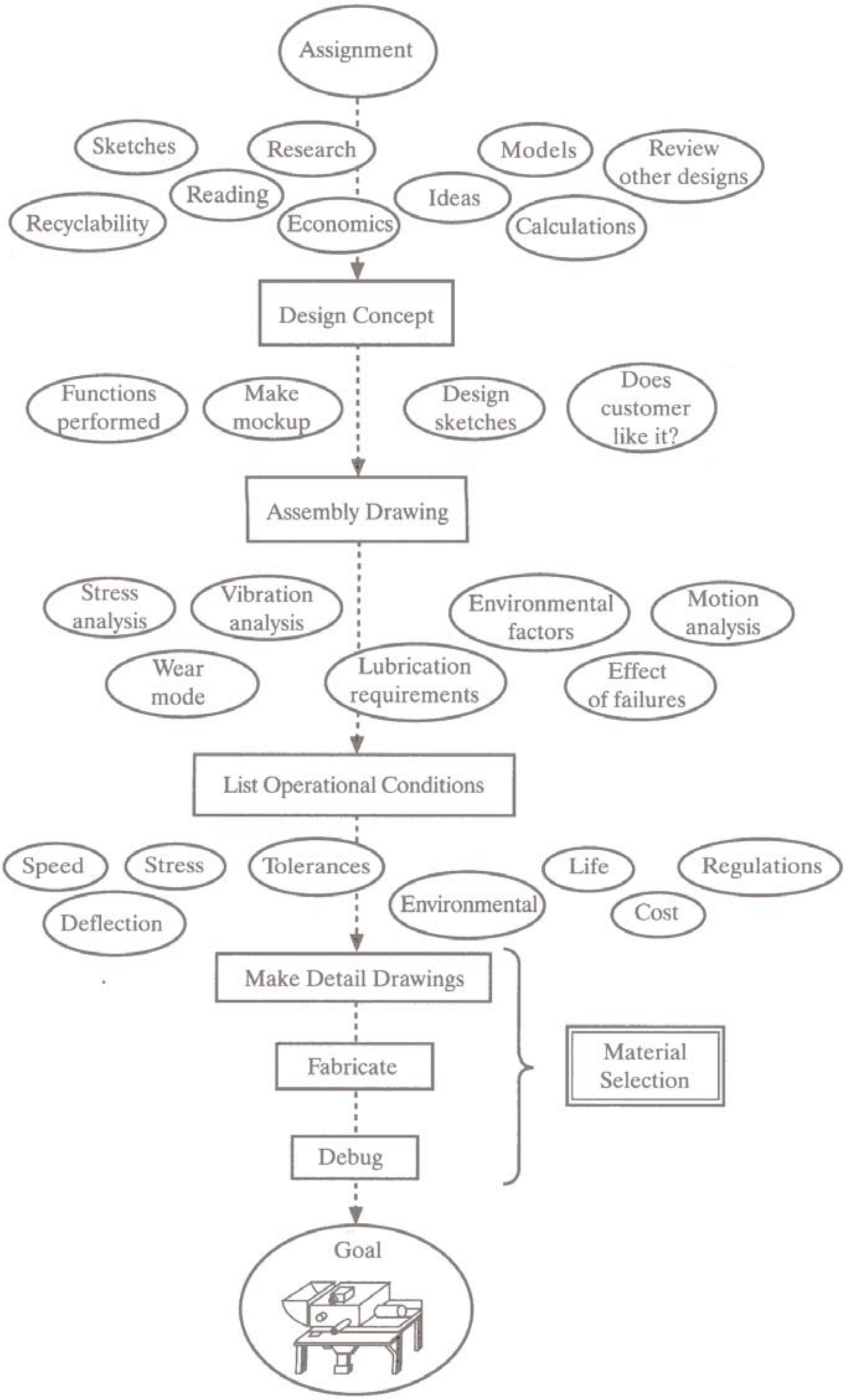

Figure 3.2 Role of material selection in the design process (Budinski, 1996, 597)

On the other hand, Ashby (1992) explains that, data for material properties is needed at every stage in the design process and the designer considers the appropriate materials at every stage. However, the nature of the data needed in the early stages differs greatly in its level of precision and breadth from that needed later on. For example, at the conceptual design stage, the designer requires approximate data for the widest possible range of materials. All options are open: a polymer may be the best choice for one concept, a metal for another, even though the function is the same. He adds that, the problem, at this stage, is not precision; it is breadth and access: how can the vast range of data be presented to give the designer the greatest freedom in considering alternatives? (8)

A similar approach comes from Mangonon (1999). According to him, choice of a material should start at the conceptual stage when a very broad class of materials is identified as possible materials. Like Ashby, he also emphasizes that, although the designer needs materials data from the beginning of the project, the types and level of information differentiate at every stage. For instance, preliminary designs can be made based on the published range of properties in handbooks. In addition to making the decision on the type of material, the designer at this stage should identify the materials seller. In the final detail design stage, final design is made based on the date of the actual material to be used, such as that coming from the identified vendor (that is seller); it also might be advisable to ask for statistical data indicating the range of properties of that material (430).

Therefore, as stated by Ashby (1992), the further advances the process, the higher level of precision and detailed information needed by the designer. For instance, embodiment design needs data for a separation of materials, but at a higher level of precision and detail. They are found in handbooks or in computer databases, which contain the same information (Sections 3.3.1 and 3.3.2.). They list, schemes and compare properties of a single class of materials -metals, for instance -and allow choice at a level of detail not possible from the broader compilations which include all materials. However, at the final stage of detailed design requires a still higher level of precision and detail, but for only one, or very few, materials. Such information is best found in the data sheets issued by the material producers themselves (Section 3.3.2.).

Ashby (1992) believes that, in the detailed design stage, a supplier must also be identified, and the properties of his product used in the design calculation; that from another supplier may be different. Sometimes even, if the component is a critical one (meaning that its failure could, in some sense or another, be disastrous) then it may be prudent to conduct in-house tests, measuring the critical property on a sample of the material that will be used to make the product itself (8,9).

Budinski (1996) also emphasizes this issue like Ashby and states that, the latest steps in the process are to fabricate (manufacture), debug (control), and put in service. Materials enter into these steps in fabricability and substitution of new materials for the parts that did not make it through debugging. The major principles pointed out are that the designer should start to think about materials of construction quite early, and, more important, effective material selection is predicated on knowing the operational requirements of every part. He adds that, the designer simply cannot select a material for a part without knowing what that part must do in service (595,596).

When the material selection process is discussed specifically, it can be said that, the selection process is divided into two main phases: (1) defining the problem and establishing the essential and desirable requirements and (2) searching for materials that best meet these requirements. Considering the number of candidate materials, unless the problem is of very special nature, an industrial designer is seemingly faced with the problem of making the right choice out of thousands of materials. However, in practice neither it is necessary to work with a huge list, nor it is possible due to a number of constraints. The main objective of the designer is to make sure that all material alternatives are given fair consideration before the material for a certain application is specified. How is it possible?

According to Ashby (1992), the selection of a material cannot be separated from the choice of shape. To achieve the shape, the material is subjected to manufacturing processes. To him, function, material, shape and process interact and the interaction between them lies at the heart of the material selection process (Figure 3.4).

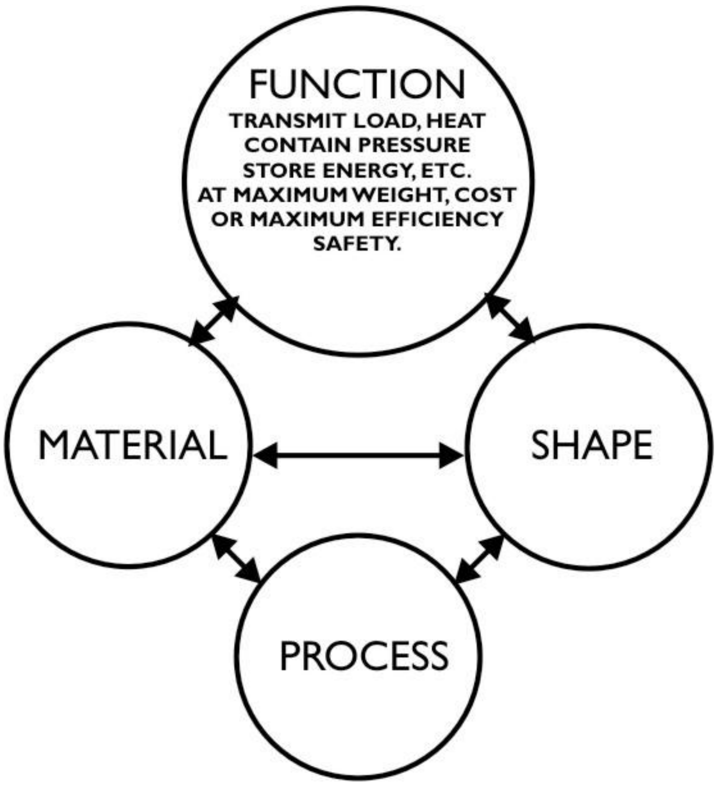

Figure 3.4 The interaction between function, material, process and shape (Ashby, 1992, 10).

Function dictates the choice of material. The shape is chosen to perform the function using the material. Process is influenced by material properties: by formability, machinability, weldability, heat-treatability and so on. Process obviously interacts with shape -the process determines the shape, the size, the precision and, of course, the cost. As it can be followed from the diagram, Ashby defines those interactions as being two-way: specification of shape restricts the choice of material; so, too, does specification of process. He adds that, the more sophisticated the design, the tighter the specifications and the greater the interactions and the interaction between function, material, shape and process lie at the heart of the material selection process (Ashby, 10).

Edwards and Endean (1990) also define the material selection as a subsystem in design process placing at the center of the whole activity (Figure 3.5). They explain that, comparison of designs at material selection stage involves evaluating them with respect to the marketing requirements of the product. It also involves using specific algorithmic tools such as stress analysis, fatigue design and costing (24).

Apart from the defined criteria above on material selection procedure, the final selection also differs naturally from culture to culture. For example, Ashby (1992, 175) states his own observation about Turkish people and points out that, in Turkey, people rely on domestically produced materials and Turkish designers can accept it as a design philosophy. Therefore, these kind of considerations must be evaluated at every stage of design on material selection.

There were several examples to examine in some detail the interaction between ways of making a relatively simple product and the materials from which it can be made at different sources. One of them was the electric kettle by Edwards and Endean (1990).

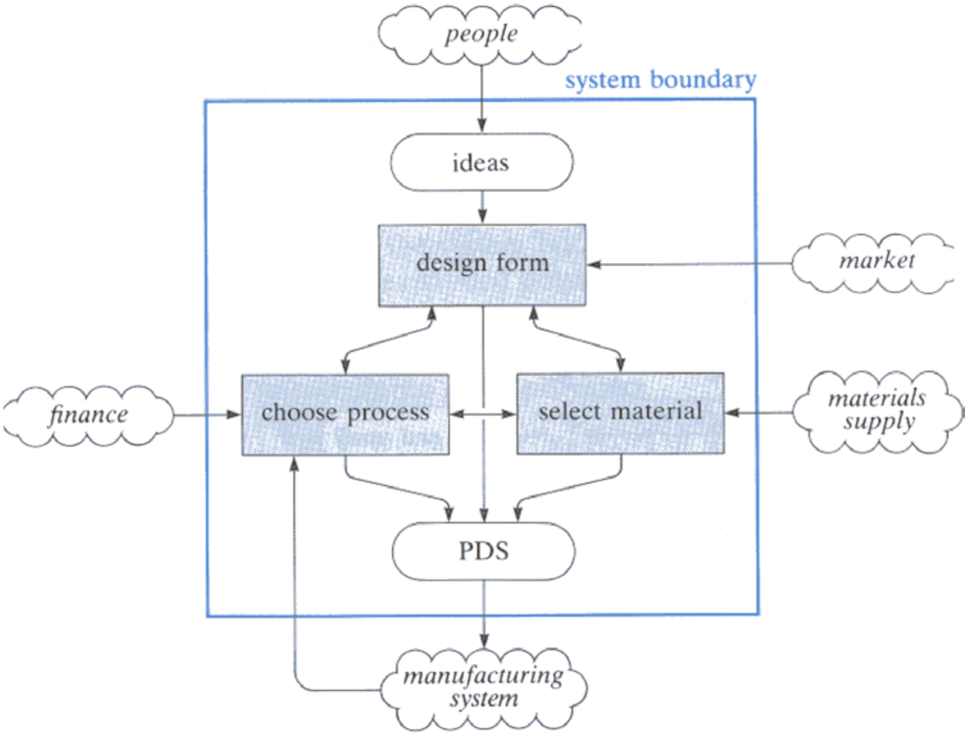

Figure 3.5 The design subsystem (Edwards and Endean, 1990, 24).

b) Material selection for 'electrical kettle'

Before examining the functional requirements of the design and deciding what materials could be used, Edwards and Endean (1990) find helpful to review the history of the electric kettle from a manufacturing standpoint. They believe that, the history of a product often provides a good illustration of improvements on different materials. After that, they want the designers to write a requirements list aimed to achieve with the newly designed kettle body, and to ask himself these two basic questions:

> "What types of material can we rule out without further consideration?"
>
> "Why can you not choose a specific material at this stage?"

At that point, Edwards and Endean emphasize that, when thinking about different materials for an application, it is important to differentiate between the characteristics of a material, which make it either suitable or unsuitable, and those, which, if unsatisfactory in some way, can be modified to suit. For instance, regarding the kettle project, rubber is unsuitable because it does not have an adequately high modulus to retain its shape when full of water; on the other hand, earthenware is unsuitable because it is porous, but it could be glazed with a glassy outside layer to keep the water in (386).

In order to narrow down the choice some further decisions have to be made about what the kettle will look like and how it is going to be manufactured. The emotional aspects and some cultural values can also be helpful for that stage.

In the end, the designer evaluates all the factors and selects the best material and manufacturing process combination which will provide the lowest overall manufacturing cost for the whole kettle. Obviously, the 'cost' factor in material and process selection again takes its place at the end of the activity for the final decision. Therefore, it is important to consider not just the production of a simple container but also other parts and connections from handles to switches. Fortunately, with the help of the sources including comparison charts among materials, the designer can simplify the decision process and combine one process with a different material. (386, 415)

Therefore, to sum up, the act of selection involves defining set of design requirements and converting them to a list of viable materials and processes. For the detailed selection, a profile of required process performance is deduced for the manufacturing system and this is compared with the known performance of the short listed candidates. There are several methods on material selection activity. Johnson and Ashby (2002) classify those methods as: (1) analysis, (2) synthesis, (3) similarity and (4) inspiration (127-132).

Actually, a designer, consciously or not, uses those methods. For instance, he or she sometimes uses precisely specified inputs and the well established deign methods of modern drawing on databases of materials, which is defined by Johnson and Ashby as ‘selection by analysis’ method by deductive reasoning. The other way of selection can be basically depended on past experiences, recovered by seeking a match between the desired features, intentions, perceptions or aesthetics and those of documented design solutions, stored in a database of product ‘cases’, which is called as ‘selection by synthesis’.

If the designer looks for materials with selected attributes matching with those of another existing material, the method is called the ‘selection by similarity’ method. And finally, if the designer visits stores, viewing the products and materials for seeking ideas by randomly until one or more are found appropriate for the project. This time, the method is called as the ‘selection by inspiration’.

Each of the methods has some strengths and weaknesses, and one of them may suit for one project, the other for another. Ashby and Johnson recommend designers to combine all those methods for a more powerful selection. The results of the field study will be evaluated also from the perspective of Ashby and Johnson’ s approach at Chapter 6.

3.3 EXISTING MATERIALS SELECTION SOURCES

After exploring the material selection process in design activity, now in this section, the author will concentrate on existing material selection sources used by designers at material selection process.

The main sources on the practice of material selection (but not particularly for industrial designers) include the databases- both published and software products. As regards with designers, the 'fairs' and 'conferences' are also used as sources, which are related with the direct experiences of practicing designers which will be mentioned in Chapter 4. There are also some organizations practice for developing new materials and present them to designers for prevail usages of them at market. Therefore, this section will list some examples from those mentioned sources above and finally evaluate their presentation techniques in general.

3.3.1 Materials' Suppliers

The author explored some significant suppliers and selected four widely known as examples. Actually, those suppliers offer a number of engineering design tools that can aid the engineers and designers especially in the design of plastic products. These tools provide access to valuable engineering data, and the ability to perform material searches and online calculations to help determine design feasibility.

The first one is **GE Plastics**, which is one of the leading organizations in materials technology and customer support in plastics industry. GE Plastics has remained the pacesetter in high-performance polymers since introducing its first engineering plastic, LEXAN® polycarbonate resin, in 1958. The company's global stature and phenomenal growth are attributable to a commitment to develop advanced technology, and to deliver practical customer support and unparalleled service.

The organization provides datasheets for designers and also sends samples of their products. The employees of GE Plastics visit the companies regularly and make demonstrations to present new technologies and new materials of the company. Anyone who wants to be a member of the organization can easily access the membership information and some datasheets from the firm's website: http://www.geplasics.com.

The second common material supplier firm is **3M**, which was founded in 1902 at Minnesota. 3M is contributing in many markets by different range of materials. For example, recently, 3M introduced a halon-replacement alternative to hydrofluoric carbons and perfluorocarbons for extinguishing fire. Plastics compose the majority of the firm's products' range. The website of the firm: http://www.3m.com

Third one, which may be the oldest one, providing datasheet is **Dupont** founded in 1802. When Dupont was founded, it was primarily an explosives company. One hundred years ago, their focus turned to chemicals, materials and energy. Today, they are delivering science-based solutions in areas such as food and nutrition, health care, apparel, safety and security, construction, electronics and transportation. The website of the firm is http://www.dupont.com

The last one is **Bayer**, which was founded in 1883 and developed into a chemical company with international operations until 1913. The creation of a worldwide sales organization was a decisive factor in the company's continuing development. Today, the Bayer Group intends to maintain its focus on its core businesses and in the future concentrate on health care, nutrition and innovative materials. The website of the firm is http://www.bayer.com

The firms mentioned above provide online material selection database for users as well as the datasheet. The examples of those sources will be explored extensively in sections 3.3.2 and 3.3.3.

3.3.2 Published Sources

The traditional sources of materials data are handbooks. Interestingly, the first significant literature on materials was written by a practical metalworker not a materials engineer in about 1123 (Forester, 1988, 109).

Two of the most frequently used handbooks for material selection are the *Materials Engineering " Materials Selector" (1991)* and the *Elsevier Materials Selector* (1991). Others deal with a single class: for metals, the *ASM Metals Handbook* (1973) and *Smithells Metals Reference Book* (1984); for polymers and elastomers, the *Handbook of Plastics and E/astomers* (1975), the *International Plastics Selector* (1987) and others; there are equivalent publications for ceramics and glasses; for composites; for foams; rocks and minerals; wood and wood products (Ashby, 1992, 211).

Another example dealing with a specific material is Sylvia Katz's book: *Plastics: Design And Materials* (1978) systematically examines over 60 kinds of plastic, both natural and synthetic, and the extraordinary variety of products they have made possible. It also includes a chapter on the chemistry of plastics and an appendix on molding processes. Walker (1989) states that, the descriptions of materials and processes can easily result in a highly technical handbook. Therefore, it is difficult to find sources combining a materials approach with a socio-historical study arranged chronologically. This is, however, what Katz attempted in her more recent publication in 1984, *Classic Plastics: from Bakelite to High-Tech (102*).

Ashby (1992) classifies other significant books, which are used for materials selection by both engineers and designers, according to the groups of materials they specifically concentrate on. The list can be seen in Appendix A.1. Ashby states other crucial books that span the full spectrum of materials as follows (216-217):

- Pahl, G. and Beitz, W. *Engineering Design.* The Design Council, Berlin: London and Springer, 1984.
- French, M. J. *Conceptual Design for Engineers.* The Design Council, Berlin: London and Springer, (1985).
- Ullman, D. G. *The Mechanical Design Process.* New York: McGraw Hill, 1992.
- Crane, F. A. A. and Charles, J. A. *Selection and Use of Engineering Materials.* London: Butterworths, 1984.
- Budinski, K. *Engineering Materials, Properties and Selection 1st Ed*. New Jersey: Prentice Hall, Englewood Cliff, 1979.
- Dieter, G. E. *Engineering Design, A Materials and Processing Approach.* London: McGraw Hill, 1983.
- Farag, M. M. *Selection of Materials and Manufacturing Processes for Engineering Design. London:* Prentice Hall, 1990.
- Lewis, G. *Selection of Engineering Materials.* New Jersey: Prentice Hall, 1990.

As it can be followed from Appendix A.1, ASM, which is published by American Society of Testing Material (ASTM), is also one of the most widely used sources. For over one hundred years ASTM, as it is known throughout the world, has been concentrating its work in the field of materials. The intensive activities have been channeled into two fields: (1) The standardization of specifications and methods of testing, and (2) Research. Over 2000 widely used specifications and ASTM has issued methods of testing materials. Hundreds of technical books, pamphlets, and reports involving thousands of pages have been published (ASTM, 1958).

Other hard-copy sources come from special organizations and trade associations compiling source books, which list data for the products of all their members.

Individual suppliers provide data sheets for their materials. Some important suppliers were explored in the previous section. One of them was GE Plastics, whose datasheet on LEXAN can be seen in Appendix A.2.

'Design Magazines' are the other published sources, which are used by designers both for the exploration of manufactured design objects and following improvements and novelties in materials technology. Two of the most widely known ones: ID and Domus.

3.3.3 Software Programs and Online Data Sources

Increasingly, materials data are packaged as software: computerized databases[2]. Databases are either provided by independent organizations interested in materials or by suppliers. The number and quality of computer-based materials information systems is growing rapidly.

One of the most important software databases is CMS: Cambridge Materials Selector (1992) developed by Cambridge University Engineering Department in the U.K. It is a remarkable tool centered on methods developed by Mike Ashby and colleagues at Cambridge University and Granta Design. It combines three principal functions: (1) straightforward search for information, material properties, process methods, suppliers, and so on; (2) a systematic approach for analysis of material and process information and optimal selection; and (3) modeling of complex properties such as creep or fatigue, or of process cost. The CMS consist of all materials types.

[2] A database is a collection of information organized and presented to serve a specific purpose - usually is that of retrieving selected items of data. A telephone directory is a database. So is a dictionary (Ashby, 1992).

Another one is the PLASCAMS 220, which is the Plastics Materials Selector (1990) including Polymers only. The user can find the mechanical and processing properties of polymers, thermoplastics and thermosets. According to Ashby (1992), the 'PLASCAMS 220' is easy to use for data retrieval, with much useful information. However, the selection procedure cumbersome and not design related. This database is updated regularly. For example, a version updated in1998 is in use presently. A number of databases can be seen in Appendix A.3.

Apart from those databases, there are several online software programs belonging to materials' supplier firms, the most common four of which were described in the previous section. In this part of this section, the author selected two online database cases as examples for the online selection procedure. One of them is GE Plastics, which was mentioned in Section 3.3.1 and the other one is the BASF Corporation, which offers a different material selection model for the users.

GE Plastics

The first firm is **GE (general electric) Plastics**. GE Plastics provides a number of selection tools. For instance, *material selector*: is a tool that can help users to narrow their choices, providing a quick and easy way to identify GE Plastics resins based on their performance criteria; *engineering design data*: contains a wealth of multi-point engineering data. This data is valuable in design and analysis, for engineers by providing more in depth engineering data and the ability to compare multiple materials on the same graph. All users can also gain access to valuable rheological[3] data that is essential for performing mold-filling analysis; *experiments optimizer*:

[3] Rheological: a science dealing with the deformation and flow of matter.

displays data from real world experiments conducted by GE Plastics for various injection molding applications. The user can alter the production parameters to see how they may affect the product quality attribute listed and to visualize the parameters to make easy the comparison between candidate materials, etc. The process used in ‘material selector’ tool can be followed below:

The tool uses descriptions to make the users write their required parameters and use the next button to submit their search. At the end of the ‘input parameters’ part, the program offers some materials and their datasheets consisting of specific information on required parameters. In the example (Figure 3.6), the author gave parameters for *tensile modulus, thermal index- electrical property* and *water absorption*. After defining those parameters, another chart comes out with a number of materials providing given parameters (Figure 3.7).

