USER-CENTERED DESIGN CRITERIA IN AUTOMOBILE DESIGN WITH A CASE STUDY OF AUTOMOBILE DASHBOARD DESIGN

A Thesis Submitted to
the Graduate Scholl of Engineering and Sciences of
İzmir Institute of Technology
in Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

in Industrial Design

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January 2006
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ACKNOWLEDGEMENTS

At the first place, I would like to express my gratitude to my thesis supervisor, Asst. Prof. Dr. Yavuz Seçkin for his guidance, support, and patience both throughout my research study and all through my graduate education. I am also grateful to Asst. Prof. Dr. Can Özcan from İzmir University of Economics and all the members of the Department of Industrial Design at İzmir Institute of Technology, especially Asst. Prof. Dr. Önder Erkarslan. for their support and guidance all through my graduate education.

Eventually, I would like to express my gratitude to my family and my friends for their endless love, support, and patience.

ABSTRACT

Our era provides us enormous changes and unforeseen advancements in technology, which lead to specific changes in economic and socio-cultural values. As a result of this shift, consumer's need and expectations have changed into a search for new experiences. Companies, in search of satisfying the new expectations of this era's consumer, aspire to be innovative. To achieve this, they are concentrate on the user as the main source of innovation and design their products taking into consideration ergonomic, user needs and functionality.

Automotive Industries is the one of the most developed and changed industries. Nowadays, especially interior of the automobile has changed with significant development. This paper describes and discusses the approach, development aspects, and evaluation phases of a new generation interior design of automobile. The primary interest in the driver's environment is the relationship between the driver's seat, steering wheel and dashboard location. These are the workstation components that the driver required to stay in constand contact with, and the location of these control dictates the driver's posture.

Consequently, this study mainly aims to explore the role of user-centered design criteria's for design phase and the role of ergonomic and human factors for automobile dashboard design.

ÖZET

Çağımızda teknolojideki önüne geçilmez gelişim ve büyük değişimler sonucunda, toplumumuzun ekonomik ve sosyo kültürel değerlerinde de değişiklikler meydana gelmiştir. Bu değişimler sonucunda, yeniliklerle beraber, müşterilerin istek ve beklentileri de tekrardan şekillenmeye başlamıştır. Firmalar ise değişime ve müşterilerin beklentilerine cevap verebilmek için yeniliğe ve gelişime can atar hale gelmişlerdir. Bunu başarmak için de ilk olarak kullanıcıya konsantre olmuşlar ve ürünlerini tasarlarken ergonomiyi, kullanıcıların ihtiyaçlarını ve fonksiyonelliği göz önünde bulundurmaya başlamışlardır.

Otomotiv endüstrileri, en çok gelişen ve değişen endüstrilerden biri durumuna gelmiştir. Son zamanlarda ise en önemli değişiklikler özellikle otomobilin içinde gözlenmeye başlanmıştır. Bu çalışmada otomobilin yeni nesil iç tasarımı üzerine tartışılmıştır. Sürücünün çevresinde asıl incelenen nokta, sürücü koltuğu direksiyon ve kontrol panelinin yerleşimi arasındaki ilişkidir. Bunlar sürücünün devinim ve iletişim içinde olduğu sabitlerdir; ve sürücünün araç içerisindeki duruşunu belirlemektedirler.

Sonuç olarak bu çalışmanın asıl amacı kullanıcı odaklı tasarım kriterlerinin, tasarım aşamasındaki rolü ile ergonomi ve insan faktörünün otomobil kontrol paneli tasarımındaki önemini ortaya koymaktır.

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CHAPTER 1

INTRODUCTION

1.1. Definition of the Study

Our era provides us enormous changes and unforeseen advancements in technology, which lead to specific changes in economic and socio-cultural values. Along with the change in values, the society has shifted its focus from production to information and creativity. As a reflection of this shift, the needs and expectations of individuals have changed into a search for new experiences. As a result, the consumer of this era has started to assess novelty, creativity, and innovation.