Datasheet	Material	Grade	Generic Name	Tensile Modulus (MPa)	Thermal Index, Elec Prop (deg C)	Water Absorbsion (%)
online pdf	LEXAN	3412ECR	PC	6,000	130	0.29

Figure 3.7 Number of materials providing given parameters.

The program presents one material with the given parameters. The users can reach the datasheets if they want (an example datasheet can be seen in Appendix A.2). For the aim of accessing this kind of data, the user should register to the company from the http://www.gepolymerland.com address. The firm also interacts with the user with their virtual learning center for ‘live’ on-line education. From this online service, the user can both learn about the firm’s latest innovations on materials and join the e-seminars on existing products.

Choose Region: Americas

Choose Units: (•) SI ( ) British

Mechanical						
Display	**Property**	**Min**	**Max**	**Range**		**Units**
☐	Tensile Strength/Stress			10	745	MPa
☐	Tensile Elongation/Strain			1	700	%
☑	Tensile Modulus	1	20	1,000	30,900	MPa
☐	Flexural Modulus			210	26,000	MPa

Thermal						
Display	**Property**	**Min**	**Max**	**Range**		**Units**
☐	HDT 0.45 MPa			55	270	deg C
☐	HDT 1.82 MPa			38	270	deg C
☐	Vicat Softening Temperature			60	270	deg C
☐	CTE, Flow			3.8E-7	7.0E-3	1/deg C
☑	Thermal Index, Elec Prop	50	200	50	220	deg C
☐	Thermal Index, Mech, w/Impact			50	220	deg C

Electrical						
Display	**Property**	**Min**	**Max**	**Range**		**Units**
☐	Dissipation Factor @ 50/60Hz			1.0E-4	0.18	
☐	Diecectric Constant @ 50/60Hz			2.65	3.53	
☐	Diecectric Constant @ 1MHz			2.12	5.70	
☐	Surface Resistivity			100.0	7.3E17	ohm

Other						
Display	**Property**	**Min**	**Max**	**Range**		**Units**
☐	Specific Gravity			0.86	2.40	
☑	Water Absorbsion	0.01	0.54	0.01	0.54	%

Figure 3.6 GE Plastics Online Material Selection Program: data entry (GE Plastics Web Site)

BASF Corporation

The second firm with its different selection procedure is the **BASF Corporation**. BASF's diverse product mix includes chemicals, polymers, automotive and industrial coatings, colorants, and agricultural products. Although this selection database had been designed basically for automotive sector, the author found its selection method valuable. (http://www.corporate.basf.com)

When the user selects the '*material selection*' title at the firm's website, he/she is directly confronted with a chart offering the '*application*' choices (Figure 3.8), with the instructions below:

- Select one or more items from the list (using the shift or ctrl key), then click 'Search'.
- Clicking 'Search' without choosing a selection will skip the search and go to the next level.
- The numbers in parentheses correspond to the number of matching products.
- Skip to another property at any time by clicking an item under 'Property'.
- View results at any time by clicking an item under 'Matches'.

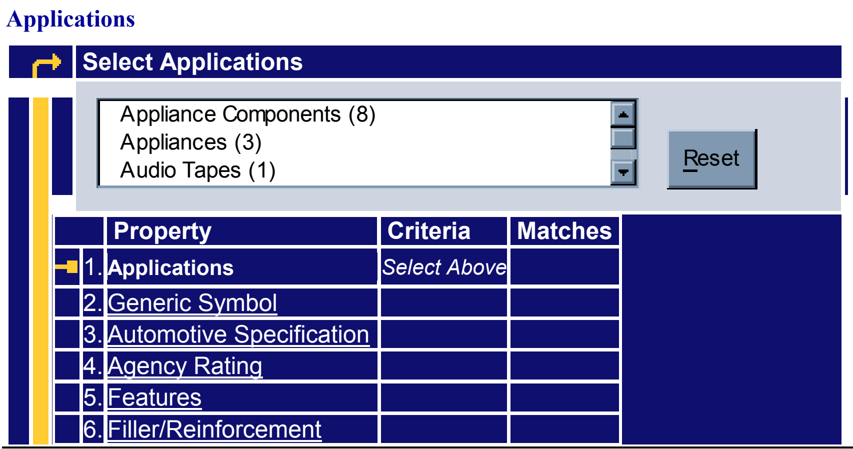

Figure 3.8 'Material Selection Chart' of BASF Corporation.

After selecting every property one by one (generic symbol, automotive specification, agency rating, etc.) and defining criteria from the list, the user narrows the materials' range appropriate for his/her selection criteria. For example, as it can be followed from the Figure 3.9:

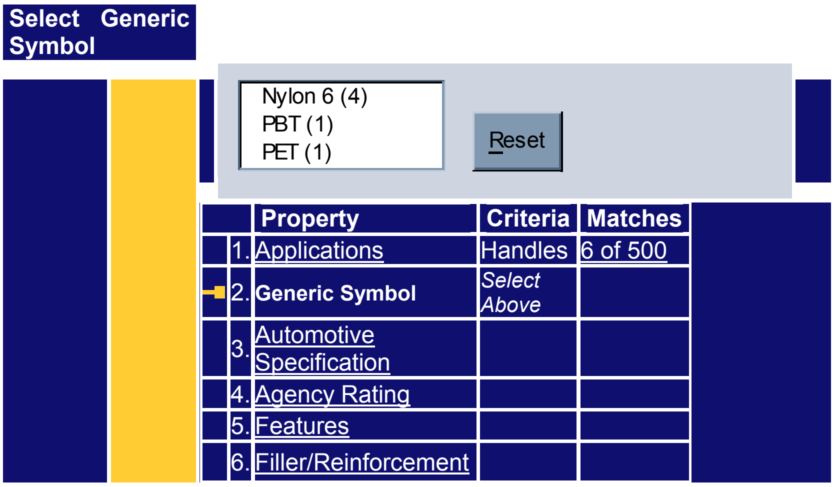

Figure 3.9 'Generic Selection Chart' of BASF Corporation.

The author selects 'handles' as the application area, and the program directly offers 6 out of 500 products. '*Generic symbol*' means that the 'material' the user wants to explore. After entering all the selection parameters, there appears a **view current results** button to see the selected material. As it is seen at Figure 3.10, the user can access the data with four alternatives datasheets: BASF PDF, ASTM Datasheet, ISO Datasheet and Multi-Point. BASF and ISO datasheets are similar with the ones exemplified in Appendix A.2. However, the ASTM and Multi- Point offer another selection chart in addition to its' datasheet (Appendix A.4). It is an advantage for the user that the program gives chance to compare materials when it offers more than one appropriate material at the end of the process. Comparison process can also be followed in Appendix A.5.

Legend **For** **Actions**

- COMPARE - BASF PDF - ASTM Datasheet - ISO Datasheet - Multi-Point

Page 1 of 1. Products 1 to 1 of 1..

Action	Product	Density - Specific Gravity (sp gr 23/23°C)	Tensile Strength @ Yield (MPa)	Notched Izod Impact (J/m)	DTUL @264psi - Unannealed (°C)
☐	Capron® 8200 (Dry)	1.13	84.8 (23 °C), 23.0 (121 °C), 136 (-40 °C)	64.1 (23 °C), 48.0 (-40 °C)	65.0

Figure 3.10 View of results including candidate material (s) appropriate for the defined parameters.

Plastics Technology

There are also some websites, which are not owned by materials suppliers, which provide online material selection databases. One of them is '**Plastics Technology** ', online web resource for plastic processor with over 13,196 grades of plastic materials. (http://www.plasticstechnology.com/index.html)

The '*Plastics Technology Materials Selection Database*' of the website delivers a materials list based on the user's unique criteria in three steps:

In **step one**, the program applies specific "filters" to select the plastics materials that match the user' s requirements. In **step two**, it designates what "properties" to display with the user' s tailored materials list. **Step three** it builds the required list.

The course of the method can be followed with the sample selection procedure below:

STEP 1: Select your **preferred material characteristics** from the Filters menu below.

- ☐ Search for materials using **Supplier Name**
- ☐ Search for materials using **Generic Family**
- ☐ Search for materials using **General Information**
- ☐ Search for materials using **Processing/Physical**
- ☐ Search for materials using **Mechanical Properties**
- ☐ Search for materials using **Thermal Properties**
- ☐ Search for materials using **Electrical Properties**
- ☐ Search for materials using **Optical Properties**
- ☐ Search for materials using **Features/Characteristics**

For the selection of each characteristic, the program proffers a list of names to make the user specify his/her requirement. For example, under the option of '*supplier name*', there are several of names consisting worldwide firms producing plastics (Figure 3.11).

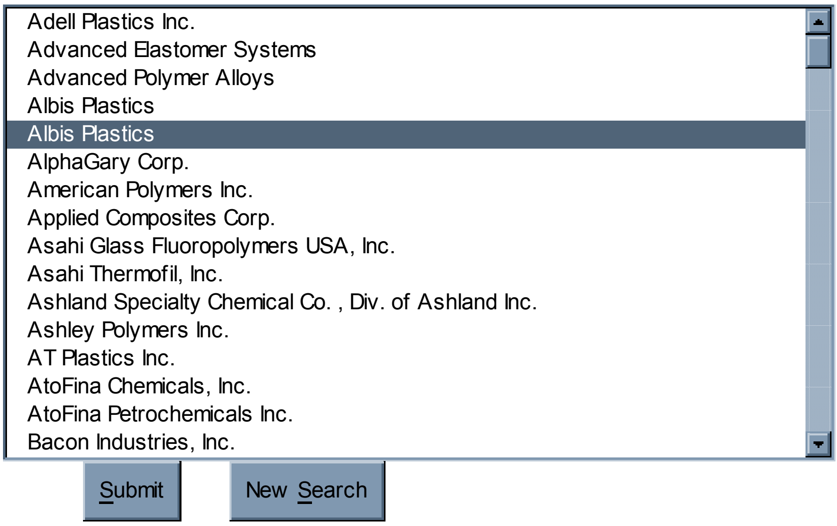

Figure 3.11 'Supplier- based' material selection at 'Plastic Technology Online Database'.

The user can select a firm from the list or go back to the main menu and define another characteristic. For both situations, the next step appears for the aim of listing candidate materials by asking the user these questions below:

STEP 2: **Designate the properties** to display with your tailored materials list:

- Include Supplier Name
- Include Generic Family
- Include Chemical Type
- Include Trade Name
- Include Grade
- Include all General Information

- Include all Processing/Physical Characteristics
- Include all Mechanical Properties
- Include all Thermal Properties
- Include all Electrical Properties
- Include all Optical Properties
- Include all Features/Characteristics

The user makes selection once more and designates the properties required to see in the list. Then, for the third step, he/she clicks the 'view complete list' button, and finds out a list of all candidate materials, which can be supplied by the selected company, which had been defined in the first step. A section from a sample list of materials can be seen in Appendix A.6. If the user select 'generic family' option in the first step, the program offers the list of materials, such as ABS, polypropylene, polystyrene, etc.

Design inSite:

Another example for websites providing materials properties data is '**Design inSite**', which is a widely known one among industrial designers. The author had also used this website as an example for one of the questions of field study. (www.designinsite.dk)

Design inSite is a Danish website, founded in 1997, aiming to be a guide to manufacturing for especially industrial designers. Various manufacturing processes and materials are described as well as the products where they are used. They define their purpose as to inspire designers in their design work to consider materials and processes, which are new or unknown to them. The web site includes descriptions of about 190 products, 120 materials and 100 processes. By selecting one of those topics, the user is offered a list of products, materials or processes (an example of a 'product- base selection process' represented by the author can be seen in Figure 3.12).

The focus of the site is on the more unusual materials like polymers, ceramics, composites, smart materials. Both traditional processes and newer processes like rapid prototyping techniques, powder metallurgy and surface treatment processes are covered in the Site.

MatWeb:

The MatWeb is a searchable database of material datasheets, including property information on thermoplastic and thermoset polymers such as ABS, nylon, polycarbonate, polyester, polyethylene and polypropylene; metals such as aluminum, cobalt, copper, lead, magnesium, nickel, steel, super alloys, titanium and zinc alloys; ceramics; plus semiconductors, fibers, and other engineering materials. The web site is freely available and does not require registration. (http://www.matweb.com)

The users can find materials property data with several tools such as supplier-based or material-based type searches. There are also convenient drop-down lists of polymer trade names and polymer manufacturers. Mat Web is used as a materials selection' database sources by several other software programs such as CMS (Cambridge Materials Selector).

Aircraft wing
Air register for car
Appealing bottle
Badminton racket
Baking tin
Bottle for mineral water

Bottle for mineral water

This bottle for mineral water holds the pressure from the carbon dioxide in the liquid. It is made from PET plastic which is transparent and well suited for recycling. The bottle is produced using injection blow molding which implies two steps. First the small preform (right) is produced by conventional injection molding. Then the preform is transferred to a blow molding machine where it is blown into the desired shape (left).
Danish Name: Sodavandsflaske
Materials: PET
Processes Injection blow molding
Keywords: Bottle, Container, Transparent, Pressure, Plastic
Environmental notes: Disposal: PET bottles can be recycled 20-30 times. Furthermore PET plastic can be converted into Polyester fibers that can be used for clothing.

PET (polyethylene terephthalate)

PET has good barrier properties against oxygen and carbon dioxide. Therefore, it is utilized in bottles for mineral water. Other applications include food trays for oven use, roasting bags, audio/video tapes as well as mechanical components. PET exists both as an amorphous (transparent) and as a semi-crystalline (opaque and white) thermoplastic material. Generally, it has good resistance to mineral oils, solvents and acids but not to bases. The semi-crystalline PET has good strength, ductility, stiffness and hardness. The amorphous PET has better ductility but less stiffness and hardness.
Danish Name: PET - thermoplastic polyester
Category: Plastics, Thermoplastics
Products: Bottle for mineral water, Trays for oven use, Oven foils
Processes: Plastic molding, Plastic injection molding, Extrusion, Blow molding, Vacuum forming
Similar materials: PA (technical applications), PVC (packaging material), PE (packaging material)
Price: High cost plastic (see also Plastics general overview)
Environmental notes: *Creation:* Production of 1 kg of PET requires the equivalent of about 2 kg of oil (raw material and energy). *Use:* It is very inflammable and inflammability can be reduced by the use of additives. *Disposal:* Incineration in an incineration plant mainly produces water and carbon dioxide. Heating value is equivalent to ½ kg of oil. PET can be recycled into fibers that are used for polyester fabrics.

Figure 3.12 Product– based selection process in Design inSite.

3.3.4 Fairs and Conferences

The growing excitement and exploration in materials and manufacturing in the design community encouraged new organizations to present the advances in technology and materials world to the market and at the same time to industrial designers. Today, most of the practicing designers believe that these kinds of organizations, consisting of 'fairs' and 'conferences', are enhancing their creativity and they are offering a good way of experiencing materials by observing them in their embodied products (Chapter 4).

For the aim of using different materials, designers mostly prefer 'design fairs' rather than 'materials fairs'. As explained briefly before (in chapter 4-field study evaluation, a detailed explanation can be seen), they would like to see manufactured products rather than raw materials. Some of the organizations aimed to combine two titles- 'materials' and 'design'- to provide the essential information for industrial designers with the recently produced design objects. One of the most important shows was, *Mutant Materials in Contemporary Design,* organized by Paola Antonelli[4]. The *Material Connection*, for instance, conceived by George Beylerian is another outstanding example of this renewed energy focused in this essential aspect of design (Lesko, 1999).

Material ConneXion holds one of the most famous worldwide materials' exhibitions, which was named as '**materials without boundaries**'. Founded in 1997*, Material*

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[4] Paola Antonelli has created several architecture and design exhibitions in Italy, France, and Japan. Her first acclaimed exhibition for MOMA, *Mutant Materials in Contemporary Design* (1995), was followed by *Thresholds: Contemporary Design from the Netherlands* (1996), *Achille Castiglioni: Design* (1997- 98), *Projects 66: Campana/Ingo Maurer* (1999), *Open Ends,* and *Matter* (September 2000 - February 2001). (source:Designboom Web Site)

ConneXion, a new firm respect to the other ones, is the largest global resource of new materials. The significance of the firm is that, it has the biggest material samples library which houses over 1,400 new and innovative materials representing eight categories: polymers, glass, ceramics, carbon-based materials, cement-based materials, metals, natural materials and natural material derivatives. The complete library information of the organization is accessible via the Internet, using Material ConneXion's database. They have numbers of material experts offering market research, exhibit services and other business tools to help address a variety of material challenges. The organization has two centers: one is in New York and the other one is in Milan. The website of the organization is http://www.materialconnexion.com.

Being the president and the founder of the Material ConneXion, George M. Beylerian says that:

> In fact, time and again it is materials that allow innovative solutions for designs that would otherwise have been impossible to create to become a reality. We take great pleasure in touring Materials without Boundaries since we find creative professionals are riveted to the material innovations they would otherwise never see.

Within the Industrial Designers Society of America (IDSA), the American industrial designer Dave Kusuma was active in organizing the Materials and Processes Group and in bringing the Society of Plastics Engineers and IDSA together for meetings and conferences. In order to aid in materials education these two groups got together to provide a designer's toolbox with samples of the various parts for students to study (Lesko, 1999). Some important fairs and conferences, which are preferred by designers as the inspiration sources, stated by Ashby and Jordan (2002) are: Milan' s Furniture Fair, Hanover Trade Show and the Polymer Trade Show -K- in Düsseldorf (40).

Milan's Furniture Fair:

In its 43rd year, the Salone Internazionale del Mobile (international furniture fair) takes on a new, more encompassing name: Milano Design Week 04. It is an event that involves the Salone Internazionale del Mobile (home ware and furniture), Eurocucina (bathrooms), EIMU (office furniture), Tessile (fabrics), Salone Satellite (young designers), Dining Design, Designing Designers, Material ConneXion, and Street Dining Design. The Figure 3.13 consists of some example products from the Milan Design Fair.

Figure 3.13 Some example products from Milan Furniture Fair in Italy (Web Site).

Hannover Trade Fair:

HANNOVER MESSE 2004 is confirmed as one of the world' s leading technology events all around the world. It sets new standards and this year it underlined its commanding position as the only showcase to feature the entire industrial supply chain. 180,000 visitors -nearly 50,000 of whom came from abroad- were on hand to see exhibits staged by 5,040 exhibitors across a total display area of 151,500 square meters. http://www.hannovermesse.de/homepage_e?x=1

K International Trade Fair for Plastics and Rubber Worldwide- Düsseldorf:

It is believed as the most extensive trade fair for plastics and rubbers. K 2004 will be held in from 20 to 27 October, and exhibitors from all around world will showcase their products and services over some 160, 000 square meters of net exhibition space. The structure for the distribution of exhibitors across the halls in the form of the three tried-and-tested product categories *raw materials*, auxiliaries; *semi-finished products*, technical parts and reinforced plastics as well as *machinery and equipment*. http://www4.k-online.de/cipp/md_k/custom/pub/content,ticket,g_u_e_s_t/lang,

The next two fairs are the ones that were emphasized by the interviewed Turkish industrial designers as the sources of materials selection (chapter 4).

Turkey Build Fair (YAPI FUARI):

The fair has being arranged since 1988 at different fair centers in Turkey. It is a valuable source for both architectures and industrial designers as it contains wide range of products from building sector such as lightings, glass and transparent elements, doors and windows systems, etc (Figure 3.14).

Figure 3.14 The poster of Yapı Ankara Fuarı 2004 (Yapı Endüstri Merkezi Web Site).

<u>IMM Köln (Cologne Furniture Fair):</u>

With 40 trade fairs a year, total hall space of 286,000 square meters, over 38,000 exhibitors and some two million buyers, Koelnmesse (Köln Fair Center) is one of the world's leading trade fair organizers. The focus points of the Köln Fairs concepts are as follows: House, garden and leisure, communications and new media, health, environment and facilities, art and culture, food, furniture and interior design, fashion.

IMM Fair is one of them held in Köln basically concentrated on furniture. It's the international trade and communication platform for the furniture sector that features outstanding export opportunities and a center of ideas for the entire furniture and interior -decoration sector (Figure 3.15).

Figure 3.15 IMM Cologne Furniture Fair Logo (Web Site).

Materialica:

There is also another important fair basically concentrating on materials: Materialica. The fair, which has being organized for seven years in Munich, is an international trade show for Materials Applications, Surface Technologies and Product Engineering with Congress Materials Week. The focus areas of the Materialica 2004, which will be held in September 2004 (Figure 3.16), will be:

Materials applications: Plastics & Composites World, Metal World and Ceramic World

Processes: Surface and Nano World, Testing and Research World.

Figure 3.16 Materialica 2004 Logo (Web Site)

In this section a number of software and online products provide material selection databases with several advantages and disadvantages are reviewed. The evaluation of those sources can be seen in the next section.

3.4 EVALUATION OF THE EXISTING SOURCES

Materials for product design, as stated earlier, fall into the general categories of metals, plastics, woods, ceramics, and composites. Designers are forced into situations where suitable choices must be made from databases of available materials, and there are many published lists of engineering properties of these substances some examples of which were demonstrated in previous sections. The data presented in those sources is restricted to general descriptions of material characteristics and their application. Lindbeck states that (1995), the initial design specification must be followed by discussion with materials specialists and suppliers regarding properties, characteristics, process technology, availability and cost. This information will aid in the material selection decision (105-107).

The mentioned initial design specification can be provided from the direct experiences of practicing designers or the established design practices in engineering organizations.

However most of the time, the design project is not found clear although one particular project is found working well in the past. These guidelines, therefore, are more frequently specific to a particular area and can represent a wide range of experience in the use of existing technology. Design for manufacture and assembly guidelines are further specific in that they concentrate on a particular aspect of design and range from high level and generic to low level and field specific good practice (Edwards, 2002).

Therefore, it is indispensable to use other guidelines for expanded material selection information. As mentioned in previous sections, rising speed of computing made databases increasingly attractive. They allow fast presentation of data of properties for a material, or the selection of a class of materials that have properties within a specified range and their presentations as charts and graphs. Commercially available databases already help enormously in materials selection, and are growing every year. Some of those currently available are reviewed in Section 3.3.3.

A common feature of all such databases is that they contain information that can be presented as rows and columns, each starting with the name of a material. Ashby (1992) explains the properties of databases and states that,

> A database is just a table, though it can be a very big one (thousands of records, each with, hundreds of fields). It is manipulated through a *database management system* (DBMS); that is why you pay for when you buy a commercial software package like dBase IV or File Maker Pro. (211)

Therefore, the software packages are not always open to public usages; the designer buys it and the management system lets him/her create and use database files.

Another widespread feature of the databases is that all have defined identifier (that is a name of a material here). The user gives a name, such as polypropylene and the databases find and display the data associated with a given identifier. They can also find the substitute identifiers that satisfy certain same criteria. Many of them design graphs using the selected data, or print the data in various appealing formats. It can be said that, they are efficient with their ability on storing, sorting and retrieving the data (Ashby, 1992, 211).

Some of the existing databases, such as '*Plastics Technology Materials Selection Database',* offer the 'supplier names' to the users, which is a considerable advantage for the users (see section 3.3.2). Because, as mentioned in section 3.1: factors affecting materials selection, the one of the most important criteria for selection is defined as the 'availability' of the material.

Another advantage of the existing sources is that, some of them are the application-based sources. For example, at the BASF Corporation' s online material selection database, the procedure starts with the defined application area by designers (see Section 3.3.3). As explained in Section 3.2 on material selection process, the 'defining of the need' is the initial step for the design process. As regards to the design processes, to narrow down the exploring region by defining 'application area' depending on the 'need' is a time saving method. However, since the defined 'needs' can be from various areas, so as the given 'application areas' should be. The limited numbers of those areas can make a negative effect on the creativity of designers.

Similarly, another application- based selection example was "Design inSite" website, although it also includes the materials- based selection process. In this website, designer selects a product from a defined list. According to the present author, the most significant drawback of this program is the limited number of products offered to the designers.

Ashby (1992) also emphasizes some drawbacks about databases. According to him, the main drawback of the simple or common database is the lack of qualification. Some data are precise others are only approximate. Some are valid under all conditions; others are properly used only under certain circumstances. The qualification can be as important as the data itself. Some of the simpler tests used to assess materials properties have been discussed in previous sections.

The other crucial point occurs when the quality of the images in those databases is evaluated. There are images of materials a well as the charts, graphs and texts presented to the users. They are strong on numeric properties but weak on the rest (Ashby, 1992). Since the access to the samples of the materials is not always immediately possible, the designers are supposed to make selection by what they see in those sources. Therefore, the examples should be of the highest quality. The same problem occurs in the website of Design inSite when the quality of the images used for the examples of the products are examined. The same point is also valid for the 'fairs' and 'exhibitions'.

Another drawback of the databases is that, there are too many information to present, which can cause chaos for industrial designers. The classification is used in most of them to reduce the effects of that problem. Within each class there is a common set of scientific principles, which governs all the processes and can be used to analyze them independently of the material being processed (Edwards and Endean, 1990, 52). However, the problem is observed explicitly at the hardware databases. The action of finding specific information frequently takes time. On the other hand, for software and most probably the online (and interactive) databases, another problem comes out again related with time. Most of the designers find the databases hard to use because of their vague interfaces (Chapter 4).

To sum up, the most of the existing sources have technical data, which is largely numeric (for example values for toughness, or density) and backed up with a little text-based information and well-qualified images of materials. However, this kind of data is not adequate for an industrial designer who wants to make selection among wide range of materials. The quality of images and the apprehensibility of the charts and diagrams play a crucial role in that case. Most of the sources do not contain comparison charts that are very important for making selection among a number of candidate materials, either.

3.5 OTHER RESEARCH ON MATERIAL SELECTION IN DESIGN ACTIVITY

The author came across with a similar research made by Dr Owain Francis Pedgley in 1999. Dr. Pedgley received his doctoral degree from Loughborough University, Faculty of Social Sciences and Humanities, Department of Design and Technology in the U.K. the title of his doctoral thesis was '*Industrial designers' attention to materials and manufacturing processes: analysis at macroscopic and microscopic levels*'.

His thesis consists of four sections. In Section One, a framework for analyzing industrial designers' attention to materials and manufacturing processes is developed. To do so, Pedgley offers the definitions of industrial design and the nature of design decision-making from both macroscopic and microscopic perspective with the interviews given with undergraduates and professional designers based in the U.K. uses of information, knowledge, values and cognitive modeling are discussed, and comparisons are drawn between engineers' and designers' involvement with materials and manufacture. Section Two contains a critical review of methods of capturing and analyzing design activity. The results of the data analyses are contained as discrete studies in Section Three. The Third Section also includes an evaluation of the diary[5] as a data collection instruments.

Conclusions are drawn on how industrial designers know about materials and manufacturing, the nature of creativity in this area, how information is used to supplement experience and, tentatively, how cognitive modeling is used to help

[5] Pedgley uses the development of a novel 'diary of designing' method for collecting data on design process.

determine a suitable manufacturing route for a product idea. The findings of his research and the comparison between the findings of both this thesis and Pedgley' s will be evaluated intensively in Section 4.3.

As it was seen in Chapter 2 and 3, there are considerable numbers of sources for industrial designers, which include data on materials, their properties and usage environments. However, most of those sources are engineering based, thus they do not respond completely the designers' expectations from them. Therefore, in Chapter 4, an outline is given of the constraints and opportunities that affect industrial designers' choices of materials and manufacturing processes.

CHAPTER 4

DESIGN AND CONDUCT OF FIELD STUDY

4.1 METHODOLOGY OF THE FIELD STUDY

As it was mentioned in the introduction part of the thesis, what is aimed with this study is that to examine, the ways through which industrial designers reach the materials' data, the kinds of resources from which they benefit, and their awareness about the existing resources in industrial design process. In addition to this, it is also expected to get information about what kind of a source they desire and what they would like in the whole.

For this aim, every kind of criteria, which would affect the designers' material selection processes and their capability of choosing materials, was defined. The foremost one of those criteria was whether the designer works as an in-house designer in a manufacturing firm or as a consultant designer to various different firms.

Before starting the field study, the author's observation was that though the in-house designers who have been experts in specific materials in their sectors were following every improvement closely about them, they were not familiar with other materials out of their sectors. On the other hand, in consultancy firms, designers who usually work with different manufacturers have more chance to experience different materials. However their access is limited to materials information, because, the intensity of the information flowing to their firms from the raw materials' suppliers is limited due to the size of their firms.

Therefore, the author aimed to form a "sample group", which will be defined in the next Section, including both in-house and consultant industrial designers in equal numbers.

4.1.1 Definition of the Sample Group

The research was applied to 20 industrial designers in Turkey, who work professionally. The designers taking part in this study have defined their sectors under the following titles:

- **Arif Özden** (ÖZDEN DESIGN): Product design
- **Akın Oral**
- **Arda Tunçman** (CENTIPEDE DESIGN): Design of furniture and accessories
- **Bedii Koş**
- **Cengiz Öztürk** (VESTEL): Electronics, televisions
- **Değer Demircan** (ARÇELİK): Cooking Equipment Industry
- **Demet Eryürek** (ASELSAN): Defense Industry
- **Deniz Patlar** (ASELSAN): Defense Industry
- **Fırat Ant** (MAN): Production of buses
- **Gamze Türkoğlu Güven** (TASARIM ÜSSÜ): Sanitary equipment made of ceramic, promotion products, kitchen products, components of constructions
- **Kenan Erdinç** (MAN): Production of buses
- **Kunter Şekercioğlu** (KİLİTTAŞI): Product design
- **Mehmet Asatekin** (METU): Various
- **Mehmet Yetkin** (ASELSAN): Communication equipment
- **Murad Babadağ**: Product design and interior architecture
- **Murat Erciyas** (NURUS): Furniture
- **Nurtan Meral** (KAREL): Electronic communication devices

- **Osman Ünver** (UNIQUE PROJECTS FACTORY): Various
- **Oya Akman** (ITU): Home products and accessories made of glass
- **Özlem Perşembe** (NESNE): Electronics, furniture, defense industry and packaging design

The in-house designers of the sample group were selected from the firms that involve the R&D (Research and Development) departments in their body; the designers work in the same atmosphere with people from different kinds of professions and have a huge capacity of production. These were ASELSAN, VESTEL Electronic, KAREL, ARÇELİK, NURUS and MAN Türkiye.

The consultant designers of the sample group were from the firms that serve for design and consultation and do not involve the production in their body, such as Tasarım Üssü, Nesne Design, Centipede Design (kırkayak design), and Kilittaşı, Unique Projects Factory, Özden Design Ltd. Apart from those firms; the research was also implemented to two designers who are related to product design not being under the name of any firm in addition to their academic identity in universities: Assoc. Prof. Dr. Mehmet Asatekin (Middle East Technical University) and Assoc. Prof. Dr. Oya Şenocak Akman (Istanbul Technical University).

4.1.2 The Data Collection Process

Two techniques have been used to analyze the group: an interview and a four-question questionnaire. Before the application of the interviews and questionnaires, a pilot study was conducted with two industrial designers from Ankara. This pilot study assisted to reevaluate the contents of the questions.

To conduct the interviews, the author communicated with industrial designers individually beforehand. By electronic mails or telephone calls, she explained the research subject and how much time it would take for making interviews with them. 25 industrial designers from different sectors were communicated with and five of them rejected the request because of their intense workload. Remaining 20 were interested in the subject and said they could accept the author.

Attention was paid to conduct the interviews in designers' original working environment, in case they would like to give exact names for the sources they use for material selection in their offices. However, for two of them, again for the reason of time limitation, the study was conducted after the working hours of the day, in their homes.

The interview took approximately 40 minutes. The author repeated the aim of the study to the designers before each interview. The interviews were recorded and after that, the designers were requested to fill-out the four-question questionnaires. Having all the requirements been completed, one hour had been spent per designer. The length of the field study was totally one and a half months. After finishing the application of the study, the author commenced the evaluation period. It took one and a half hours to decipher each interview.

4.2 EVALUATION OF THE DATA

For the evaluation process, the author classified the answers of the interview questions and prepared charts for the answers of the questionnaires, as they appeared to be easily categorized quantitative data.

4.2.1 Evaluation of the Interviews

The interview consisted of ten questions focusing on the issue of 'material selection processes and sources' (Appendix B.1). The questions and the evaluations of them are as follows:

a. The considerable topics on material selection process for industrial designers

The first question was under which titles the interviewee would like to categorize materials information. Almost all of the interviewees replied that it depends on the 'concept of the projects given to the designer' and on the 'existing possibilities' such as production facilities. As it is seen, the given answers were not directly related with the question asked to them. The author realized that, the interviewees found the first question too general that they wanted to begin the conversation by explaining some crucial factors, which affect their materials selection process. These factors emphasized by interviewees will be considered one by one.

<u>(1) The effects of the project and concept on materials selection</u>

For the interviewees, the "definition of project" contains various aspects such as the '***definition of sector***' (like a medical product or a communication equipment for military), the '***usage environment***', and the '***target market***'. These constitute a primary attitude for almost all of the interviewees, regarding the issues of choosing materials. For instance, if it is a military product and the users are determined as 'soldiers', the designer lists some kinds of characteristics particularly like the candidate material should be light, it should have a matte surface, and it should be resistant to open air conditions and alterations of heat.

(2) The effects of existing possibilities on materials selection

For all of the interviewees the **appropriateness of the manufacturing techniques** and the **volume of the production** were the second most important issues that affect categorizing material information needed by them.

For the in-house designers, the manufacturing techniques and the volume of the production are certainly defined even before starting the project. Therefore, an in-house designer should make the selection considering the appropriateness of the candidate materials to those defined conditions of his/her firm. For this reason, the term "material selection" does not completely depend on the in-house designers' preferences. Whereas, they make selection from limited alternatives formed by specialists or engineers of the firm beforehand. In that case, for those designers the 'color' and the 'texture' of the materials become the most important factors they desire to learn about.

On the other hand, according to Murat Erciyas (NURUS), in the firms keeping their own production services available and founded directly for 'product design', such as NURUS, the in-house designers can persuade the firm to use a new material, which they find critical for their new products.

(3) Availability of the candidate materials

For the consultant designers, the second significant issue that affects categorizing material information was the criterion of '**availability'.** The in-house designers working in big manufacturing firms like ASELSAN, ARÇELİK or VESTEL do not have the 'availability' problem for the selected materials, because high number of raw materials' suppliers get in contact directly with the big manufacturing firms. In fact, at this point a conflict appears among the designers in Turkey: if the firm is a consultancy firm formed for only product design like NESNE or TASARIM ÜSSÜ, the designer working for this firm will have more authority on choosing material than the ones working for big manufacturing firms like VESTEL or ASELSAN. However, if the consultancy firm is not big and famous enough, like KİLİTTAŞI, it is very difficult to access even to the samples of the selected materials for the designer working for this firm.

(4) The cost of the manufacturing process

All of the interviewees stated that, they select materials considering the appropriateness of the selected ones to the existing manufacturing techniques because they try to reduce **the cost**. Therefore, it is another important subject affecting the categorizing of the needed materials information. For example, if a designer will make selection among three different materials, he/she can prefer the cheaper one although its appearance does not meet his/her expectation.

(5) The effects of chemical and physical properties of the materials on selection process

According to the interviewees, the technical features of materials (chemical and physical properties) are effective on choosing them during the whole design activity. However, they define some specific factors about which they need to get information in different phases of the design process. For example:

After the definition of the project, all of the interviewees envisage whether the material will be bright or matte, what its color, texture and degree of transparency will be, all of which are called the '*physical criteria'* by them, according to its usage environment and the target market. They carry on this process consciously or unconsciously for all kinds of projects. In this phase of the design activity, they rarely need 'technical data', that is, the data about the physical or chemical constructions of materials.

As the process goes further, the designers appraising number of restrictive factors need to learn more profoundly about the candidate materials. Moreover, they want to see comparatively if the material they selected will be appropriate to some kind of defined physical conditions and how its **durability** will be among other similar materials.

Therefore, it can be said that, the first step is the decision making on the physical appearances (characteristics towards senses, such as colors and textures) and the second step is confirming the appropriateness of the candidate material through the detailed technical data regarding chemical and physical constructions of it.

Only two of the interviewees stated that they wanted to get information about the chemistry of materials. Moreover, they defined some subtitles about which they want to access the data: the chemical construction of a material, its components, its crystallized construction (if it has) and the possibilities on making alteration on its physical appearance by changing its chemical structure. Neither of these two interviewees was working as an in-house designer. One of them had a particular interest about glass and the other about wood.

b. The effects of the 'sensorial' qualities and the 'perceived values ' of the materials on designers' materials selection process

The second question was what kind of information the interviewee needs in making sense of materials. One of the goals of this question was to remind the designer those two criteria, which could have been ignored in the first question. Assuming that the interviewees usually use materials selection sources submitting technical information, another goal was to take their opinions whether other kinds of information such as sensorial and perceived values would be given in a source or not.

For all of the interviewees, sensorial properties and perceived values affecting from cultural differences, trends, associations, and etc., are very important and in fact, they are the issues in which the designers can directly reveal their efficiency and can make their design be distinguished. However, two of them stated that, although these issues are very significant, owing to the limitations related with the *production techniques and the availability of the materials*, they couldn't express themselves by accentuating those values of materials in their products.

The common idea among all interviewees was that the designers emphasized the materials' meanings, which are defined with their belongings to the main design periods. That is, some materials are associated with some design movements, such as *wood* and *Shakers*. As the design products symbolize the obvious design movements, the materials of these products can do the same in their time spans.
One of the interviewees explained that,

> The user first sees the product, than touches it. After that, he constructs a cognitive model in his mind depending on the feelings that the product creates. The 'material' of that product, as well as the form of it, is used for constructing this cognitive model. In other words, the form and the material motivate the user to draw a spiritual picture by associations and aspirations.

> For instance, a material may give the sense of quality with its appearance. Therefore, we, the industrial designers, use frequently those sensorial properties of a material, like sight and touch, to contribute the creation of the 'perceptional properties'. (Kenan Erdinç, MAN Türkiye)

Another designer stated that,

> All of the materials have a particular language. This language is reflected so much to your design product. For example, wood gives a natural feeling. If you do not keep this feeling alive, the product becomes artificial. For instance, there are eras of materials; in other words every material has a period in which it becomes popular and addresses to a feeling. I think this is inevitably significant and unequivocally pertaining to the designer's spirit and experiences. (Bedii Engin Koş, CENTIPEDE DESIGN)

It was mentioned above that the interviewees who tackle with the technical limitations find themselves efficient on selecting materials depending on the 'perceived values' and the 'sensorial' criteria of the materials. One of the interviewees explained that,

> Being designers, we do not know much about the technical information of a material. Inevitable we learn a material and its limitations by experience when we come into the sector. As far as I am concerned, it is perceptional dimensions that are very crucial and they are the real issues in which we have efficiency. Especially in fashion related sectors, which are formed by trends-like home accessories-, you can see a material that is becoming prevalent immediately. Transparency is an example. I believe that iMAC's success is totally pertaining to transparency. It is also related to the feelings that peculiarity of transparency in material makes. Similarly, rubber, for instance, is used frequently in current days in promotion products. Whereas the plastics, it emerges incredible warmth at people because of its velvety texture. It is more distant than the cold emotion that plastic gives because of its bright surface. You feel like touching a natural material as wood and this is very important in users' preferences. (Gamze Türkoğlu Güven, TASARIM ÜSSÜ)

It was surprising that, four other designers emphasized the velvety texture of rubber like Gamze Türkoğlu Güven. Therefore, it can exemplify how a material turns into a trend among designers.

Osman Ünver (Unique Projects Factory) stated that, " If I want to make an invisible thing be perceptible, I stress the sensorial properties." What the designer mentioned here was that, the user frequently experiences difficulty in determining and defining the characteristics of a product, which direct him/her to choose it. Therefore, he/she may prefer the products by touching which he/she feels different things, which cannot easily be explained. According to Ünver, one way for accomplishing this is '*astonishing the user* '. He explained that, " The answer for the question of "how can it be done with the material" will be probably that touching to a material of a product may create more special feelings than the appearance of it."

Consequently, it can be said that, for the interviewees, the '*sense of touch'* is one of the most important criteria as being initial perceptional value for the users. Because, according to them, the user perceives an object as a whole visual image and without touching it, she/ he cannot evaluate the material of it.

On the other hand, for the designers, all these perceptional inferences are utterly related with the designer's experiences. A designer who works on glass for a long time can estimate that what kind of senses a glass may create on the user with the change in its color, thickness and texture. Therefore, they stated that, there are series of common ideas and information on the perception of materials in industrial design and the designers are reflecting these without using a written source by benefiting from their own experiences. Kenan Erdinç (MAN Türkiye) stated that:

> *Emotions* can be emphasized thoroughly with the quality of the surface. For instance, in our sector, our experience showed that bright products are always

> perceived as *cheap* products. Conversely, the main indicator of the qualified products is their mat surfaces. Let's look at the trends; inner coatings of Audi are made up of mat surfaces totally. This means, firstly the view makes you perceive something, secondly you touch it.

After the explanations of the interviewees on 'sensorial properties' and 'perceived values' of materials, the author asked them if those kinds of information about the these values of the materials are involved in a material selection source.

Almost all of the interviewees (18/20) stated that, the data towards the senses could be provided ***as long as the sample of the selected material existed***. The basic issue the designers stressed seriously was that *"Without feeling the material, a designer cannot cause someone to feel"*. Thus, it is necessary to experience with the material by touching before introducing it to the user.

For the 'perceived values' of a material, only two of the interviewees stated that they believed the necessity of that kind of data in a course of material selection source. Nevertheless, they added that such data could only be obtained after long and intensive analyses. One of these designers pointed out the Ezio Manzini's book (1989) of '*Materials of Invention'* as a valuable book for industrial designers on perceptional values of materials. Even though the other interviewees did not give clear references, they suggested that the perceived value and sensorial properties data of materials could be given by harmonizing various adjectives with materials (for instance, *X material may create a cold feeling, or Y material reminds the prestigious objects*, etc.)

On the other hand, 18 out of 20 designers stated that, "using the perceived values of a material for a design product" could only be the expression of a designer's feelings or thoughts and how he/she wanted his/her product to be perceived. For this reason, this kind of data could not have written regulations. Furthermore, people could evaluate the same material differently according to its usage environment or the places where they were put in the market.

In brief, the expected data for the sensorial properties and perceived values of the materials can be obtained only after intense researches. Deniz Patlar (ASELSAN) explained her opinions regarding this issue as:

> Fundamentally, the ‘perceived value’ of a material is usually a thing that we discover through our efforts. In ASELSAN, there are number of criteria during the design process, which we have to abide by. Hence, if this kind of information is given in a written source, the unique area under our control will be limited in the framework of rules. At least, this should become in our hands.

Therefore, many of the designers believe that such information restricts and affects their creativity negatively.

c. What kinds of material selection sources do industrial designers use?

The third and fourth questions aim to find out the resources, which the designers use while choosing materials, and to bring in that through which ways they access the data of material in general.

<u>(1) Materials’ suppliers</u>

All of the interviewed designers stated that the ‘raw materials’ suppliers’ were their most valuable materials selection sources. Particularly, the in-house designers explained that those suppliers made presentations about their new products and distribute regularly their catalogs and CDs with their digital presentations. Moreover, they emphasized that the suppliers also brought the samples of the materials involving in their catalogs.

From another aspect, as mentioned in the first question, using the suppliers' catalogs as the materials selection sources enables designers to overwhelm the problem of the 'availability of the selected materials' beforehand. Furthermore, because the suppliers always renew their materials' data, the designers rely on their advices and recommendations on materials.

(2) Fairs

The fairs were defined as the best ways to learn about the materials' usage environments and their suppliers by all of the interviewees. Because a lot of products take place in fairs, the designers can easily access the contact data about the manufacturers of the objects and the suppliers of the materials they are interested in.

(3) Magazines

Among the designers' preferences on material selection sources, the *magazines* took the third place in line. According to them, a magazine do not have to be a specifically for 'materials'. On the contrary, they prefer it as the design magazine, so they can inspire from the existing objects and materials like being affected in fairs by touching to the real products. Therefore, some of the interviewees follow the design magazines such as ID (3/20), Domus (2/20) .

(4) Consultancy

For most of the interviewees (12/20), the ‘material selection process’ cannot be done without getting consultancy from colleagues, engineers, friends or a specialist on a material. In manufacturing firms, the materials specialists give materials data to the designers and this data is kept ready for another use.

(5) Internet

According to all of the interviewees, Internet is a huge data garbage, especially for the ones who did not know for what he/she was searching for. Most of the interviewees use Internet only for exploring the specific addresses they knew beforehand, such as the addresses of the suppliers’ firms.

(6) Books

Among all of the interviewed designers, only three interviewees stated that they benefited from the books as the sources of materials selection. The other 17 interviewees explained that, they did not have time to search for a material from a book in any design process. Therefore, they prefer the easiest and the fastest way for accessing the data they require, such as the catalogs of the materials suppliers.

d. The ways through which designers access data: positive and negative aspects

In the fourth question, the interviewees were asked about the methods utilized in the source they use to convey materials information and their advantages and disadvantages. Almost all of the interviewees replied that the evaluation of the positive and the negative characteristics of a materials selection source depends on how easy and fast they could access the data and if the data source was a renewed one.

(1) Time-saving in material selection

According to the ten of the interviewees, if the design process is separated into various phases such as concept creation, collecting data, sketching etc., 'material selection phase' takes frequently less time considering the whole process. As a result of this, they believe that, in a limited time span, they cannot spend time for selecting new materials and they prefer the traditional ones, which is an obstacle for the 'innovative design ideas'. An in-house designer stated that:

> I wanted to apply a different material on the frame of the X product. The 'mechanical design department' objected to the idea and they tried to change the design of the product. The problem they stated that they did not know how they could attach the new frame to the old foot cover. Therefore, I immediately began to search on a material and found that it could be possible by using adhesives. It was a product of 3M. I got in contact with the people from this firm; they came and made presentations about their extremely powerful adhesives. And, we all understood that it could be possible to stick the frame onto the foot cover. However, it was too late; the X product had been sent to mass production lines at that time. I realized that, you have to struggle for your ideas if they were really far from the traditional ones of your firm. And for those efforts, you don't have sufficient time.

(2) Renewed Data

The interviewees defined 'renewed data' as the data that enables to be up-dated. The three of the interviewed designers said that the communication between industrial designers in Turkey was very weak and they did not discuss the new materials and technologies on the design platforms. They explained its cause with the competition among the designers and the firms who endeavor to get the large share in the market. Therefore, the 'renewed data' in a source is a very significant point to follow the improvements and the trends.

e. Accessing to the samples of the materials

This question was if the interviewee had easy access to the samples of materials he/she selected.

12 of the 20 interviewed designers stated that the access to the samples of the materials was very easy. Nine of them were in-house designers. The rest were consultant designers working with only specific materials such as wood or glass and they were not experiencing with the different materials.

Seven out of the eight interviewees, who had problem of accessing the samples of the selected materials, were consultant designers and stated that, the relations between the manufacturing companies and raw materials' suppliers are in a correct balance. Murad Babadağ stated that:

> There are few powerful architects or designers in the market and the samples especially are delivered to these people. For the designers like us, who design for a B+, which is not for the high-income target market, it is not easy to reach the samples and products of suppliers. Indeed, you should use your persuasion ability. Actually the materials suppliers are right in one respect. It suits their interests to give their products to the well-known designers to provide the occurrence of their materials. But, we are right, too.

Like Murad Babadağ, Gamze Türkoğlu Güven stated that, " We try to reach firms which have distrubutor in Turkey, by telling them their materials will be used in our project. Nevertheless this method is not always easy, if you are not a large scale or a well-known firm, it would be hard to convince them."

Only one out of the eight interviewees was an in-house designer and explained that,

> I needed a plastic material for my design a few months ago. GE plastics have a firm named Polimerland. This is a world-known firm and in addition to this they have distrubutors in Turkey. They could not give the materials although they promised to provide. Because, it was impossible to find the that material in the same colours I requested in the stocks of them. They demand lots of money and it is hard to procure these products. It takes six months to bring a plastic to Turkey. It is a long time, and these points make me anxious.

f. Following the advances in materials and material technologies

In this question, interviewees were asked if they could follow the advances in materials and materials technologies. All of the interviewees stated that, the answer of this question was directly related with the answers of the previous one. They explained that, if the suppliers got in contact with their firms, they could easly follow the improvements in materials technologies.

Nevertheless, according to them, to follow the advances in materials technologies is easier than to access the materials' samples. 18 out of 20 designers stated that they were aware of recent improvements. The remaaining two were academics not

involved actively in the sector or working for a firm. For all of those 18 designers, 'fairs' are the most important sources to follow the novelties in materials world. Three of these 18 interviewees mentioned that they could only attain information through their own efforts because the information run very slowly in Turkey.

g. Do the industrial designers consider themselves competent in selecting materials?

The answers of the interviewees to this question can be grouped under three subtitles: (1) the designers who said absolutely yes (7 designers), (2) the designers who said absolutely no (10 designers), and (3) the designers who stated that it couldn't be possible for anyone (3 designers).

The interviewees of the first group emphasized that their competence in selecting materials were related with the '**experience**' keyword. All of them designed different products for various sectors and they finally experienced the sector they work today and were specialized in it.

The ten interviewees from the second group, who said "absolutely no", can also be divided into two groups in itself according to their answers. The first group, including five designers, stated that the process of materials selection went on without their initiative in their firms and because of this they could't have any proficiency on this subject. In other words, they believed that they had not even a chance for being competent. On the other hand, the second group, including other five designers out of ten, explained that, altough initiative was given to them, they couldn' t reach the perfection level. Because, according to them, the term "materials selection" was not an issue which designers could determine by themselves.

The third group, consisting of three designers, stated that the concept of 'competency' depended on the conditions, project and experiences about those materials. Two of these designers emphasized that it could be more suitable to use the term *'sufficient'* instead of *'competent'*. All of these interviewees of the last group were consultant designers and they said that they found themselves only sufficient especially about a material they experienced before.

h. Material knowledge in design education

This question was how the materials information should be given in design education. The reason of this question was the author's observation that the readability of any resource, which can be recommended to the designers about selecting material, is directly related with what they learn about materials and processes in their design education.

All of the interviewees answered this question firstly by giving examples from their own experiences in their design education and gave their opinions about the sufficiency of them. The five of twenty interviewees find their design education on materials sufficient. Three of them stated that the success of their education process depended on the '***industry trips***'[1] made to different sectors in the different regions of the country. Two of them emphasized that a general philosophy about materials was given to them and this had been ample for them in the term "material selection".

The five of the twenty designers stated that the materials' courses should absolutely be renewed every year with the advances in materials and materials technologies. Three of them mentioned that the industrial design departments should have close relations with large scale firms and every improvement should be transfered to the design students by these firms through seminars, material samples and catalogs.

[1] 'Industry Trips' (Middle East Technial University) , repeted every year with the second year design students, aim to demonstrate different kinds of industrial products, their material and manufacturing techniques at their own factories. These take a week or temn days, to approximately 6 cities of Turkey.

The other four of the twenty interviewees stated that it was more reasonable to demonstrate the sample materials to the students instead of giving written information to them. Two of these designers uttered that the information given to the students was very detailed in schools. According to them, when students were compelled to use this information in real life, they only used it for certain materials and because of this situation it was unnecessary for them to get information for every kind of materials. According to these designers, real important issue was to determine the methods and stages in material selection process to the students.

On the other hand, the four interviewees emphasized the importance of giving detailed information for each material. One of them, Oya Akman, who gives an elective course on 'glass' in Istanbul Technical University, stated that it was necessary to form various lectures for each material. She emphasized that:

> I give an elective course for only glass in one year. It is very essential to intensify different materials by planning projects about these materials. Every kind of education should be given to designers regarding the materials. This education should comprise everything from attitudes to consumers' tendencies. Every educational system should be understood. You can only be competent in the field of a material by having detailed informations.

Another designer from this group, Osman Ünver, mentioned that it should be compulsory to give "technician courses" to students for materials knowledge. He also stated that it is a need for students to learn production and mass production processes and even the energy spent for the production techniques of an individual material in a detailed way. He explained that,

> The student trying to make a rectangular prism by filing a piece of iron during a week will see that it is easier with a wooden piece regarding time and energy. By this way, he will learn the specific features of the material by exercising with it. No need to learn the philosophy of the work, nevertheless it is necessary to make some practices.

Only one of these interviewees, Murad Babadağ, stated that it would be appropriate to give these lessons with the title of "the effect of materials on form". He told his own experience in his graduate study and stated that it was more effective to give the aims for inventing new materials in a historical order and to tell the students the importance of these materials.

To sum up, it can be seen that, twelve of the twenty designers stated that the materials lectures should involve practical lessons. Three of the twenty designers empasized the significance of giving a general method for the materials selection. Four designers stated that it was needed to give a sector-based education which comprises visits to industrial regions, manufacturing firms and materials suppliers. Finally, one designer advocated the idea of giving these lectures in a philosophical way and giving the historical process of the materials selection.

i. The evalutions of the designers on some examples from existing sources

In the 9th question, the interviewees were asked to compare and prefer different techniques of materials data presentation from various existing sources. The different characteristics of the same material (Nylon) were presented with varied methods such as texts, charts and graphs. In this question, the author aimed to get the information of the designers' preferences on appearances and readability of information without studying the contents of the data thoroughly.

For this question, the author selected 15 samples of presentations from different sources. She did not select them haphazardly. Whereas, she considered all of them carefully for the aim of demonstrating various presentation techniques to the interviewees (Appendix B.2).

For instance, in the graph '**a**', the heat deflection tempreture feature of nylon is shown in a comparative way along with three materials which were similiar to it. In the graph '**a**', the significant areas are defined through linear circles not through stains.

In the graph '**b**' , lines with three different colours showing the performance indices are used. There is a small text which give the information about the graph. In '**c**', the alterations of heat and density are explained through two charts by comparing them. In presentations '**d**' and '**e**', only one feature of the material is explained by using a linear chart. In presentation **f**, the recycle fraction and the cost relations are presented in a graph through using cloured areas.

Presentation '**g**' uses a similar method with '**f**'. However, the polimers are described in a more detailed way. In this presentation, the user can have chance to compare nylon with other polimers.

Presentations **'h'** and '**i**' exemplify the techniques with written explanations. The first one determines the features of nylon under the title of "physical insight" and the second one illustrates example products in their usage context.

Presentation **'j'** describes 11 products, which resemble nylon and explains different features by using basic headlines. In '**k**', the price evaluation is made according to the length, thickness and width of nylon. Presentations '**l**' and '**m**' are the ones only with written explanations. **'l'** gives very general information about nylon. Nevertheless, in presentation **'m'**, information is collected under captions. Production techniques, similar materials and environmental notes are some of them.

In graph '**n'**, a comparative presentation about "transparency levels" and 'prices' of polimers is made. This presentation is resembling to presentation '**g'**, but for '**n',** the vertical lines are used. In the last presentation '**o'**, every material was described by using coloured spots.

Viewpoints of designers about these presentations can be grouped under three categories namely '*the designers who prefer graphical presentations*', '*the designers who prefer written presentations*' and '*the designers who prefer presentations, which contain both of them*'.

Three out of twenty interviewees stated that they needed specific information on materials and it was hard to comment on these graphical presentations about materials. These three designers emphasized that they wanted to obtain specific answers for their required criteria on materials, but that process took lots of time. Furthermore, they asserted that the materials selection process couldn't be done without consulting an expert. For this reason, these designers neither approved these presentations, nor they commented on them.

Two of the interviewees stated that the presentations should be in the form of the written explanations. Both of these interviewees, who stated that the graphical presentations were for the engineers, were in-house designers and designing electronic systems with engineers.

Another two interviewees stated that they wanted to see the written encyclopedic data- such as the origin of a material' s name- before the technical data was given. On the other hand, 14 interviewees stressed that the graphical presentations were more important than other styles. According to them, the comparative information was very essential. Most of them affirmed that they wanted to see the material they had chosen and its privileged features by comparing them with other materials. For this reason 11 interviewees from this group found presentation ‘**j**’ very successful and they said that, any information could be obtained by using this graph. These 11 designers asserted that the designers could easily understand the numerical data.

Conversely, three interviewees claimed that the numerical data charts were very complicated and designers could understand the given information more easily in the graphics using colored codes and stains. For this reason, they found graph ‘**j**’ complicated and instead, they preferred presentation ‘**f**’ finding it more readable.

14 interviewees who preferred graphical presentations stated that a written task including main titles could be given. Three of these designers asserted that every presentation must be similar to the traditional ones. According to them, a designer should not spend time to understand the logic of a new graph. For this reason, they said that linear presentations -like ‘**e**’ and ‘**d**’**-** can easily be interpreted. These three designers asserted that in any presentation, the definitions of every component of the presentation must be given such as in presentation ‘**b**’.

j. Designers’ expectations from a ‘materials selection source’: how do they want to access the data?

In this last question, the author wanted to learn the designers’ expectations from a materials information source, and in what sort of environment and how they prefer to access the data in general.

(1) The expected content of the materials data

The expected content of the data of a materials selection source can be listed according to the interviewees' preferences as follows:

- The contact data of the manufacturers and the materials' suppliers (10 /20)
- Mechanical properties such as durability of the material to the manufacturing processes or to the environmental impacts (10 out of 20)
- Production techniques which are appropriate for the candidate material (8/ 20)
- The recommended usage environments for the candidate material (6/ 20)
- The example products manufactured by the same candidate material (5/ 20)
- The cost (5/ 20)
- The ultimate appearance of a surface with the application of the candidate material (that is finishing) (5/ 20)
- Emotional properties: perceptional values (3/20)
- The examples for the 'extreme' usage areas about it (1/ 20)
- 'Sustainability' and 'recyclablity' of the candidate material (1/20)

(2) The expected presentation methods of the materials' data

Four of interviewees stated that, they preferred to **enter the selection criteria** before selecting a material. Gamze Türkoğlu Güven explained it:

> We are not speaking with engineering terms or percentages so much. Every product has specific criteria. For example, Let's suppose that you are designing a water closet, the most important criterion should be the hygiene for you. There are also some other factors. It won't hold the germ, it will stand water and shock and what the cost will be. It must be a kind of source that, perhaps a web site, you should be able to enter your data and at the same

> time it should offer a few alternatives to you about your entry. In addition, I want to see the other characteristics of those alternatives and compare them practically. For instance, when I say compare these materials with the production methods I should see which material is more suitable right away. By this way, while trying to choose a material, we can have some knowledge for the other a few different ones and may use them for another project.

Eight of the interviewees affirmed that to give the information in a **digital** format would be better. Because, they explained that, a digital source could be with them all the time and they could reach it as soon as possible whenever they wanted. Three of these eight interviewees added that another important point was the update ability of it. One of them stated that, "It is easy to update a digital source. It may be a downloadable source and we can download a new version from the Internet or a continuous online sources." However, another eight designers stated that whether the source was a digital or a hardcopy one was not important for them, even if it was a time saving source.

On the other hand, four designers insisted on **the hardcopy sources**. They said that it was very difficult to read and follow the information from the PC screen. They emphasized that, when they found something important, they wanted to underline and took some notes on it. Three of them mentioned that, in a hardcopy source like a catalog arranging the information from the general to the specific, seeking for a material was easy and understandable. One of them stated that the color-coding at the edge of the pages was an important criterion making easier to find the required data.

Seven interviewees out of twenty expressed that it is necessary to see the sample of the materials. Arif Özden transferred a dialogue with his friend as follows:

> We have thought this source should be a home; not a place there are only magazines and catalogs inside but a continual living exhibition place. This kind of a place will look like an information bank and visitors will have

> financial support by small amount of the membership fee. Perhaps I visit once a month, but if I start to a new project, I absolutely go there. Because, a brochure becomes a garbage.

In addition to the samples of the materials, the interviewees expressed their wish to see all of the candidate materials. The designers, who had preferred presentation **'j'** (11 of 20) in the previous question, stated that they wanted to see all the alternatives and **compare** them. Particularly four designers emphasized that, "a source which indicates "this is the alternative material in the comparisons the cost or the other specifications of your selection" would be incredibly useful.

On the other hand, Osman Ünver stated that: " In my opinion the designers' real expectations from this kind of a source may be to learn the names of the experts about the materials to consult."

4.2.2 Evaluation of the Questionnaires

In the field study, the questionnaire consisted of 4 questions focusing on the issues of 'material selection criteria' and 'the sources of material selection in the design process'. The aim of the questionnaire was to make designers consider again the same topics, which had just been asked during interviews, and to make them emphasize the critical points affecting their selections. The questionnaires provided the author with systematic and concrete data on subject (Appendix B.3).

Because the interview was to take approximately 40 minutes, it was significant to prepare the questionnaire with less questions summing up the subject. The goal was to access the intended information without annoying the interviewees.

a) ‘Design and materials’ relationship

The first question aimed to make interviewees define the relationship between the ‘***design and material***’. They were wanted to write some keywords, which comes their mind immediately, after discoursing about the issue in the interview.

After evaluating all of the answers, it was seen that, designers used some of the keywords frequently, which can be seen in Figure 4.1. Other keywords were used for only once were: product, process, astonishing, recycling, ecology, softness, hardness, coldness, health, solution, variety, detail, the spirit of the product, the psychological impact, high technology and Ali Günöven (the instructor of the ‘Manufacturing Materials’ course for 15 years at Middle East Technical University, Department of Industrial Design).

As it can be followed from the chart (Figure 4.1), ‘production’, ‘texture’ and ‘cost’ are the most often used keywords by designers. When it is compared with the findings of the interview, it is not surprising to notice these three words as the most frequently used ones.

The word production involves some other words in it like the production techniques and the suitability for mass production. Similarly, the keyword ‘texture’ also contains the ‘outlook of the surface’ or the ‘appearance’.

The main idea, which was explained by the interviewees about the word ‘harmony’, is that, the ‘design and material’ can be evaluated as a whole, which cannot be separated. Material integrates the design and without the material knowledge, it is impossible to design a product. In other words, according to them (5 out of 20), the decision process for a material of a product occurs synchronously with the designing process and the user evaluate the material of a product without abstracting it from whole design.

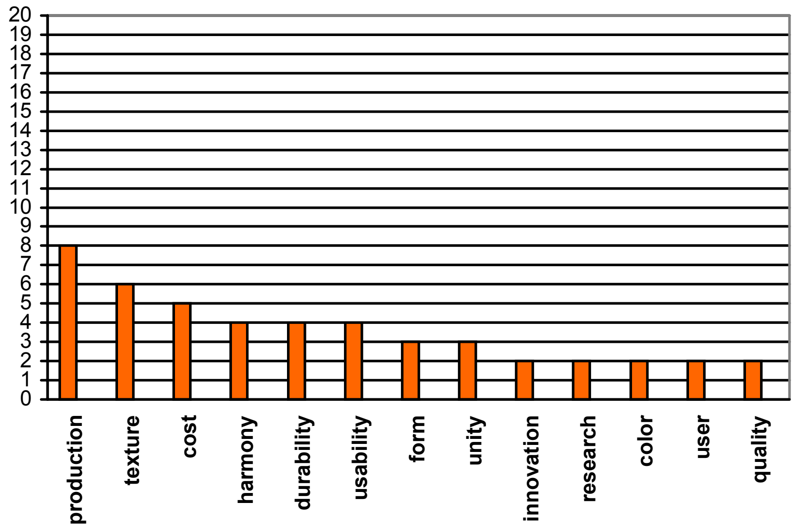

Figure 4.1 The division of the keywords on the relationship between design and materials.

b) The factors affecting the decision making process during the materials selection

The second question was a ranking scale question. The author offered them six criteria affecting their decisions on the evaluation of the candidate materials. They were asked to rank them by giving number '1' for the most important option. The evaluation of the designers' preferences can be seen in Figure 4.2.

When the chart is analyzed, it seems that the most preferred choice among all others, is the '***technical properties***'. The meanings of the terms involved in the question were defined beforehand to the designers. The technical properties at this study are the characteristics of a material related with its physical and chemical constructions such as its density, heat conductivity, friction coefficient, flexion coefficient, and etc. As all of the interviewed designers explained, the technical properties of a product determine its ease of manufacture and ease of use.

Another concern, which industrial designers took into account about this option, was whether or not the given manufacturing route, depending on the chosen material, will satisfy the utilitarian functions of a product. That means the technical properties of a material determine if it could be used as a handle of a kettle, with its strength, or durability.

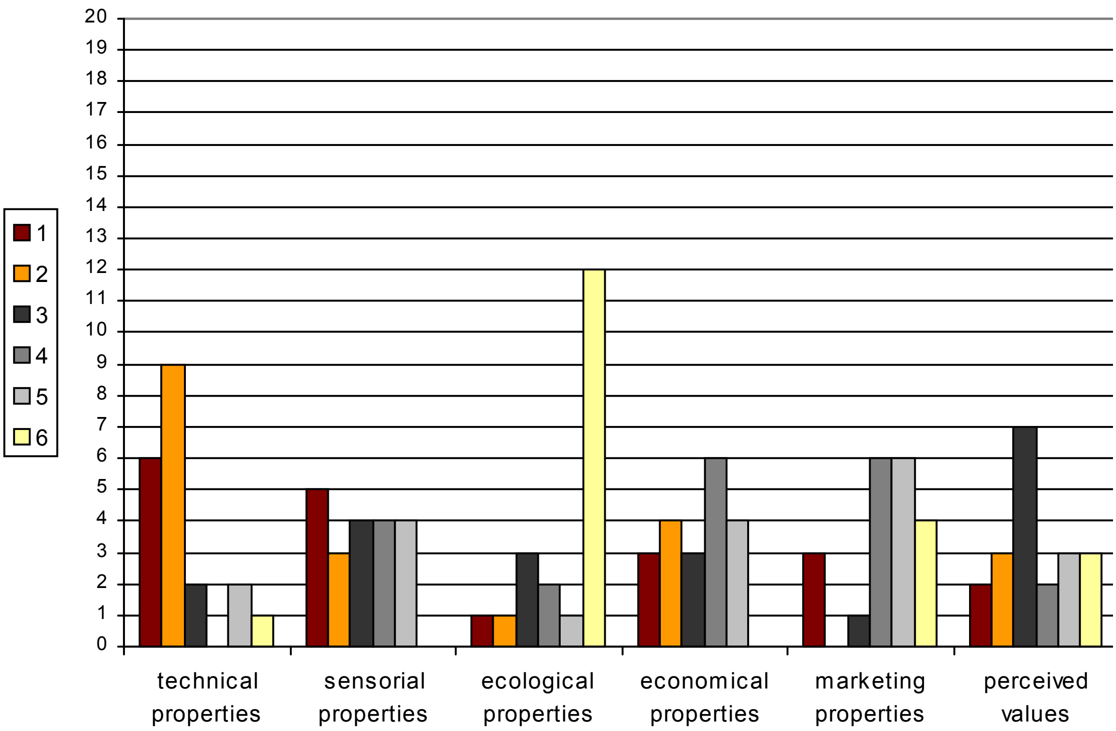

Figure 4.2 Factors affecting the decision making process during the materials selection.

As expected from the evaluation of the interviews, the second most preferred option in this question was the '***sensorial properties***' of a material, which was defined as the characteristics of a material having the effects on users' senses such as sight, smell or touch. According to the interviewees, although a product may stimulate all five human senses, 'sight' and 'touch' were the most considerable ones among all. Regarding to the first question, the 'texture' including 'appearance' is used as a contributing factor for the desirability of the product.

7 out of 8 industrial designers, who defined the 'sensual properties' as their first and second preferences, defined the '***perceived values***', such as the aspirations, emotions and associations related with the cultural differences, trends, etc., created by a material, as their third choices.

The consensus amongst the interviewed industrial designers was that the technical properties option automatically covers the 'budget account' by referring the ease of manufacture. However, as a separate option, the '***economical properties***' includes the cost of the material and its accessibility, too. They define that issue with the word of 'feasibility'. As it can be followed from the chart, this option was preferred as '1' by 3 designers, and '2' by 4 designers.

All of the designers who ranked that option '1' were from small companies respect to other big firms. For this reason, they were the ones who have to think all kind of financial criteria affecting their companies' budget. On the other hand, the 3/4 designers who defined that option as their fifth choices were from big companies as expected. Those designers associated their choices with the amount of given responsibility to them by their company on those financial issues.

Astonishingly, the '***ecological properties***' of a material do not have the expected influence on design activity for interviewed industrial designers. Ecological factors consisting of the ‘recycling of the materials’ and the ‘use of natural materials’ were selected as the last criteria on material selection activity by 12 industrial designers.

All of them made a short explanation after their choices expressing their unhappiness concerning on the subject. Some of the reasons behind their choices were:

- The cost of recycled materials and manufacturing techniques
- Target groups’ approaches to the recycled materials (if they design for a specific group of people who gives care to the green issues, the companies’ strategies may be figured out according to their expectations)

The exception was a consultant designer, Kunter Şekercioğlu, who selected the ‘environmental properties’ option as ‘1’. He stated that,

> Actually, I first evaluate the production techniques of the firms who want me to design for them. This of course consists of the technical properties of the material. But, from the ‘green issues perspective’, I had some experience on rejecting a material just because it is harmful to the environment. Unfortunately, somehow it seems like an ideological approach in Turkey. Every designer wants to take into account that subject but it is nearly impossible here.

When it is evaluated totally according to the calculation of the 4^{th}, 5^{th} and 6^{th} choices, for 16 industrial designers, it seems that the least significant criterion is the ‘***marketing properties***’ of a material. This criterion contains the ‘trends’, ‘the target market’ and ‘cultural issues’, etc. The interviewed designers evaluated those titles as a whole combining with the ‘product design’. Differently saying, it is mostly the form and the function of the product, which determines its marketing properties. The material of that product may be used as a contributing factor to create these two. For that reason, material is not a determining factor for the market when it is evaluated separately from form and function. However, for 3 designers, the material of a product may satisfy a target market without needing the other factors of product such as form and function. One of those 3 designers, Gamze Türkoğlu Güven stated that,

> We are all designing especially for a specific target market. Therefore, whatever the criterion is, I immediately evaluate the 'marketing strategies'. The material, as alone, can satisfy a group of user helping them to create associations or a mental image of that product. I mean that, the materials have their own meanings and we use those to contribute the design at all. If there is a trend using wood in kitchen among high-income society, a wooden cub will remind a 'wealthy kitchen' to the ones from low-income one. We use this knowledge, whether or not consciously.

c) The materials selection sources used by industrial designers in Turkey

The third question addresses what kind of sources industrial designers use while selecting materials during the design activity. To obtain specific names of sources for that question, it was given care to make interviews in their usual working environments, with all of their sources around. The evaluation of their answers can be seen in Figure 4.3.

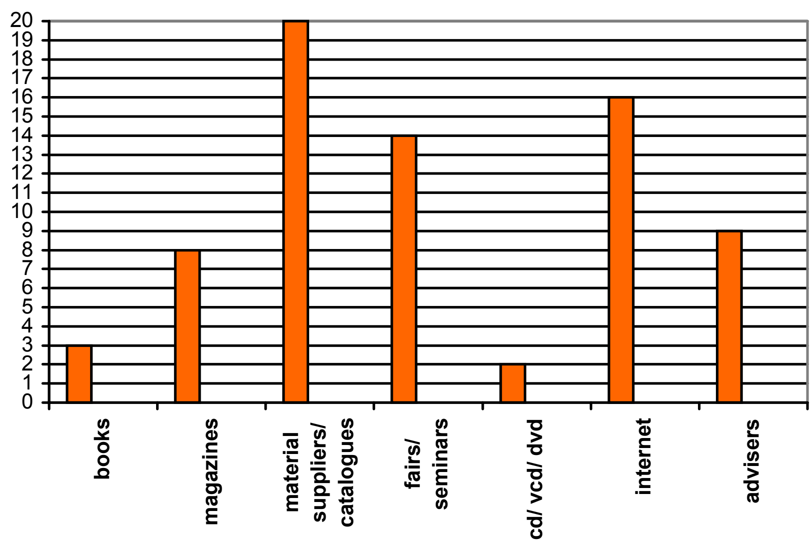

Figure 4.3 Materials selection sources used by Turkish industrial designers.

(1) Material suppliers/ manufacturers and their catalogues

All of the designers pointed out this title as the most frequently used sources of materials, as it was the same in the results of the interviews. The three mostly pronounced firms among industrial designers were GE Plastics, Dupont and 3M (the detailed explanations of them can be seen in Section 3.3.1). Some other companies mentioned were: Yapı Kataloğu, Bayer, DOW, Kimetsan and IM.

(2) Internet

When turned back to the 'evaluation of the interviews' section, it is observed that the designers do not often prefer using Internet while they are searching for a material. Conversely, in this question, the most of the designers (16/ 20) are seemed as using Internet sources to explore data about materials. The reason is that, they use the Internet, but they don't prefer. However, only a few of them (5) are using the 'material search' web sites directly for providing information on materials, such as 'Design inSite' and 'Material Connexion' (the detailed explanations of the Sites can be seen in Section 3.3.3 and 3.3.4). Other 11 designers are using Internet to access the contact data of material suppliers. The two major motives for their preference on Internet sources are:

- The updated information can be found especially on new production technologies and material innovations.
- Accessibility of the source is easy and it does not take too much time (as expected, all of the designers have computers and Internet connections).

(3) Fairs and seminars

Other important sources of information for interviewed industrial designers were 'fairs' and 'seminars'. As it was explained in the evaluation of interviews section, the most of the in-house designers are joining regularly to the 'international' or 'national' design fairs. 'Milan Design Fair', 'IFA Berlin', 'Köln Fair' are some of the international fairs they visit every year. 'Yapı Fuarı' is the best-known national fair among industrial designers (Detailed information can be found in Section 3.3.4).

(4) Magazines

Eight of the interviewees are the subscribers to some magazines on 'design issues' or 'new technologies'. Some of those mostly pronounced magazines were: ID (3), Machine Design (2), Domus (2), Ottogono (1), Frame (1), New Glass (1), and Packaging Bulletin (1). (The detailed explanations of some of those sources can be found in Section 3.3.2).

(5) Advisers

Nine of the interviewees mentioned this category as a significant source of materials selection like in interviews. The author divided this category into three subcategories by depending on the explanations of the designers in questionnaires' sheets. These are: colleagues, clients (who are accustomed to using that material) and specialists (engineers, chemists, etc.).

(6) Books

When it is compared with the other options, it can be obviously observed that the books as a source of materials selection are not used efficiently among industrial designers. Five of the designers selected this choice. However, only two of them could remember a specific name of a book: ‘The Material of Invention’ by Ezio Manzini and ‘Designing Plastic Parts for Assembly’ by Paul Tres.

(7) CD/ DVD/ VCD

Only two interviewees selected this category. They explained that they sometimes used the material supplier firms’ compact discs, which contains their catalogues.

Up till now from the beginning of the field study, the questions of the interview and the questionnaire conducted to the industrial designers were on the base of taking information on the sources they use for materials selection process. The next question- as being the last one- of the questionnaire addresses to get the information of how much they know about the existing prevailing sources on the issue of materials.

d) How much do the designers know about the common materials selection sources?

In this question, the interviewees were asked if they had heard about given six sources beforehand (Figure 4.4). These six names, distinguished by the author during her literature survey, were selected by depending on their privilege in materials' selection issue. They will be defined more detailed in the next chapter.

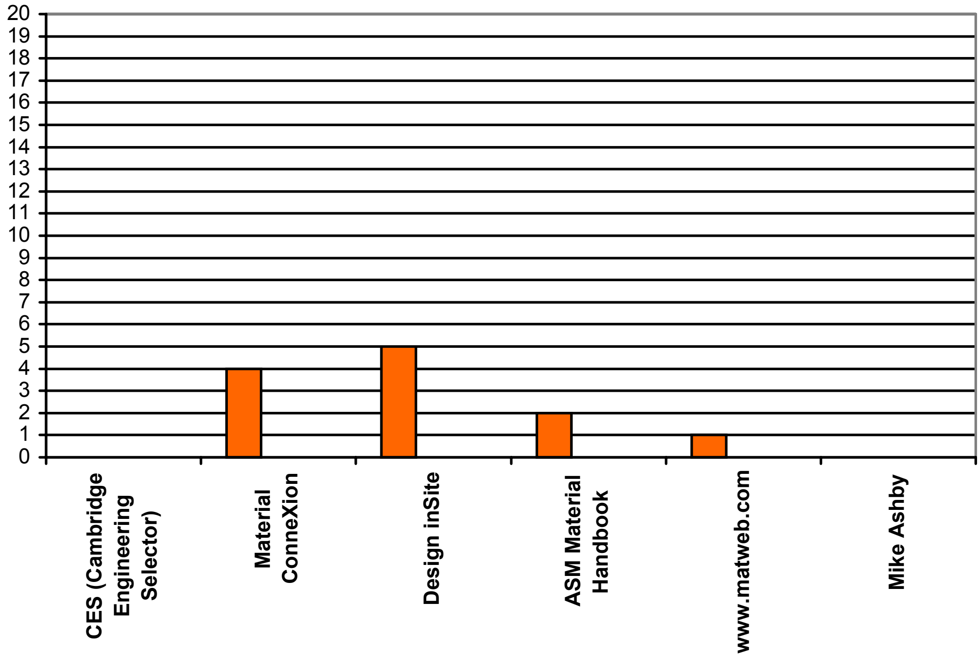

Figure 4.4 How much do the industrial designers know about the common sources?

4.3 COMPARISON OF THE FINDINGS WITH THE OTHER RESEARCH RESULTS

As it was mentioned in Section 3.5, the author examined another research made by Dr Owain Pedgley (1999). In this section, the author aims to compare the findings of the field study with Dr Pedgley' s findings.

a. Materials Selection Process and the Involvement of the Industrial Designers in the Process

The findings of the Pedgley' s research demonstrated that, all of the interviewed professional designers were obviously concerned with the external form of their product proposals. The interviewed designers in manufacturing companies generally stop their involvement with a design once the external product surfaces are determined to be suitable for manufacture and assembly. Production engineers and toolmakers then detail the design for manufacture and determine the exact material grades and suppliers to use.

A similar result had been reached through out the findings of the author' s thesis. Although several interviewed designers find themselves efficient enough for decision- making on materials selection, they do not cease the selection process and decide the candidate material without external advices from engineers and manufacturers.

b. Functions that industrial designers desire processed materials to satisfy

For the aim of clearing out the role and significance of materials and manufacturing processes in industrial designers' decision- making, Pedgley asked designers to define the functions they require to achieve with the appropriate materials. The results showed that, all of the interviewees, working in-house or at consultancies, were involved with devising ***manufacturability*** product proposals. All stressed the fundamental importance of due consideration of product manufacture. It was abundantly stated that there was no possibility in professional practice for designing a product that could not be manufactured or that did not take into account the very real and varied constraints of manufacture. Due consideration of manufacture, it was agreed, was the key to achieving a final production item with a form exactly as intended. Without due consideration, the form of a product can be expected to undergo unfavorable modification in later phases.

Another point emphasized in Pedgley' s research was the significance of the 'surface finish', defined as the top layer of a product. Combinations of materials and processes give a certain finish and it was stated in the interviews that this is increasingly important in the marketing of a product, rather than the concept behind the product.

Pedgley gathered the required functions with the appropriate combinations of materials and processes from the designers' perspectives as: (a) convey (express) messages about a product to its user, for example as an opportunity to "…add some spirit to [a] design"; and (b) meet utilitarian requirements. Than, he outlined the considerations and key factors in industrial designers' decisions on product materials and manufacture (Figure 4.5).

As it can be followed from Figure 4.5, Pedgley divides the factors into two main titles: (1) Functions, which require achieving with materials and contains expressive and utilitarian functions; (2) Considerations, which includes constraints and opportunities as being effective factors in materials selection.

He defines *expressive functions* as properties of materials and processes used by industrial designers to entertain people's senses and, in so doing, contribute to the desirability of a product. Processed material forms are chosen not just for their utilitarian functions but also to stimulate people's thoughts and provoke responses too, such as associations, perceptions, aspirations, emotions and a sense of quality (i.e., elements of product semantics). The *utilitarian functions* are defined by interviewees as such functions vary widely between products, such as, transparency for reading the fill level of a jug kettle; elasticity for comfortable handles; an ability to be wiped clean for hygiene.

FUNCTIONS

Expressive

SIGHT; TOUCH; SOUND; SMELL; TASTE

Utilitarian

BASIC UTILITY
HARSH CONDITIONS

CONSIDERATIONS

Constraints

Availability of materials and manufacturing processes
Budget
Corporate identity
Design brief and the client
Detail Preferences of the toolmaker/manufacturer
Directives from in-house marketing departments
Health and safety
Limitations for form creation
- Overall external shapes
- External surface details
- Internal surface details

New technology
Problems with mixed materials
Product precedents
Volume-cost relationship

Opportunities

Advancement on design
Cosmetic details
Design for disassemble
Design for disposability
Fashions
Market differentiation
Miniaturization
New technology
Obsolescence/ longevity
Personal objectives and aspirations
Scope for capital expenditure
Use of recyclable materials
Use of recycled materials

Figure 4.5 Key factors in industrial designers' decisions on product materials and manufacture (Pedgley, 1999).

For the *constraints* part, Pedgley states that, in proposing a manufacturing route that satisfies the desired expressive and utilitarian functions of a product, a designer will take account of a number of important practical constraints.

As followed from the Figure 4.5, he listed all mentioned constraints according to the alphabetic order including: *availability of materials and manufacturing processes, budget, corporate identity, design brief and the client, detail preferences of the toolmaker manufacturer, directives from in-house marketing departments, health and safety, limitations for form creation, new technology, problem with mixed materials, product precedents, volume-cost relationship*.

Most of the key factors stressed above were also considered in the context of this thesis. However, the interviewed designers in the present research did not emphasize some of the factors (for example, some of the factors were mentioned by only one or two designers) and surprisingly they occurred as the separate crucial considerations at Pedgley' s study. One of them was the factor of 'corporate identity'. At Pedgley' s study, it was defined, as the color scheme a company uses for its products is a major part of its corporate identity. Whether if the candidate materials are compatible with that color scheme or nor is an important consideration factor by industrial designers.

As like in Pedgley' s findings, the interviewees of this field study stated that, the defined project and the concept (defined as 'design brief' at Pedgley' s study) is one of the most important factors affecting materials selection process. These factors also consist of detail preferences of the manufacturers and the directives from marketing departments.

On the other hand, 'health and safety' issues weren't the factors mentioned a lot by the interviewed designers for this study, although it was listed as being one of the effective factors for decision- making on materials selection at Pedgley' s study. Two designers, one of whom was designing medical instruments and bathroom accessories while the other was designing toys for children, only underlined the 'health and safety' aspects. Because, the concepts of the given projects were directly related with these aspects.

Green issues' in practice

Green issues were not a large influence on the work of the interviewed professional designers as do in this study. Pedgley listed a number of similar reasons with the author' s list for why serious attention to 'green issue' is currently not widespread amongst interviewed industrial designers (314).

- Cost is a central issue. To test and implement 'design for disassembly', 'design for recyclability' and to use recycled material adds time to the normal design process and this, in turn, increases costs. Regard for these 'green issues' may move overall costs beyond a level at which a product can remain competitive. 'Greener' product finishes are often unproven technologies and, as such, require thorough investigation before committing to them [Nokia].

- Regard for 'green issues' is generally reactive rather than proactive. If competitor manufacturers are not paying serious attention to the issues, and if consumers are not demanding 'greener' products, a high priority is then not set on addressing the issues. The general feeling among the interviewed designers was that, currently, proactive consideration of 'green issues' by manufacturers amounted to little more than a corporate gesture.

- It was stated that virgin material is cheaper to purchase than equivalent post-consumer recycled material. The unknown melt processing characteristics of post-consumer polymer was cited as a major reason for manufacturers' avoidance of such material. Johan Santer of Kenwood suspected that post-consumer recycled polymer would not qualify as a food grade material. No mention was made in the interviews of the use of post-consumer semi-finished recycled material (i.e., material pre-formed into boards, tubes and other shapes).

As it is followed, the given reasons about 'green issues' are more or less similar for both studies.

c. Use of information on materials: sources on materials selection

Pedgley states that, the interviewed professional designers identified a large range of information sources as helpful for decision-making on the manufacturing route for a product. He lists them again in an alphabetical order as follows:

(1) Client/colleagues

According to the designers involved in Pedgley' s research, clients and colleagues can provide expert advice on materials and processes choices and constructive criticism of design ideas and details. As remembered from the evaluations of the interviews of this study, this factor was also defined as one of the crucial sources used by industrial designers in Turkey.

(2) Designed artifacts and the wider world

The interviewed professional designers were agreed that there was no substitute for hands-on examination and handling of products to learn about design. The varied applications of materials and processes can be learnt this way, especially from competitors' products. This source had been defined under the title of 'fairs, exhibitions and conferences' at which designers find chance to examine similar or completely different products made from the same candidate materials.

(3) Experiments (R&D)

Experiments can be undertaken to uncover currently unknown characteristics of processed materials. This was not defined as separately being 'Research & Development' for this study, but the designers, especially the ones who were working for big manufacturing firms, emphasized that they were getting help from the engineers and material specialist from the R&D department.

(4) Internet sources

Pedgley shares his own experience here and states that, he had used the world wide web to gather materials performance data, recommendations for design details and contact information for materials suppliers. For free accessible database and design advice, he recommends the MATWEB web site, and GE Plastics web site. GE Plastics was one of the most stated firms by interviewed designers for this study, too. On the other hand, although MATWEB was asked specifically, only one of them said that he had recognized it.

(5) Liaison (cooperation) with end manufacturers and material suppliers/manufacturers

Companies can provide design advice and advise on the availability of new materials. Direct liaison with companies overcomes the problem of relying on out-of-date literature. This source was the most valuable one for the interviewed designers for this study.

(6) Physical samples

He states that, a library of processed material samples is often kept at a design firm. As designed artifacts, material samples can be handled and this helps to envisage their use in an emerging design proposal (or can spark ideas for new products). This point was also valid for this study. The all of the designers states that it wouldn't' t be possible to make the last decision on materials selection without seeing and touching the samples of the candidate materials.

(7) Printed sources

According to the findings of the Pedgley' s study, professional industrial designers make use of a wide range of literature, including:

- Leaflets and brochures of material ranges
- Manufacturers' design advice (especially for injection molding)
- Directories of materials and manufacturing companies;
- The design press (e.g., Design Week, Blueprint), showing materials and processes implemented into products;
- In-house material specification sheets containing performance data

Turkish designers also use the similar sources, with some exceptions such as the names of the design press. On the other hand, Pedgley highlighted a problem, which was mentioned by interviewed designers at this study, as a printed source can quickly become out of date.

(8) Specialists/specialist services

Designers will sometimes gather information on materials and processes at exhibitions and conferences. Pedgley also states that, there are some consultancy agencies and institutes that give design consultancy. This is not as prevalent in Turkey as in the U.K. Therefore; the Turkish designers prefer to take advices and recommendations from manufacturers, colleagues and the designers who experienced with same product beforehand.

d. Use of computers by industrial designers

Pedgley considers this point as a separate issue and ask designers if they use computers in decision making for materials selection. He finds that, computers do not assist the decision-making on the combinations of materials and processes to be adopted in a product. That is to say, computers are not used to provide explicit advice on whether to pick for one manufacturing route or another, or provide suggestions for suitable routes. Computers were used by the interviewed professional designers to (a) generate photo-realistic renderings to show to clients what a product would look like different materials and finishes, and (b) perform searches of material databases to identify materials with specific properties, as like the same in this study.

e. Students' materials and processes knowledge

If it is recognized from the field study, one of the questions of the interview was about the designers' thought in materials in design education and if they had any recommendations on the materials' courses. Pedgley evaluated the same topic, too.

Pedgley states that, the students involved themselves predominantly, though not exclusively, with visual-form exercises (i.e., styling) and did not integrate the details of manufacture into their design proposals. According to the results of his study, at a most basic level, first and foremost, an industrial designer needs to know of the combinations of materials, processes and finishes that can be combined to create a desired component form. Pedgley defined two points stemming from this finding as:

- Materials and processes for industrial design students should be taught from a product design perspective (rather than from the perspectives of materials science or process engineering), which was the same point reached at this study.

- Although students' design proposals are on the whole not destined for production, students should still be thoroughly familiar with the opportunities and constraints of professional practice. Many of the opportunities and constraints also apply to students' client-based projects. Turkish designers also emphasized this point that, the industrial design students should be in correlation with the industry and manufacturer companies and also involved in workshop practices.

f. Implications for information providers: guidelines

Pedgley also gives implications for information providers, which will be the next chapter for this study containing ‘the guidelines for a source of materials selection source’. Consistent with him, there currently exists no literature (or other information source) on materials and processes selection that is targeted to an audience of industrial designers (whether students or practitioners). The format and structure of the resource would need to be carefully thought through by the information designer. It is likely that the sections on product utility, product expression and product manufacture and assembly would need to be included in the resource.

<u>(1) Product utility</u>

Pedgley mentions a study of his supervisor, Dr Norman, who put forward a case that materials data presented as written or numerical information may not be conducive to manipulation in the 'mind's eye' and that, presented this way, the data may not be particularly suited to industrial designers' decision-making. From this perspective, the worth of images illustrating utilitarian uses of materials (to complement materials data) should be considered in any new materials and processes resource for industrial designers.

(2) Product expression

Pedgley states that, there is a need to categorize processed materials by: (a) their potential effects on people's senses; (b) their use in high and low end products; and (c) their use in different worldwide markets. The author also believes that those points are very significant for industrial designers because findings of the field study showed that those points have great influences on consumers' preferences on products as stressed by designers.

(3) Product manufacture and assembly

Pedgley also recommended a visual library, as did by an interviewed designer at this study, holding good for general industrial design practice and manufacturable shapes. Pedgley' s guidelines will be considered again in conclusion chapter.

CHAPTER 5

GUIDELINES FOR A SOURCE OF MATERIALS SELECTION FOR INDUSTRIAL DESIGNERS

Up till now, the author assessed the existing materials selection sources in view of professional industrial designers' expectations from these sources. In this chapter, the author aims to combine the findings of the field study and the literature survey and emphasize the crucial criteria for a material selection guide.

The chapter starts with giving the aim of a materials selection source for the industrial design activity. Then, it offers some guidelines for the 'presentation techniques of the data', including comparative discussions such as '*charts versus texts*', '*software versus hardware*' and '*samples of materials*' Sections.

5.1 AIM OF THE SOURCE

As it was mentioned in the previous Chapters, the selection process basically is divided into two main phases: (1) defining the design problem and establishing the essential and desirable requirements and (2) searching for materials that best meet these requirements.

Considering the number of candidate materials, unless the problem is of a very special nature, a designer is seemingly faced with the problem of making the right choice out of thousands of materials, the main objective is to make sure that all material alternatives are given fair consideration before the material for a certain application is specified. Therefore, **including all industrial materials[1]- used by industrial designers- by giving equivalent considerations to them** can be defined as the major aim of a material selection guide for industrial designers.

The guidelines exist for all of the stages of the design process, but predominantly the detail design stage, in which the specific information is needed and fine details are clarified about manufacturing and assembly. However, in the conceptual design stage, the concrete information is limited and the abstract thinking about manufacturing and assembly is prevalent (Chapters 3 and 4). Actually, relying on the outcomes of the field study, the industrial designers look for a 'concept' specific guide, by using which they can define their interest in a peculiar sector in advance.

Furthermore, the author realized with the evaluation of the field study that industrial designers tend to talk with their colleagues and benefit from their experiences on candidate materials. For this reason, if a material selection guide consists of the samples of the design products, which had been produced from the same material beforehand, and the names and contact information of the 'suppliers' or the 'designers', it will be a valuable advantage for the industrial designers.

It was noticed in Section 3.1 on 'factors affecting the material selection process' that, material selection is initially based on the properties of the materials such as mechanical, physical or chemical. The designer must decide the required properties of a material for a part and then weigh the properties of candidate materials (Budinski, 1996). Therefore, another aim of such a guide should be to offer the comparison opportunity among the candidate materials to the designers. As it was

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[1] 'Industrial' materials had been defined before as the materials used for industrialized products such as metal, wood, plastic, glass and ceramic.

seen in Chapter 4, while comparing the materials, the designers need some other factors rather than properties, such as ‘cost’. Ashby (1992) emphasizes some of those properties, which should be included in a guide:

> Ideally, a materials database should do a number of things well. It must contain the data the designer needs: not just properties like modulus, but information on cost and availability; on processability (how to shape, finish and join the material); on difficult properties like corrosion and wear; on user experience (typical uses, for instance); and, sometimes, general advice on new, unfamiliar, materials which might be better than those he uses now. And if the design involves a critical component -one which, if it failed, would cause serious difficulties -the user would wish to have an assurance of the quality of the data in the database, and some way of tracing its origins.

Consequently, the main questions, whose answers will provide guidance to the designers consistent with the findings of the field study, and what Esin (1980) emphasizes in his thesis are listed as the aims of a material selection source as follow:

- What are the *essential design requirements*?
- Are all of these requirements truly essential in materials selection process?
- Can they be listed in order of importance?
- What material parameters are truly essential to fulfill these requirements?
- Are all of the desirable material properties necessary?
- Which desirable material properties *contribute value* to the design?
- What are *the available production facilities*?
- Are there any essential or desirable design requirements, or material parameters, which are conflicting with the available production facilities?
- Do these attributes exist in similar designs as well?
- Will the cost of material be balanced to its qualities?
- Is the overall cost justifiable?

- Can there be a better material for intended use?
- Can a lower cost material be substituted?
- Can it be supplied for less?

According to Budinski (1996), the some of the important concepts, which he defines as the essence of a materials selection guide, are:

- The most used mechanical and physical properties should be well understood- what they mean and how they are used. The designer should also understand the difference between strength and toughness with the help of this guide.

- Physical properties can be more important than all other properties, depending on the application. They should be scanned for applicability and importance.

- Knowing the chemical composition of any engineering material is fundamental to understanding that material. It may not be necessary to know the percent of each element in the material, but the user should know the basic components and what family of materials a material comes from.

- Surface texture is often a critical use property of a material, and designers should understand how to specify and obtain appropriate surface finishes.

- The available shapes and sizes of materials are often a key selection factor (for example, when time to obtain a material is crucial) (53).

In brief, the primary aim of a material selection source, regarding the findings from the previous chapters, must be to reduce the number of candidate materials to a manageable number. For this aim, guide must offer some comparison opportunities to the designers depending on several aspects. The physical, chemical or mechanical properties can be some of those. However, as well as they do, past experiences and an investigation of materials recently used for similar designs, existing standards *codes* or legal requirements (if any), cost factor, availability, the name of the supplier firms, help to narrow the selection to a suitable number. Budinski (1996) also states that, a source should go into more detail on properties, but most designers put equal importance on properties, availability, and economics. Therefore, those data must also be built in a material selection source for industrial designers. In addition to these, the 'design philosophy', which is defined as the cultural aspects, emotional approaches and trends by Esin (1980), plays an important role in screening the material alternatives. Consequently, as being different from a guide for engineers, the designers' selection guide must aim to contain those kinds of 'design' issues, too.

5.2 GUIDELINES ON PRESENTATION OF DATA

As regards to a guide for industrial designers, good presentation of the data is significant as well as its content. For example, as the first phase on the presentation techniques, it can be easily said that, the segregation of materials parameters as being an essential and a desirable factor constitutes a very important step in the selection of materials. It is impossible to be familiar with the thousands of industrial materials unless one can be guided by some broad and simple *generalizations* as an initial step (Patton, 1968, 7).

As it was seen in Chapter 4, the designers would like to access the data through the generalized main titles to the more specific subtitles. In other words, they are inclined to the hierarchical classifications methods, from the general to the specific. Edwards and Endean (1990) explain the process for the hierarchical model, and state that, the first level in the hierarchy of processes simply divides all processes into one of the familiar groups, such as metal, ceramics, glass, plastics, wood, and the other essential for designers at an industrial process. Each of these will be gradually divided into subtitles as the designers define their more specific requirements (52).

On the other hand, Esin (1980) made another classification recommendation defending that if a designer will give his/her last decision depending on the '*availability'* of the candidate material, the first classification criteria must be 'availability', too (163). For this classification method, a designer can first define his/her location and from where he/she can access the material. It may be described with the designer's definition of his/her working environment (alone, or in a big or small company), which will probably give an idea on his/her financial support for that deal.

The other important point on presentation of data is that whether it is qualitative or quantitative. It was seen in previous chapters that critical design decisions are taken as early as possible in the design process and to achieve this, it is necessary to define constraints early in the process as much as possible. Even in that stage, quantitative data is necessary. It is generally recognized that a good principle is to quantify whenever possible, because it is easy to waste considerable time on qualitative studies on matters that might be easily and quickly clarified by calculation (Edwards, 2002).

However, qualitative guidelines complement the process in all levels. Therefore, it can be said that, the designers need the presentation of the data in a 'quantitative' manner but supported by the qualitative information, which can be the examples of past experiences of other designers or an analysis on a similar object produced by the same material.

Obviously, for both kinds of sources (qualitative or quantitative), the process of matching the property profiles of materials with the requirements can be very tedious and time-consuming unless the source is clear enough. According to Mangonon (1999), it is even more time consuming to search handbooks and data brochures of suppliers for material selection. He says that, “ fortunately, databases that compile properties of different materials are now available to aid in the selection process”. The preferences on ‘hardware’ or ‘software’ source will be discussed in Section 5.2.2.

There appears to be another question about the presentation of the data by ‘charts’ or ‘texts’. In most of the engineering sources, ‘charts’ are used for explain all relations between the properties of materials. For this reason, it is understandable that those charts are engineering based tools and are not always comprehensible for designers. Then, do the designers prefer text-based data to the charts? This question will be evaluated exhaustively in the next Section, 5.2.1.

Mangonon (1999) states that, although the information given in those charts and texts are the results from testing of laboratories, vendors and suppliers data usually reflect the best properties of the material and they do not indicate statistical variation. Therefore, a designer often needs the samples of the materials for testing real performances of them. This issue will also be discussed in Section 5.2.3.

5.2.1 ‘Graphical Descriptions’ versus ‘Texts’

In this section, the author will evaluate the presentation of the data comparing graphical descriptions and written explanations. Before starting the comparison, the author finds it useful to define the meanings of those two terms for this thesis: (1) **Graphical descriptions** include ‘graphs’ and ‘charts’, which were shown in Chapter 4 (the interview questions can be seen in Appendix B.2). Conversely, (2) without any graphical element, **texts** mean the description of the required information by using words and sentences.

Actually, the user often faces with a number of graphs and charts when he/ she searches for materials data from a standard selection guide. This most probably occurs if the guide is an engineering-based one. According to Edwards and Endean (1990), the graphical descriptions of those sources fulfill the first aim of the guides and they are surrounded by text, which contains the information the user will be using to make choices between material and processes (55).

Going back to Chapter 4, it is noticeable that, the interviewed industrial designers often explained that they found most of the ‘graphs’, which are full of ‘specific terms’, ‘signs’ and ‘symbols’, time consuming and directly for engineers. Although there appeared some exceptions, they firstly want to see all the definitions of the terms used in graphs.

As well as graphs, charts with the numerical values are not always comprehensible for designers. However, when they want to compare two or more materials, they prefer to access the data especially through the charts.

On the other hand, designers would not like to get the information by texts, particularly by the long ones. According to them, text can only be a supporting tool, not a direct presentation of data. They prefer short sentences with the highlights on the keywords, which can be vital for the selection and application of the candidate materials. Briefly, they mostly find the visually supported presentations more effective than the written explanations.

As like the interviewed designers, Ashby and Johnson (2002) emphasize that, the brain is better at pattern- recognition when the input is visual rather than text- based (51). Therefore, the aim of a guide should be to convert a large amount of data into a comprehensible, single image, rather a chart, a graph or a drawing. Ashby and

Johnson also state that, a visual presentation of data can reveal similarities and differences between materials that are hard to compare in other ways (53). A visual presentation model for comparing materials developed by Mike Ashby and his colleagues for CES[2] in 1992 can be seen in Figure 5.1.

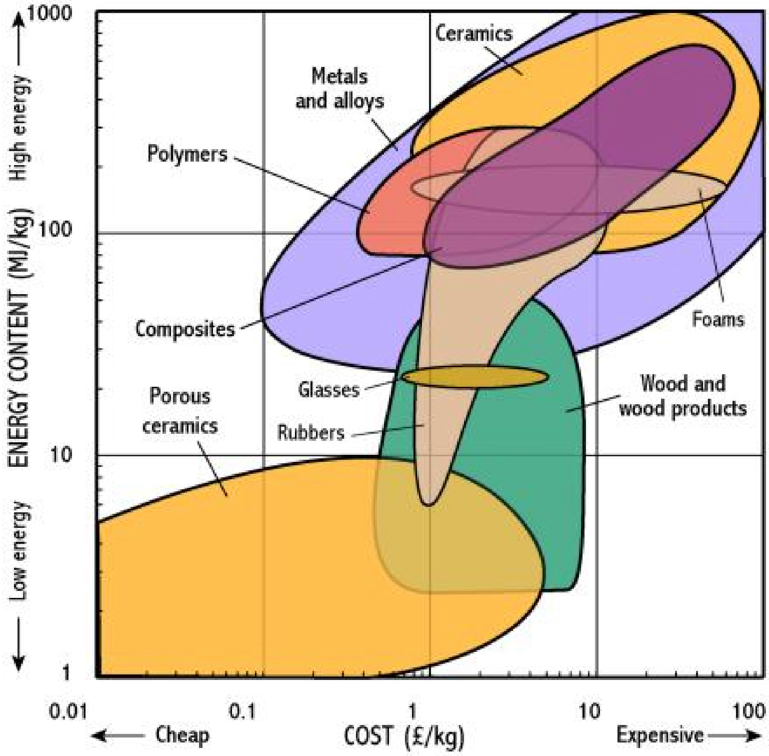

Figure 5.1 A graphical comparison example from CMS Web Site.

5.2.2 Software versus Hardware

Today, most of the sources are based on a changeable characteristic that enhances the probability of the conversion from software to a hardcopy version. If chapter 3 is

[2] CMS: Cambridge Material Selection. The detailed explanation can be found in Chapter 3.

recalled, especially the widely known online material selection packages offer hardcopy data sheets at the end of the selection processes. Whereas, the creators of a hardware selection source try to simulate it with the fruits of novel computerized technology. Subsequently, which one and with what features is preferred by industrial designers?

Interestingly, even when available in computerized form, many designers still prefer to use handbooks or brochures in preference to the computerized tools. According to the findings of the field study in Chapter 4, the four of the interviewed industrial designers also prefer a hardcopy source, because they believe that, they can easily take notes and write on it that make it more personal.

Likewise, Ashby (1992) believes that, the books and collections (like magazine series) listed in the previous section can be found in most of the libraries. The computer databases are harder to find and to run the database again the hardware is required from suppliers. Consistent with Ljungberg and Edwards (2003), the preferences of the designers towards hardware tools can be explained with the easy formats of those tools. Therefore, designers can rapidly comprehend the simple and the lucid layout of the source as recognizing the traditional ones. As remembered from the field study, the interviewed designers also stressed that they would not like to spend time to analyze the new version of a selection source. For this reason, they rather like a traditional one.

On the contrary, seven designers insisted on a digital source, which can be reached more easily and the data included in can be renewed regularly. Actually, as it can be seen from the explanations above, the reason behind the rejection of a computerized source is directly related with its readability. However, according to those seven designers, if the interface and the contents of that kind of a computerized source were designed carefully, it would provide a valuable time saving chance for industrial designers. Because, software programs are easy to access, no need to go to a library.

Furthermore, as stated by Mangonon (1999), the process of matching the property profiles of materials with the requirements can be very boring and time-consuming if a designer has to search handbooks and data brochures of suppliers. But fortunately, computerized databases that compile properties of different materials are easily available to aid in the selection process. So the required data can be seen in a more systematically way in that kind of software sources.

Edwards and Endean (1990) described another advantage of a software database as a computerized form removes the detailed technological information about the processes from the body of the book so that the designer can concentrate on the fundamental nature of the processes and appreciate their common features. In addition to this, they mention that, those sources provide a means of ordering and presenting the information so as to simplify the process choice. In other words, they allow the designer to compare certain aspects of a number of processes and materials simultaneously and the designer can easily read the classified information.

As like Edwards and Endean, Ljungberg and Edwards (2003) state that in computerized form, parameterization of the handbook stages will facilitate rapid comparison of alternatives and execution of `what-if' scenarios, making it easier to chose the `best' material, manufacturing process or physical/metaphysical balance. However, they also believe that, although there are a variety of design support tools as manual, computerized and some available in both forms, many designers favor to use the manual tools than the computerized ones. Therefore, the aim must be to adapt the hardly understood software packages to the simpler methods, which will be a worthy challenge for future.

5.2.3 Samples of Materials

As it was analyzed in Chapter 4, at the end of the reduction process among candidate materials, all of the designers want to have the samples of the materials in their hands and to test their appropriateness. Mangonon (1999) explains that, the designer must be aware that the listed properties are the results from testing of small laboratory test examples and may not be applicable in large-sized structures or components because of the presence of defects. In addition, vendors and suppliers data usually reflect the best properties of the material and do not indicate statistical variation. Furthermore, as an example, the dynamic properties of corrosion and its influence on the mechanical properties are very difficult to match with the active material because small changes in concentration of the electrolyte (or environment) cannot be predicted in the design stage. Therefore, the designers need to access the real materials as soon as possible.

Fortunately, almost all of the designers (19/20) said that they reach the sample of materials in a few days when they require from the suppliers. However, during their decision processes on alternative materials, they do not often have the chance of evaluating them according to their real samples. For this reason, although the application of it seems impossible for them, they imagine a source with all the sample materials with it.

As a final point, in the next chapter, the author will conclude all the evaluations and findings from the literature survey and the field study, and recommend a materials selection model for the industrial design activity.

CHAPTER 6

FINDINGS, RECOMMENDATIONS AND CONCLUSIONS

This chapter addresses the discussion of the findings from the study, conclusions and the recommendations for further work. The first section consists of the analysis of the findings from the field study and literature survey. In the second section, the author recommends a 'materials selection source model' for industrial designers. Finally, the last section includes the conclusions of the study.

6.1 FINDINGS FROM THE FIELD STUDY AND THE LITERATURE SURVEY

Having covered the subject of the industrial design activity, the materials selection process in this activity and industrial designers' views on this subject in previous chapters, the author aims to analyze the findings related to those topics.

The design activity can be clearly divided into three stages: conceptual design stage, embodiment stage, and detail design stage, where the concepts are filled out in order to make detailed comparisons. The starting point of a design product is a *market need.* A *concept* for a product, which meets that need, is planned and potential solutions to the design problem are conceived. If initial estimates suggest that the concept is feasible, the design proceeds to the *embodiment* stage: a more detailed analysis including calculations, performance and cost analysis and preliminary selection on candidate materials. If the outcome is successful, the designer proceeds to the *detailed design* stage, which contains the full analysis of critical components, preparation of detailed production drawings, and final decisions on materials and manufacturing techniques.

Actually, materials selection enters in each stage of the design activity. However, the intensity of the required information alters at every stage. The selection of a material for a specific design is generally a thorough and long application for industrial designers, because almost always more than one material is suited to the application and industrial designers try to select the most appropriate one for the project. At this point, many factors must be taken into account and each factor being considered repeatedly throughout the evolution of a design process.

6.1.1 Content of the Required Data on Materials Selection

As the materials selection process involves lots of considerations, most of the industrial designers do not want to get the whole responsibility on this subject. Therefore, for almost all of them, a designer cannot carry out a 'material selection process' by himself/herself without getting consultancy from colleagues, engineers, friends or a specialist on a material.

When they search about a material, they can easily access the technical data about it. However, do they make choices only depending on the technical data? Obviously, they do not. Ashby and Johnson (2002) state that, in the markets of 21st century, the society does not only desire for usable and functional products at an affordable price, but also desire satisfaction and delight, making inputs from industrial design and aesthetics a high priority (7). According to them, " a good design uses materials in ways that make the most efficient, and often visible, use of their properties and ways that can be shaped" (114). However, consumers are influenced by trends, associations, some cultural values, advertising, and among the various alternative products with different materials of nearly equal technical qualities, they buy one of them.

Therefore, the other considerations and the required data on materials selection process for industrial designers gradually appear: sensorial properties of the materials (includes texture, sense of touch and final appearance) and perceived values, which affected from cultural aspects, trends, associations, emotions, etc.

Furthermore, it is obvious that, even though the selected material is the most appropriate one for the given design project, it may not be possible to access the material at the required volume and cost. For that reason, another point comes about as a factor affecting materials selection decisions: *availability of the candidate materials*. Actually, according to the interviewed industrial designers in Turkey, 'availability' factor is mostly evaluated as the most important factor (Chapter 4), which was not different in the findings of Pedgley' s study (Section 4.3).

When the findings from the field study, from the similar research and the literature survey were analyzed, the author figured out an 'outline', which can be seen in Figure 6.1, including the *content of the required data of a materials selection source for industrial designers*.

CONTENT OF DATA

Technical Properties

- Manufacturing processes
- Volume of production
- Appropriateness to the existing manufacturing techniques
- Durability
- Cost of production

Sensorial Properties

- Sight, Sound, Touch, Smell, Taste
- Ultimate surface finishing (texture and final appearance)

Perceived Values and Cultural Meanings

- Definition of the target market
- Cultural values and emotions
- Attitudes and associations
- Design Movements and Trends

**Availability

- Suppliers (cost of materials)
- Consultancy

Design Notes

- Recommended usage environments
- Design limitations
    - Limitations for form creation
    - Limitations for combined materials (like joining)
    - Limitations for health and safety regulations
- Environmental notes
- Similar materials
- Industrial designers' notes

Figure 6.1 Outline for the content of the required data of a materials selection source for industrial designers.

If it is remembered from the evaluation of the field study that, all of the industrial designers defined ‘materials suppliers and their catalogs’ and ‘fairs and conferences’ as the most important sources for their materials selection processes. Obviously, the interviewees are inspired from the existing products and various applications fields of the materials. Consequently, the author reached two important findings here as: (1) the Turkish industrial designers look for materials with required properties matching with those of another existing material, which had been defined as ‘selection by similarity’ by Ashby and Johnson (2002); or (2) they visit fairs, exhibitions and stores, observing the products and materials for seeking ideas randomly until finding one or more appropriate for the project, which had been defined as ‘selection by inspiration’ in Section 3.2.

These two crucial results, mentioned above, provided the author with background for the ‘content of data’ outline. According to them, most of the Turkish industrial designers make their initial selections depending on the appearance of the materials, that is the texture, final surface finishing, color and all the properties appealing to the sensorial evaluations.

While evaluating the sensorial properties of the candidate materials, industrial designers simultaneously put the ‘perceived values and the meaning of the materials’, which consists of the cultural values, attitudes, associations and trends about those materials, into consideration. Because, the industrial designers desire to satisfy the target market ‘emotionally’ with the support of the sensorial properties to perceived values.

In the concept creation period, although the designers consider the technical properties and manufacturing techniques, they do not evaluate those factors deeply. When they finish the conceptual period and proceed to the ‘embodiment’ and ‘detailed design’ periods, they begin to concentrate on those subjects intensively. They search for technical and mechanical properties of the material, appropriateness of it to the existing manufacturing techniques and the cost of overall production.

The ‘outline’ (Figure 6.1) also contains some significant keywords like durability given by designers as the most effective criteria on materials selection processes. As it is seen in the figure, the ‘availability’ factor was colored differently, because the time for searching for this criterion was not defined definitely by interviewed designers. In fact, this is the most important factor for them and designers commence to consider it from the beginning of the process; it is why they state materials suppliers’ catalogues as the most useful and frequently used materials selection sources. For this aim, the ‘availability’ data consists of the suppliers’ contact data- to get the definite results of cost analysis and availability criteria- as well as the consultancies contact data if exists.

Another factor that does not have a defined place in the selection process is the ‘consultancy’. The interviewees stated that they need advice about the materials at every stage of the design activity. Therefore, if the contact data of any consultancy service on candidate materials can be offered, it would be very valuable for them.

Finally, there seems the ‘design note’ title in the ‘outline’. This title includes special design limitations related with the requirements about the form creation, combined materials and health &safety regulations, recommended using environment, similar materials which can be used instead of the selected material, environmental notes like sustainability or recycle ability of the material, and some specific design notes (can be called as the pill data) from the experienced industrial designers.

Those summarized above are the topics about which the industrial designers desire to find data in a materials selection source. In the next section, the author aims to analyze how they want to access the data; that is the 'required presentation techniques of data for a materials selection source'.

6.1.2 Required Presentation Techniques for Materials Selection

According to the most of the interviewees, whatever the techniques are used for presenting the data, the most significant point is accessing the required information in a minimum time span. On the other hand, while some of them insisted on hardcopy sources, the others emphasized the value of the digital ones. The distributions of the preferences can be seen in Figure 6.2.

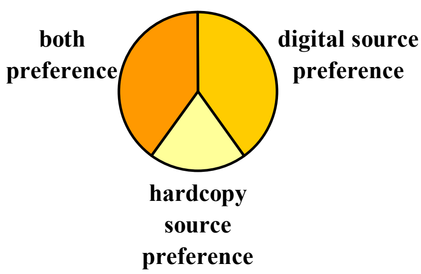

Figure 6.2 The ratio of the digital and hardcopy source preferences.

Another important point for the presented data is the update ability of it. Therefore, as mentioned intensively in Chapter 4, two important considerations on the presentation of the data can be defined as: (1) time-saving process and (2) updated data.

In addition to these, they would like to define their required preferences about materials by entering the selection criteria. In other words, an interactive selection process is valuable for narrowing down the lists of candidate materials.

Among from those, according to the interviewees, the comparative information and the classification is essential for a good presentation on materials selection. Most of the designers want to see the candidate materials comparatively, and most preferably by charts with numerical values or colorful, comprehensible graphics. The most significant criteria on the presentation techniques of the data was summed up as Figure 6.3 by the author.

As it can be followed from Figure 6.3, the designers prefer to access the data by graphical explanations. However, they sometimes prefer written explanations, if only they are short and comprehensible enough. For this reason, they rather like the explanations with keywords or divided into main titles like the explanations seen in 'Design inSite' web site (Section 3.3.3).

A 'Contact Information' requirement appears once more on this subject. The designers highlighted that the 'contact data' must be given as a separate title/option whatever the presentation technique is. Finally, designers emphasize the importance of the materials samples for their materials selection process.

PRESENTATION OF DATA

Data Entry (Definition of the requires specifications)

Graphical Explanation

- Classification
- Comparison Charts (with numerical values)
- Comparison colored graphics

Keywords and Design Notes

- Written explanations (short and comprehensible)
- 'Pill Data' (specific notes)

Contact Information

- Suppliers
- Advisers (consultancy)
- Industrial designers

Materials' Samples (presentations with the samples of materials)

Figure 6.3 Significant criteria on presentation of the materials selection data.

6.1.3 Materials Knowledge in Design Education

The materials education subject may seem a long way from the central subject of this thesis, but there are valuable findings in relation to it. For instance, without an efficient knowledge on materials' general characteristics and designers' selection criteria, it is hard for a designer to adapt to the selection process in his/her professional life as an industrial designer. The author realized that, the interviewed designers, who are successful in their professional practices, are the ones believing to the value of the data they gained with the materials courses in their design education.

The evaluation of the whole study cleared out that, in materials education, there are three important factors defined as follow:

- Renewable data
- Industry support
- Workshop practice

If a correlation between the 'industry' and the 'school' can be achieved, the firms can send their catalogues and sample materials to support the materials courses. Moreover, they can visit the schools and present their new products and improvements in their technologies. By this way the school will be provided with updated information for the students as well as the tutors. Finally, the 'workshop practice' is inevitable for the students to understand the characteristic of a material.

6.2 RECOMMENDATIONS: A MODEL FOR A MATERIALS SELECTION SOURCE

After analyzing the findings from the whole study, in this section, the author aims to recommend a model for a materials selection source for industrial designers.

Depending on the findings of the field study, as mentioned above, almost all of the interviewed designers in Turkey make materials selection by 'similarity' or 'inspiration' methods. Therefore, a source including materials samples and possible example products would be very valuable for industrial designers.

This source may be an extensive material library offering online connection to its subscribed users, who pay a subscription fee every month for its permanence. With the help of the 'online' connection, the users may search in library initially from their homes and offices for their required materials with defined properties. Therefore, the library' s web site should be an online database providing users with 'data entry' specifications and lists of candidate materials. The end list of the candidate materials should contain the materials' availability information. That is, if the searched materials exist in library or not. If not, the source should offer some contact data of the materials suppliers.

If the selected materials (or candidate materials) exist in 'library', then the users may go and see the samples or some manufactured examples of the materials. However, they may not want to go to the library. Then, they may request the samples to their homes or offices. In this situation, the library may send the samples directly if they are at enough quantity in its stock. Otherwise, it may send the suppliers' contact data.

For the continuity of this kind of a source, the materials suppliers should support the library regularly. They should acknowledge it about their new materials and technologies. Therefore, the library may also contain all the data about those suppliers and their catalogues. In addition to these, the library may organize some activities, such as seminars, exhibitions or suppliers' presentations about their products, monthly for all members.

To sum up, a visual library may be the answer of all frequently asked questions on materials and their properties. The online database of it provides all the required information, which had been analyzed by the author through out the research, and the physical part of it may offer numerous example materials and manufactured objects.

6.3 CONCLUSIONS

Advances in materials enable advances in industrial designers. In other words, the effects of new materials and technologies on industrial design are inevitable. If the form of a product is to some degree the result of its material and how it was manufactured, it follows that the designer must have a good understanding of all manufacturing processes and materials, in order to have confidence that the proposed manufacturing processes and materials are the most economical and appropriate ones.

On the other hand, 'competence in materials world' is not easy for industrial designers. Because, a material has many dimensions, and materials selection involves the consideration of too many factors such as availability, economics, and business issues and the relative importance of each of these factors depends on a particular design situation.

The appropriate selection of a material for a design product does not only provide technical functionality but also the opportunity to create the product personality. For providing technical functionality, there are lots of selection sources, which were explored in Chapter 3. However, industrial designers, who also concentrate on the creating of product personality by selecting appropriate materials, cannot find equivalent support for their materials selection activity.

The industrial designers evaluate the several aspects of materials during the selection process such as the materials' sensorial properties, their meanings and perceived values, which are created by users with associations, emotions, trends, cultural values, etc. The findings of this thesis also demonstrated that those points are very significant for industrial designers because they have great influences on consumers' preferences on products as stressed by designers.

However, the author confronted with no literature or other sources on materials and processes selection including the aspects mentioned above, that is directly targeted to the industrial design students or practitioners. Obviously, such a source can influence the creativity factor in design activity by offering special ‘key data’; operational practices information and etc. to the designers.

Throughout the thesis, the author aimed to explore what designers require learning about materials and what are the methods, and materials selection sources they use. The ultimate goal was to find out the designers’ needs and expectations from such a materials selection guide for the creation of a source for industrial designers. The author believes that, the findings presented in this thesis can be transferred into a materials selection guide for industrial designers. She believes that, the further studies on materials selection issue may convert the existing guides to an ‘**intelligent system**’ enlarging its knowledge with the experiences of various ‘designers’ all around the world. That kind of an expert system for industrial designers may combine a database with a set of reasoning rules to permit simple and logical inferences to be made by the system itself.

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APPENDIX A

EXISTING MATERIALS SELECTION SOURCES

A.1 A List of Hardcopy Sources on Material Selection

Metal

- *ASM Metals Handbook*, (1986) 9th edition and (1990) 10^{th} edition. *ASM International*, Columbus, Ohio, USA.

  The 1Oth edition contains: Vol. 1: Irons and Steels; Vol. 2: Non-ferrous Alloys; Vol. 3: Heat Treatment; Vol. 4: Friction, Lubrication and Wear; Vol. 5: Surface Finishing and Coating; Vol. 6: Welding and Brazing; Vol. 7: Micro structural Analysis.

- Smithells, C. J. (1987) *Metals Reference Book,* 6th edition (Editor: E. A. Brandes). Butterworths, London, UK. A comprehensive compilation of data for metals and alloys. Basic reference work.

- *Metals Data book* (1990) Colin Robb. The Institute of Metals, 1 Carlton House Terrace, London SWIY 5DB, UK. A concise collection of data on metallic materials covered by the UK specifications only.

- *ASM Guide to Materials Engineering Data and Information* (1986) ASM International, Metals Park, Columbus, Ohio, USA. A directory of suppliers, trade organizations and publications on metals.

Polymers and Elastomers

- *Polymers for Engineering Applications* (1987) R. B. Seymour. ASM International, Metals Park, Columbus, Ohio, USA. Property data for common polymers. It is a starting point, but insufficient detail for accurate design on process selection.

- *ASM Engineered Materials Handbook,* Vol. 2. *Engineering Plastics* (1989) ASM International, Metals Park, Columbus. Ohio, USA.

- *Handbook of Plastics and Elastomers* (1975) Editor C. A. Harper. McGraw-Hill, New York, USA.

- *International Plastics Selector, Plastics* (1987) 9th edition. Int. Plastics Selector, San Diego, Calif., USA.

- *Handbook of Elastomers* (1988) A. K. Bhowmick and H. L. Stephens. Marcel Dekker, New York, USA.

- *ICJ Technical Service Notes* (1981) ICI Plastics Division, Engineering Plastics Group, Welwyn Garden City, Herts, UK.

<u>Ceramics and Glasses</u>

- *ASM Engineered Materials Handbook* Vol. 4. *Ceramics and Glasses* (1991) ASM International, Metals Park, Columbus, Ohio, USA.

- *Handbook of Ceramics and Composites* (1990) 3 Vols. Ed. N. P. Cheremisinoff. Marcel Dekker Inc., New York, USA.

- Morrell, R. (1985) *Handbook of Properties of Technical and Engineering Ceramics* Parts 1 and 2. National Physical Laboratory, Teddington, UK.

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- Bansal, N. P. and Doremus, R. H. (1966) *Handbook of Glass Properties.* Academic Press, New York, USA.

<u>Composites</u>

- *Engineers Guide to Composite Materials* (1987) Edited by Weeton. J. W., Peters, D. M. and Thomas, K. L.ASM International, Columbus, Ohio, USA. The best starting point: data for all classes of composites.

- *ASM Engineered Materials Handbook,* Vol. 1: *Composites* (1987) ASM International Columbus, Ohio, USA.

- *Reinforced Plastics, Properties and Applications* (1991) R. B. Seymour. ASM International, Metals Park, Columbus, Ohio, USA.

- *Handbook of Ceramics and Composites* (1990) 3 Vols. Ed. N. P. Cheremisinoff, Marcel Dekker Inc., New York, USA.

Natural Materials, including Woods

- *Wood Handbook: Wood as an Engineering Material* (1987) Forest Service Handbook No. 72, Forest Products Laboratory, US Government Printing Office, Washington DC, U~A. A massive compilation of data and information for US woods.

- *Concise Encyclopedia of Wood and Wood-based Products* (1989) Editor A. P. Schniewind, Pergamon Press, Oxford, UK.

- Bodig, J. and Jayne, B. A. (1982) *Mechanics of Wood and Wood Composites.* Van Nostrand Reinhold, New York, USA.

- *The Structural Use of Timber* (1971) British Standard Code of Practice CP112: Part 2. The British Standards Institution, 2 Park Street, London WIA 2BS, UK.

- Dinwoodie, J .M. (1980 *Timber, its Nature and Behavior.* Van Nostrand-Reinhold, Wokingham, UK. Basic text on wood structure and properties. Not much data.

- Houwint, R. (1958) *Elasticity Plasticity and Structure of Matter.* Dover Publications, Inc, New York, Ny, USA.

Foams and Cellular Solids

- Gibson, L. J. and Ashby, M. F. (1988) *Cellular Solids.* Pergamon Press, Oxford, UK. Basic text on foamed polymers, metals, ceramics and glasses.

(Source: Ashby, 1992, 215-217)

A.2 An Example Data sheet: GE Plastics

LEXAN® 101
Europe-Africa-Middle East: COMMERCIAL Polycarbonate Resin

LEXAN 101 is a high viscosity multi purpose grade available in transparent, translucent and opaque colours.

Features

Heat Stabilized Opaque Platable
Translucent

TYPICAL PROPERTIES [1] TYPICAL VALUE UNIT STANDARD

MECHANICAL

Taber Abrasion, CS-17, 1 kg 10 mg/1000cy GE Method
Tensile Stress, yield, 50 mm/min 63 MPa ISO 527
Tensile Stress, break, 50 mm/min 70 MPa ISO 527
Tensile Strain, yield, 50 mm/min 6 % ISO 527
Tensile Strain, break, 50 mm/min 120 % ISO 527
Tensile Modulus, 1 mm/min 2350 MPa ISO 527
Flexural Strength, yield, 2 mm/min 90 MPa ISO 178
Flexural Modulus, 2 mm/min 2300 MPa ISO 178
Hardness, H358/30 95 MPa ISO 2039-1

IMPACT

Izod Impact, unnotched 80*10*4 +23°C NB kJ/m² ISO 180/1U
Izod Impact, unnotched 80*10*4 -30°C NB kJ/m² ISO 180/1U
Izod Impact, notched 80*10*4 +23°C 65 kJ/m² ISO 180/1A
Izod Impact, notched 80*10*4 -30°C 10 kJ/m² ISO 180/1A
Charpy Impact, notched, 23°C 35 kJ/m² ISO 179/2C
Charpy 23°C, Unnotch Edgew 80*10*4 sp=62mm NB kJ/m² ISO 179/1eU
Charpy -30°C, Unnotch Edgew 80*10*4 sp=62mm NB kJ/m² ISO 179/1eU

THERMAL

Thermal Conductivity 0.2 W/m-°C ISO 8302
CTE, 23°C to 80°C, flow 7.E-05 1/°C ISO 11359-2
Ball Pressure Test, 125°C +/- 2°C PASSES - IEC 60695-10-2
Ball Pressure Test, approximate maximum 140 °C IEC 60695-10-2
Vicat B/50 144 °C ISO 306
Vicat B/120 145 °C ISO 306

TYPICAL PROPERTIES [1] TYPICAL VALUE UNIT STANDARD

HDT/Be, 0.45MPa Edgew 120*10*4 sp=100mm 138 °C ISO 75/Be
HDT/Ae, 1.8 MPa Edgew 120*10*4 sp=100mm 127 °C ISO 75/Ae
Relative Temp Index, Elec 130 °C UL 746B
Relative Temp Index, Mech w/impact 125 °C UL 746B
Relative Temp Index, Mech w/o impact 125 °C UL 746B

PHYSICAL

Mold Shrinkage on Tensile Bar, flow (2) 0.5 - 0.7 % ASTM D 955
Density 1.2 g/cm³ ISO 1183
Water Absorption, (23°C/sat) 1L 0.35 % ISO 62
Moisture Absorption (23°C / 50% RH) 1L 0.15 % ISO 62
Melt Volume Rate, MVR at 300°C/1.2 kg 6 cm³/10 min ISO 1133

OPTICAL

Light Transmission 88 - 90 % ASTM D 1003
Haze <0.8 % ASTM D 1003
Refractive Index 1.586 - ISO 489

ELECTRICAL

Volume Resistivity >1.E+15 Ohm-cm IEC 60093
Surface Resistivity, ROA >1.E+15 Ohm IEC 60093
Dielectric Strength, in oil, 3.2 mm 17 kV/mm IEC 60243-1
Relative Permittivity, 50/60 Hz 2.7 - IEC 60250
Relative Permittivity, 1 MHz 2.7 - IEC 60250
Dissipation Factor, 50/60 Hz 0.001 - IEC 60250
Dissipation Factor, 1 MHz 0.01 - IEC 60250

FLAME CHARACTERISTICS

UL Recognized, 94HB Flame Class Rating (3) 0.7 mm UL 94
UL Recognized, 94HB Flame Class Rating 2nd value (3) 3 mm UL 94
Glow Wire Flammability Index 850°C, passes at 1 mm IEC 60695-2-12
Oxygen Index (LOI) 25 % ISO 4589

A.3 A List of Software Sources on Materials Selection

1. **CorSur** a corrosion data software package from the National Association of Corrosion Engineers (NACE) of Houston, Texas, covers the effects of 1000 corrodents on more than 25 metallic materials.

2. **The Society of Automotive Engineers (SAE)**, Inc., of Warrendale, Pa., has a software package on metals and alloys called UNSearch that provides a way of cross-referencing the many different numbering systems used to identify the tholISands of metallic materials in commercial use. More than 3500 of them are included in this package.

3. A software selection package for powder metals is available from **MPR** Publishing Services Ltd., ShrewsRury, England. Featured in the company's Ferrous P/M Materials Selector are data on the mechanical properties of 140 grades of as sintered materials.

4. **MTS Systems Corp.**, of Minneapolis, Minn., has structural analysis soft- ware programs that a fatigue life package among other things, will allow fatigue damage contours to be plotted on finite element models at early stages of design.

5. **MetSel/2** is a basic software package from ASM International, Inc., of Metals Park, Ohio. Included is data on various materials such as carbon steel, aluminum, titanium, and iron and steel castings. MetSel/2 can be used to search for data on specific topics such as chemical composition, temper conditions, and UNS (Unified Numbering System) number and processing characteristics.

6. **The National Materials Property Data (MPD) Network**, Inc., of New York City, has as its objective the establishment of a comprehensive numeric/factual material property data bank. The main feature will be a ‘gateway’ that provides single-point access by common command language to many sources of well- focused data.

7. **The Steeltuf database** on steel toughness from the Electric Power Research Institute of Palo Alto, Calif., and the Materials property Council of New York City consists of about 30,000 individual test results on filore than 80 steels.

8. PLASPEC, an engineering and marketing data bank from *Plastics Technology* magazine in New York. This package includes a complete plastic materials databank selectable on over 50 specifications, a complete plastics machinery data bank, complete supplier directories, on-line pricing information, and a product industry and pricing news service. The material selection menu, for example, covers 44 processing/physical, mechanical, thermal, electrical, and optical properties on over 100 thermoplastics, thermosets, and elastomers.

9. Thermofil, Inc., of Brighton, Mich., offers a computerized databank containing mechanical and electrical properties and pricing information on about 450 thermoplastic resins and compounds the company supplies. The program covers 53 base resins and compounds ranging from polyolefin to polyetheretherketone and grades containing any of 12 types of particulate fillers and/or fiber reinforcement and a wide range of additives.

10. GE Plastics, of Pittsfield, Mass., has developed the Engineering Design Database (EDD), a system that incorporates data acquisition, storage, and manipulation into an interactive computer network. EDD provides tensile stress-strain, short-term creep, rheology, and fatigue and failure property data about engineering thermoplastic materials that the company supplies, such as Noryl (I modified polyphenylene oxide), Lexan (a polycarbonate), and Lomod (an elastomer). EDD also includes data on filled and unfilled structural foams. All data generated for EDD is collected using appropriate ASTM guidelines for plastic testing.

11. Polyfacts, an on-line menu-driven, interactively formatted database, provided by Dupont, contains seven modules, one of which (the plastics selector and graphics module) has data on mechanical, thermal, and electrical properties as well as pricing information on about 170 products.

12. Plastivision, an on-line database offered by Borg-Warner, through CompuServe, has data not only about quantitative properties of materials but also about qualitative features, such as transparency and heat resistance.

13. The High Temperature Materials Properties (HTMP) database, operated by the Center for Information and Numerical Data Analysis and Synthesis (CINDAS) of Purdue University, in conjunction with the U.S. Department, contains data on about

600 varieties of aerospace structural composite materials, as well as metals and infrared detector/sensor materials.

14. ICI developed the Engineering Plastics On Screen (EPOS) database, which has been successfully used in many countries in Europe. In the United States, it contains data on mechanical, thermal, electrical, and other properties of injection-moldable materials.

15. CenCad Services developed a database called CenBase, which contains data on 7500 polymeric, 2000 thermoset, 1000 elastomeric, 3000 composite, and 1400 metallic materials.

16. Plascams, a package developed by RAPRA in England, and marketed by ESDU International in the United States, has data on mechanical and electrical properties of about 400 polymers.

(Source: Lewis, 1990, 551-552)

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17. CMS: Cambridge Materials Selector (1992) Cambridge University Engineering Department, Cambridge, UK (Tel: 0223 334755; Fax: 0223 332797). It includes all materials in PC format.

18. Mat.DB (1990) (replacing METSEL 2) Materials Database; ASM International, Metals Park, Ohio 44073, USA. PC format. Databases of property and processing for metals and some polymers are now available; more are in preparation. Selection based on user-defined target values.

19. PERITUS Matsel Systems Ltd, UK. PC format. A database for metals, polymers and ceramics, aimed at materials and process selection. Selection based on requesting 'high', 'medium' or 'low' values for given properties rather than numerical values; a display shows the match between candidate materials and the target profile.

20. DataPLAS: Plastics Information System (1990) Modern Plastics, New York, USA. PC format. Properties, processing and producer information for 1000 high-performance thermoplastics available from US suppliers. Updated regularly.

21. CAMPUS, Computer Aided Material Preselection by Uniform Standards (1988) Germany. PC format. A collection of four databases of Hoechst, BASF, and Bayer and Hüls thermoplastic polymers, containing information on modulus, strength, viscosity and thermal properties. Regularly updated, but limited in scope.

22. EPOS, Engineering Plastics On Screen (1989) UK. PC format. The software lists general and electrical properties of ICI polymer products, with a search facility. Updated periodically.

23. MATUS: Materials User Service Engineering Information Company Ltd, London, UK. An on-line data bank of UK material suppliers, trade names and properties for metals, polymers and ceramics, using data from suppliers' catalogues and data sheets.

24. M-Vision (1990) PDA Engineering, USA. Requires a workstation. An ambitious image and database, with flexible selection procedures. Data for aerospace alloys and composites.

25. THERM: Thermal Properties of Materials; Livermore, USA. Very simple but useful PC-based compilation of thermal data for materials: specific heat, thermal conductivity , density and melting point.

26. STARIN: Plastic Properties of Materials; USA. Very simple but useful PC-based compilation of room- temperature mechanical properties of ductile materials.

27. Copper Select: Computerized System for Selecting Copper Alloys: Copper Development Association Inc, Greenwich, USA. PC format. A database of properties and processing information for wrought and cast copper alloys.

28. DESIGN DATA-CAST IRON: BCIRA, the Cast Metals Technology Center, UK. PC system, which retrieves the physical and mechanical properties of ductile, gray and malleable cast irons.

29. UNSearch: Unified Metals and Alloys Composition Search; ASTM, USA. PC system, which retrieves information about composition, US designation and specification of common, metals and alloys.

30. CUTDATA: Machining Data System; Metcut Research Associates Inc, Manufacturing Technology Division, Ohio, USA. A PC-based system, which guides the choice of machining conditions: tool materials, geometries, feed rates, cutting speeds, and so forth.

31. SteCal: Steel Heat- Treatment Calculations; ASM International, USA. PC format software which computes the properties resulting from defined heat treatments of low-alloy steels, using the composition as input.

32. STEELMASTER: Schwing UK Ltd, UK. PC format. A database of compositions, properties, trade names and heat treatment procedures for steels.

33. ELBASE: Metal Finishing/Surface Treatment Technology (1992) Metal Finishing Information Services Ltd, UK. PC format. Comprehensive information on published data related to surface treatment technology. Regularly updated.

34. EASel, Engineering Adhesives Selector Program (1986) The Design Center Bookshop, UK. PC and Apple formats. A knowledge-based program to select industrial adhesives for joining surfaces.

35. PAL: Permabond Adhesives Locator (1990) Permabond, UK. A knowledge-based, PC system for adhesive selection among Permabond adhesives.

36. MDP Network: MDP, USA. An on-line network of eight linked data sources. Numeric data, plus references, abstracts and keywords of publications relating to materials and their uses.

(Source: Ashby, 1992, 215-218)

A.4 ASTM and Multi Point Selection Charts

a. ASTM' s chart for materials properties' specifications.

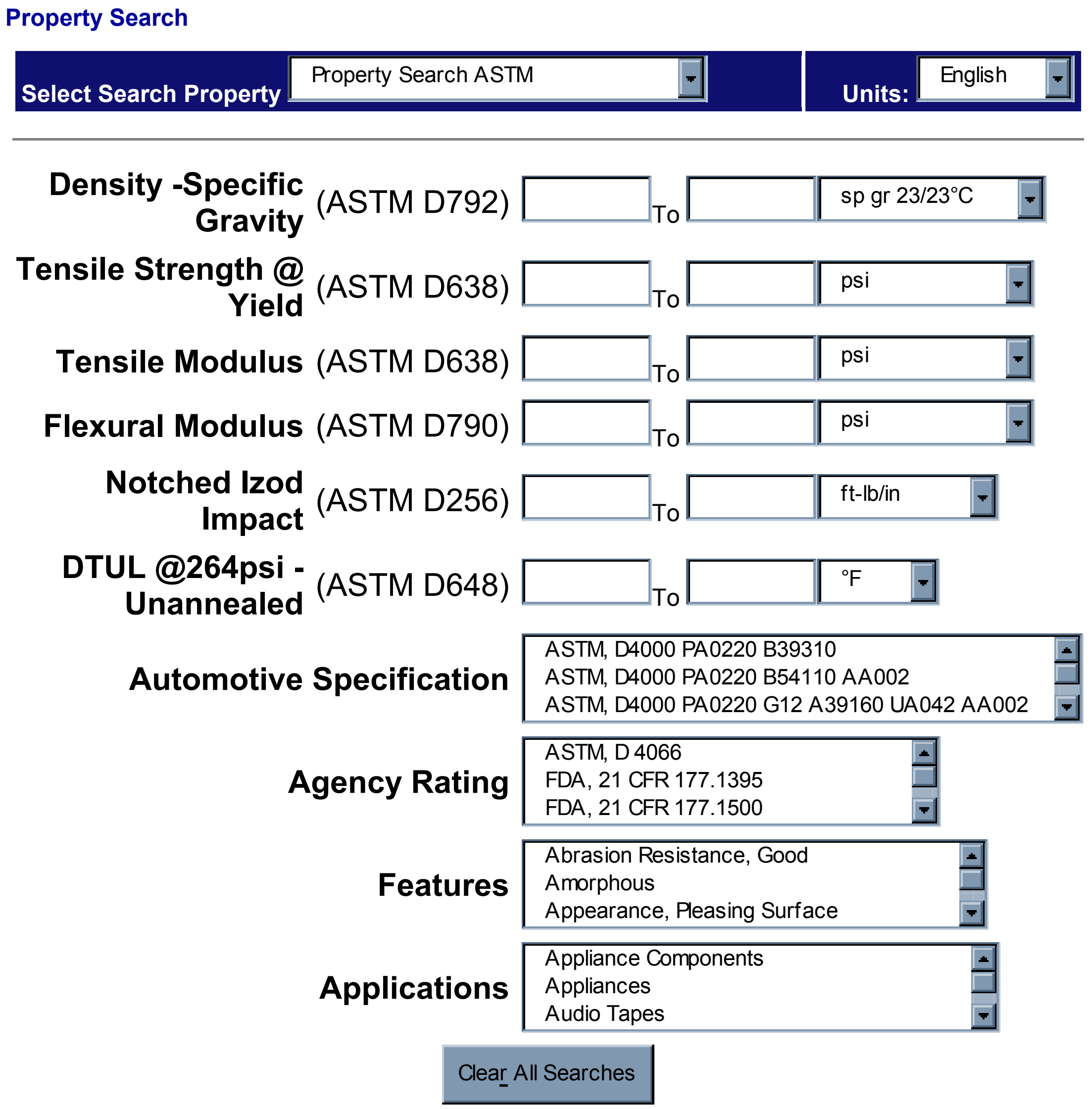

Figure A.4.1: ASTM Charts (source: BASF Corporation website)

b. 'Multi-point' option's chart

Related with the selected material, the program defines some critical titles that worth to present with graphs and the user selects from one or more than one of them. After that, a chart appears consisting of those variables below:

Available Curve Families...
Creep Modulus vs. Time (ISO 11403-1)
Isochronous Stress vs. Strain (ISO 11403-1)
Isothermal Stress vs. Strain (ISO 11403-1)
Secant Modulus vs. Strain (ISO 11403-1)

Property:	Creep Modulus vs. Time
Test Standard:	ISO 11403-1
X Quantity:	Time
X Unit:	hr
Y Quantity:	Modulus
Y Unit:	MPa
Number of Data Series:	1

Data Series:	Ultramid®B 3WG5 (Cond): 23 ℃, 10.60 MPa
Number of Data Points:	5
X	**Y**
10	4420
100	4290
1000	4110
10000	3870
100000	3570

Figure A.4.2: Multi-point Options Charts (Source: BASF Corporation website)

A.5 Comparison Process Offered by BASF Corporation

Legend For Actions

☑ - COMPARE   - BASF PDF   - ASTM Datasheet   - ISO Datasheet   - Multi-Point

Action	Product	Density - Specific Gravity (sp gr 23/23°C)	Tensile Strength @ Yield (MPa)	Notched Izod Impact (J/m)	DTUL @264psi - Unannealed (°C)
☐	Avantra® 594E	1.04	20.0	181 (23 °C, Method A)	79.4
☐	BASF PS 495F	1.04	21.4	123 (23 °C, Method A)	79.4

Figure A.5.1: Comparison process offered by BASF Corporation

There seemed two materials providing the given conditions. The user can click the boxes near the materials, which he/she wants to compare. Than, after clicking the 'compare' button, a comparison chart appears as follow:

Physical	**Avantra® 594E**	**BASF PS 495F**
Density -Specific Gravity	1.04	1.04
Melt Mass-Flow Rate (MFR) (200°C/5.0 kg)	8.00	8.00
(50% RH, 23 °C)	0.10	--
Water Absorption @ Sat. (23 °C)	0.10	0.10
Mechanical	**Avantra® 594E**	**BASF PS 495F**
Tensile Modulus	2070	2140
Tensile Strength @ Yield	20.0	21.4
Tensile Strength @ Break	17.2	20.0
Tensile Elongation @ Brk	60	55
Flexural Modulus (Method I (3 point load))	2280	1650
Impact	**Avantra® 594E**	**BASF PS 495F**
Notched Izod Impact (23 °C, Method A)	181	123
Gardner Impact (3.18 mm)	36.2	31.6
Hardness	**Avantra® 594E**	**BASF PS 495F**
Rockwell Hardness (L-Scale)	55	55
Thermal	**Avantra® 594E**	**BASF PS 495F**
DTUL @264psi - Unannealed	79.4	79.4
Optical	**Avantra® 594E**	**BASF PS 495F**
Gardner Gloss (60°)	70	45

Figure A.5.2: Comparison Chart of BASF Corporation

A.6 List of Candidate Materials in the Plastic Technology Selection Program

Supplier	Generic Family	Chem Type	Trade Name	Process Type	Filler Type	Filler %	Applications
Albis Plastics	PET	Polyester	Petlon	Blow Molding	Long Fiber	30	Automotive,Building Construction, Electrical,General Purpose,Slit Film
Albis Plastics	PET	Polyester	Petlon	Injection Molding,Blow Molding	Long Fiber	30	Automotive,Building Construction, Business Machine,Electrical, General Purpose,Slit Film
Albis Plastics	Nylon	Type 66	Albis	Injection Molding			
Albis Plastics	Nylon	Type 66	Albis	Injection Molding	Glass Fiber	30	
Albis Plastics	Nylon	Type 66	Albis	Injection Molding	Glass Fiber	33	
Albis Plastics	Nylon	Type 66	Albis	Injection Molding	Mineral	40	
Albis Plastics	Nylon	Type 6	Albis	Injection Molding			
Albis Plastics	Nylon	Type 6	Albis	Injection Molding			General Purpose
Albis Plastics	Nylon	Type 6	Albis	Injection Molding	Glass Fiber	30	
Albis Plastics	Nylon	Type 6	Albis	Injection Molding	Glass Fiber	30	
Albis Plastics	Nylon	Type 6	Albis	Injection Molding	Mineral	40	
Albis Plastics	Nylon	Type 6	Albis	Injection Molding	Mineral	30	
Albis Plastics	Nylon	Type 6	Albis	Injection Molding			
Albis Plastics	Nylon	Type 6	Albis	Injection Molding			
Albis Plastics	Nylon	Type 6	Albis	Injection Molding			

Figure A.6.1: List of candidate materials selected by the supplier based database.
(Source: Plastic Technology Selection Program)

APPENDIX B

THE FIELD STUDY

B.1 Interview Questions

1. Genel olarak 'ürün tasarımında malzemeler' ile ilgili edinmek istediğiniz bilgileri hangi başlıklar altında toplardınız?
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
2. Malzeme seçiminde, malzemenin ne tür duyusal ve algısal bilgilerine sıklıkla ihtiyaç duyuyorsunuz?
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
3. Malzeme seçiminde, ne tür kaynaklardan faydalanıyorsunuz?
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
4. Kullandığınız kaynakta, malzeme bilgisi ne tür bir method ile verilmektedir? Olumlu ve olumsuz (ya da yetersiz) bulduğunuz özellikleri nelerdir?
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

5. Seçimini yaptığınız malzemenin örneklerine kolay erişebiliyor musunuz? Belirtiniz.
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
6. Yeni malzemeleri, malzeme teknolojilerindeki yenilikleri takip edebiliyor musunuz? Nasıl?
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

7. Kendinizi genel olarak malzeme seçimi konusunda yetkin buluyor musunuz? Neden?
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
8. Sizce tasarım eğitminde malzeme bilgisi nasıl verilmeli?
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

9. Size şimdi, farklı malzeme kaynaklarından alınmış, malzeme bilgisinin sunum teknikleri göstereceğim. Bunlardan hangisini (ya da hangilerini) tercih ederdiniz? Nedenlerinizi açıklayınız.

……
……
……
……
……
……

10. Genel olarak, 'bir malzeme seçim' kaynağından beklentileriniz neler?

……
……
……
……
……
……

B.2 Selected Charts and Graphics for Question 9

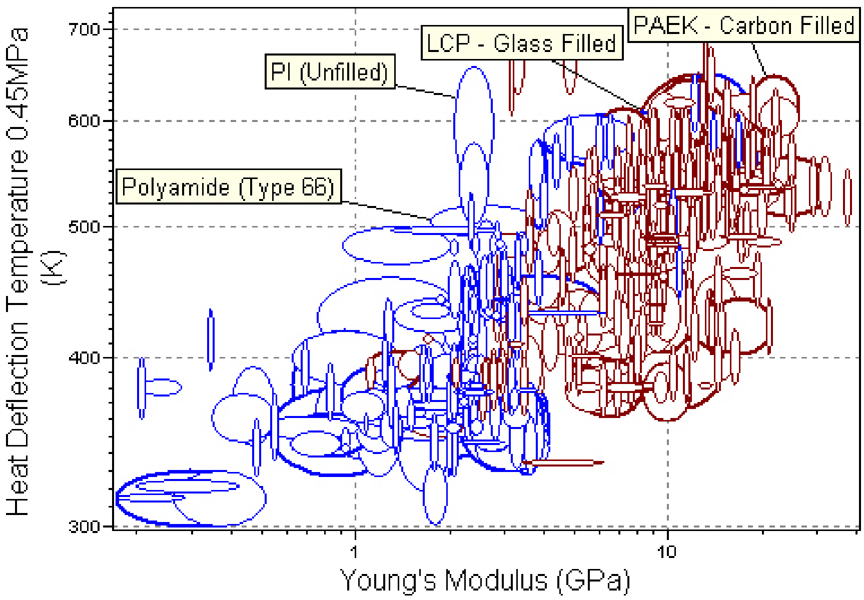

Figure B.2.1: Question 9- graph a (source: CMS Web Site)

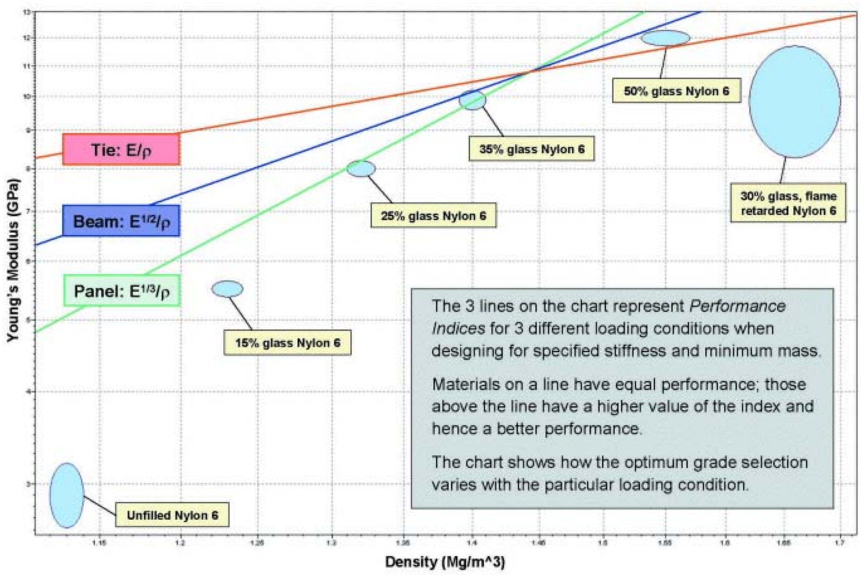

Figure B.2.2: Question 9- graph b (source: Mat Web)

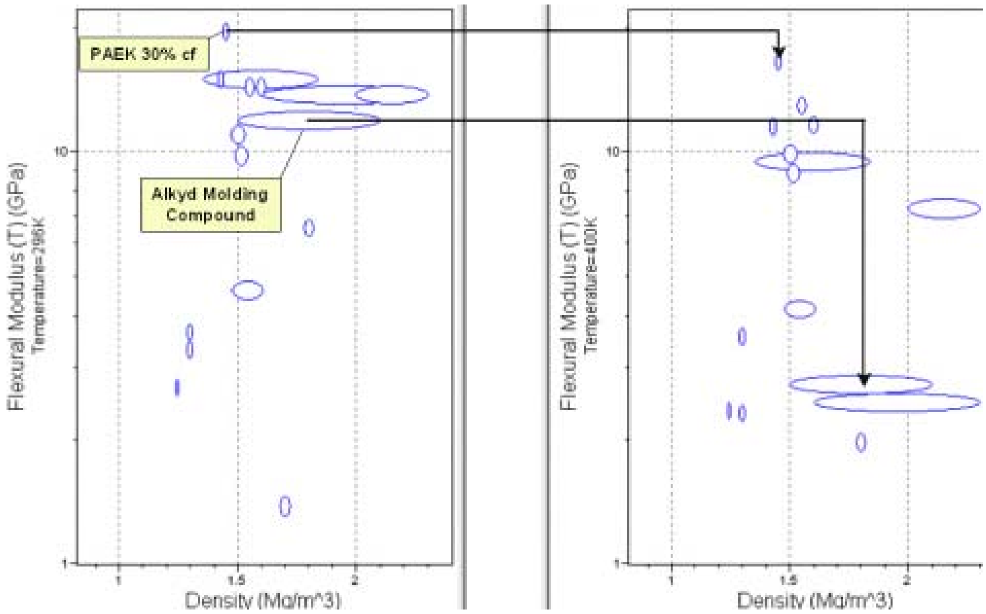

Figure B.2.3: Question 9- graph c (source: CMS Website)

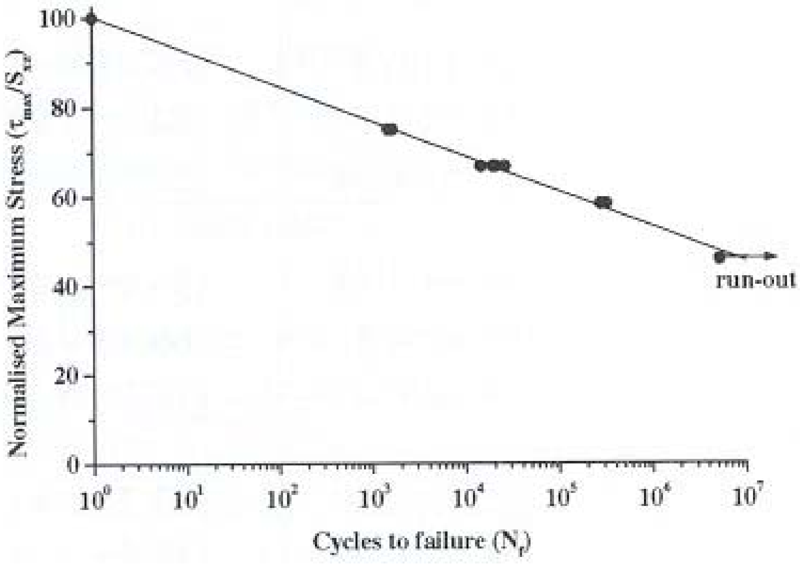

Figure B.2.4: Question 9- graph d (source: 3M Website)

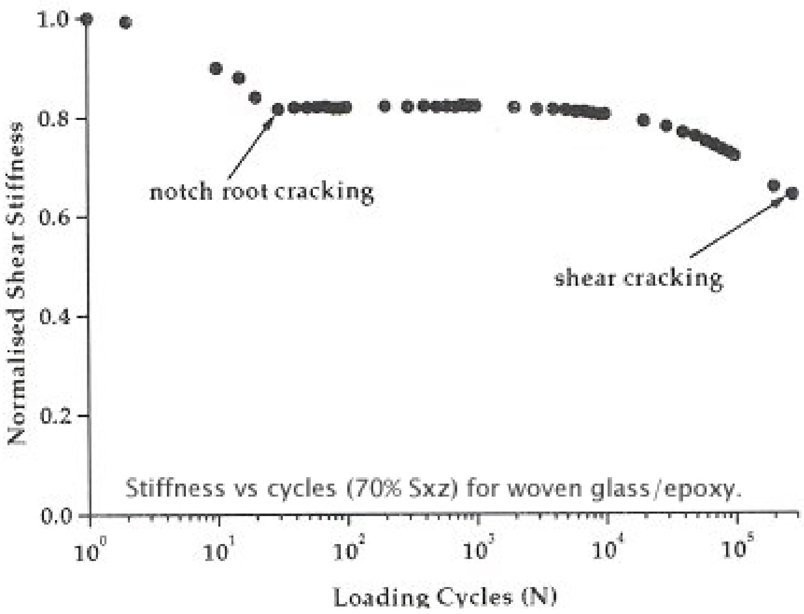

Figure B.2.5: Question 9- graph e (source: 3M Web Site)

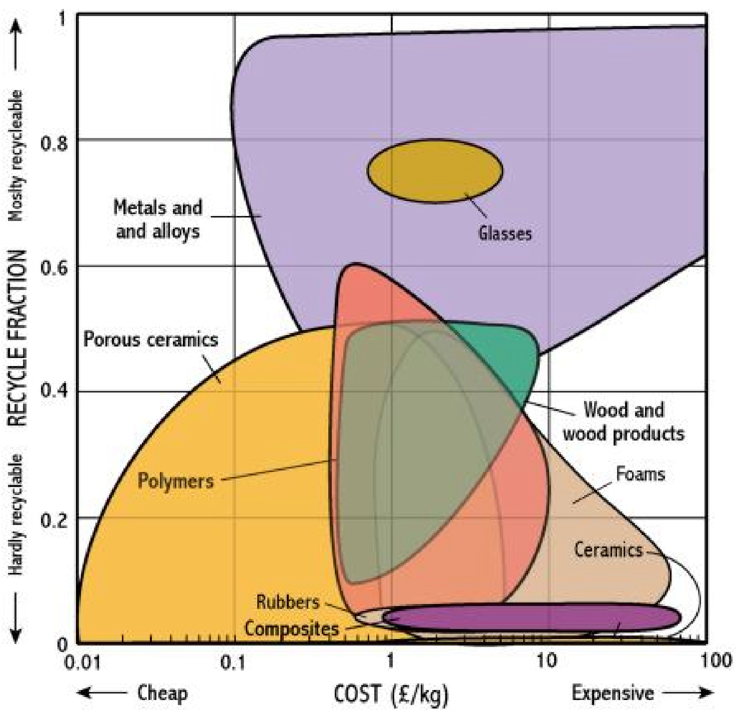

Figure B.2.6: Question 9- graph f (source: CMS Web Site)

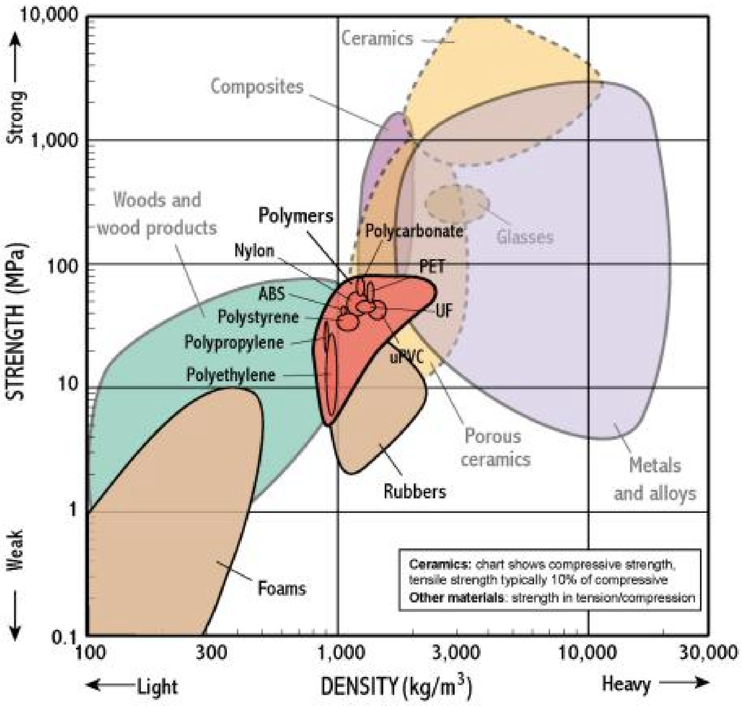

Figure B.2.7: Question 9- graph g (source: CMS Web Site)

h.

Physical Insights

- The bubbles are elongated along the strength axis, but not density. This is because alloying and heat treatments have a strong effect on strength but little on density
- Strength is correlated to density so that most materials lie on the bottom left-top right diagonal
- Composites provide a means of achieving high strength at low weight because they exploit very strong fibers in light matrices
- Woods are somewhat like polymer foams having pores full of air and so float in water.
- Wood achieves high strength at low density by its efficient cellular microstructure

i.

Example Uses

- Hang gliders tend to be constructed from light and strong materials (metal tubes with nylon or similar coverings).
- Zimmer frames often use aluminum tubes for low weight

(Source: Design inSite Web Site)

1=Recommended 2=Satisfactory 3=Poor 4=Marginal 5=Not Recommended																					
Material	Relative Price	High Temp °F	Low Temp °F	Steam <250 °F	Steam <500°F	Sunlight/Fluorescent Light	Weathering/Ozone	Compression Set	Wear/Abrasion	Permeation/Vacuum	Chemicals/Solvents	Petroleum Oils (most)	Fuels/Gasoline (most)	Brake Fluids	Transmission Fluids	Steering Fluids	Refrigerants/Freon (most)	Dynamic Applications	FDA Compliant	NSF61 (Drinking Water)	Marco Compound Number
Teflon (Virgin)	D	450	-250	5	5	1	1	5	2	2	1	1	1	1	1	1	1	1	N/A	N/A	T1000
FEP (Teflon) Encapsulated O-Rings)	E	300	-10	5	5	1	1	2	2	2	1	1	1	1	1	1	1	4	N/A	N/A	T1002
Fluorosilicone	D	350	-75	5	5	1	1	3	4	4	3	3	1	3	3	2	2	3	N/A	N/A	F1001
Urethane	C	225	-65	5	5	1	1	4	1	1	5	2	3	5	5	5	5	1	N/A	N/A	P1001
Polyacrylate	C	350	-20	5	5	3	3	3	3	1	5	4	5	5	1	1	5	2	N/A	N/A	Special
Neoprene	C	225	-40	5	5	2	2	3	2	2	5	2	5	5	3	3	2	1	N/A	N/A	N1000
Butyl	C	200	-65	5	5	1	2	3	2	1	2	4	5	5	5	5	5	2	N/A	N/A	Y1000
Nylon	C	200	-40	5	5	1	2	3	2	2	3	4	5	5	5	5	2	2	N/A	N/A	H1000

Figure B.2.8: Question 9- graph j (source: Mat Web)

Nylon 6-12 Sheet Natural Color				
Thickness	Length	Width	Stock #	Price
.125	12 "	12 "	KS-1751	$54.38
.250	12 "	12 "	KS-1752	$108.28

Figure B.2.9: Question 9- graph k (source: Mat Web)

PA - polyamide (nylon)

Arguments for using PA include strength (fishing line, axe handle), wear resistance (bearings), barrier properties (food packaging) and machinability. Strength and stiffness are often improved using glass fibre reinforcement. PA absorbs water which makes it softer. UV-stabilizators are required for outdoor applications.
PA is a group of amorphous (transparent) and semi-crystalline (opal-white) plastics. The latter are distinguished by a numeric code indicating the number of carbon atoms between two nitrogen atoms in the molecular chain (e.g. PA6 and PA11).

Figure B.2.10: Question 9- graph l (source: Design inSite)

m.

Danish Name: PA - polyamid (nylon)
Category: Thermoplastics
Products: Nylons (stockings), Fishing line, Bicycle trailer, rainproof cover, Bearing, Axe Hedge cutter, casing, Handle for high pressure cleaner, Bottle for tomato ketchup (barrier layer), Ensemble chair (PA blended with ABS), Bottle-opener
Processes: Plastic moulding, Plastic injection moulding Machining, Extrusion
Similar materials: PET, PBT
Price: High cost plastic (see also Plastics general overview)
Environmental notes:
Creation: Production of 1 kg of PA requires the equivalent of about 3 kg of oil (raw material and energy). Common additives are: UV-stabilizators (e.g. carbon black) and colouring agents.
Use: Polyamides are biologically indifferent materials.
Disposal: Incineration in an incineration plant mainly produces water and carbon dioxide. Heating value is equivalent to 1/2 kg of oil.
Additional Info: PA has very good resistance to fuels, oils and solvents, but is affected by acids and strong bases.

Source: Design inSite Web Site

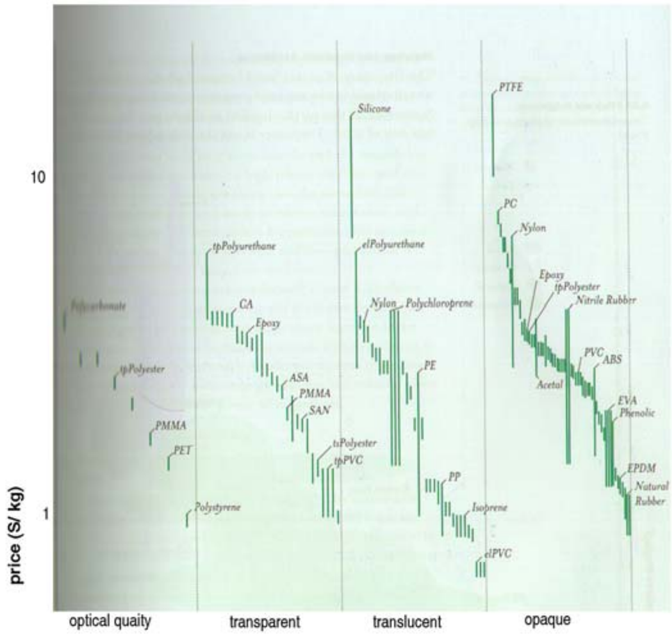

Figure B.2.11: Question 9- graph n (source: Ashby & Johnson, 2002)

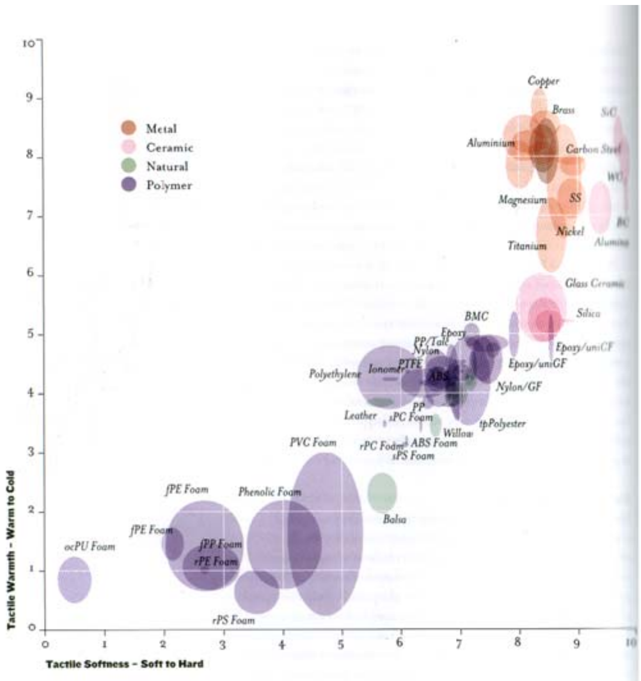

Figure B.2.12: Question 9- graph o (source: Ashby & Johnson, 2002)

B.3 Questionnaire Employed After Interviews

Bu anket, Orta Doğu Teknik Üniversitesi, Endüstri Ürünleri Tasarımı Bölümü araştırma görevlisi Elvin Karana tarafından hazırlanmıştır. Bu çalışma ile hedeflenen, profesyonel olarak kendi meslekleri ile uğraşan 'Türk Tasarımcıların', malzeme seçimi konusunda faydalandıkları kaynakları saptamak; bu kaynaklardan yararlanma biçimlerini değerlendirip, genel olarak malzeme bilgisine erişim ve bu bilginin sunum şekli ile ilgili beklentileri üzerinden bir 'yöntem' önermektir.
Anketlerin değerlendirme aşamasında, isminizin veya firmanızın isminin açık olarak kullanılmasını istemiyorsanız, lütfen belirtiniz. Zaman ayırdığınız için teşekkürler.

---

ad/ soyad: **yaş:** **eğitim seviyesi:**

firma/ kuruluş adı: **sektör tanımı:**

---

1. 'Malzeme ve tasarım' denildiğinde, aklınıza ilk gelen 'anahtar kelimeleri' yazınız.
....

2. Ürün tasarımında seçeceğiniz malzemeye karar verirken, malzemenin hangi özellikleri tercihizi öncelikli olarak etkiliyor? (en önemli seçeneğe '1' numarasını vererek, 1' den 6' ya kadar sıralayınız)
☐ Teknik özellikleri (yoğunluk, ısı yalıtkanlık, elektrik iletkenlik, sürtünme katsayıları, vb.)
☐ Duyulara yönelik özellikleri (renk, doku, ses, koku, tat)
☐ Ekolojik özellikleri (geri dönüşümlülük, doğal malzeme)
☐ Ekonomik özellikler (malzeme fiyatı, üretim, ulaşım-erişim harcamaları)
☐ Markete yönelik özellikler (trendler, hedef kitle kriterleri, farklı kültürler, v.b.)
☐ Algısal özellikler (çağrışımlar: tasarım akımlarına, kişilere, mekanlara, sosyal ve ekonomik sınıflara, farklı kültürlere, v.b.)
☐ Diğer..

3. Malzeme seçimi konusunda aşağıdaki kaynaklardan hangisi ya da hangilerinden faydalanıyorsunuz? Belirtiniz.
Kitaplar:...
Dergiler (üye iseniz belirtiniz):..
Kataloglar / üretici firmalar:..
Fuarlar, seminerler:...
CD, VCD ve DVD :...
İnternet siteleri:..
Kişiler:..
Diğer:...

4. Aşağıdaki isim ve başlıklardan daha önce duymuş olduklarınız var ise işaretleyip, karşısına kısaca açıklamasını yazınız.

Cambridge Engineering Selector (CES)…………………………………………………

Material ConneXion……………….

Design inSite...................................

ASM material handbook..

Mike Ashby...

www.matweb.com...