Manufacturing companies that operate in a global business environment face challenges and opportunities to develop their business by providing a variety of attractive products to the market in an environment where speed and agility are essential. Companies, in search of satisfying the new expectations of this era’s consumer, aspire to be innovative. They try to develop real novel products matching the consumers’ real needs and expectations. To achieve this, they utilize certain innovation processes in which design, especially industrial design plays a significant role by creating meaningful products and features for consumers. Beside that companies design their products using user-centered design methods. They are concentrate on the user as the main source of innovation. These methods not only apply user information to the innovation process but also stimulate users to be creative and involve in the innovative activity.

The attractiveness of a product depends strongly on how we perceive the product with all our senses in relation to the expected performance of the product. The attractiveness of a product is normally related to its aesthetics. However, this statement is an oversimplification, since the attractiveness of the product is related to how we perceive the product with all our senses in relation to what we expect to get from the product. The products should have someting more. Ergonomic, anthropometry, anatomy, human factors engineering can play an important role in the design phase.

1.2. Aims of the Study

This study mainly aims to explore the role of user-centered design criteria for design phase and the role of ergonomic and human factors for automobile dashboard design. The primary interest in the driver's environment is the relationship between the driver's seat, steering wheel and dashboard location. The dashboard extends from just under the inside portion of your windshield and includes all the dials, knobs, buttons, and instruments that essentially run the automobile. In essence, the dashboard of a car serves as the control center.

1.3. Methods of the Study

This study includes the following structure:

Chapter I (*Introduction*) aims to build an introductory background to the research subject. In this chapter, the structure of the study is also explained concisely.

Chapter II (About Automobile) presents the history of automobile and cahanging of the user's expectations from automobile.

Chapter III (*User Centered and Interface Design*) discuss user-centered methods and the importance of interactive properities.

Chapter IV (*Human Factors and Anatomy*) aims to highlight the importance of 'human factors and ergonomics'and define the anatomy of the seated driver's posture.

Chapter V (*Design Concept*), before designing new automobile dashboard, presents the automobile interior and its mesurements, define design criteria and trends.

Chapter VI (*Conclusion and Design*) includes a conclusion of the study and presents the dashboard was designed as a case study.

CHAPTER 2

ABOUT AUTOMOBILE

Although the automobile was invented more than 100 years ago, substantial technical advances have again been achieved during the last 20 years. We only need to remind ourselves of the introduction of the closed-loop controlled catalyst, the four-valve technology, four-wheel drive and steering, and also of the considerably longer maintenance intervals.

Customer wishes provide the strongest incentive for continued progress. For the majority of customers the automobile is the fastest, the most convenient, and often the least expensive means of transportation from one place to another, Customers would welcome further improvements in performance, fuel economy, safety and comfort. Many car owners have strong emotional ties with their automobiles. They want designs that reflect the spirit of the time and vehicle concepts that express their individuality. Others would wish that more progress be made with respect to reliability and quality combined with the lowest possible purchase price. The pressure to comply even more closely with these wishes results from the worldwide competition among automobile manufacturers and from the importance a well-selling product has for the prosperity of the individual carmaker, as well as for the economy of the whole nation.

The automobile design activity comprises the shaping of the automobile in all its visible aspects, in styling of the outer body shape and in graceful appointments of the interior; even the arrangement of the components in the engine compartment are included. Since direct sense perception acts strongly on the world of feelings, styling assumes a key function in the development of an automobile. Styling often determines individual acceptance or rejection of a given product even before technical features are evaluated.

A car can be a work tool, an object of cult and a symbol of power or counter-power. It can either be economic or expensive, practical or just beautiful. Besides changing the way people move around, the car has also changed the way people live.

Economy, industry and the air we breathe, as well as the way we behave, all this is always related with the existence or non-existence of this particular machine. For some, the car is a work of art. For others it is just a noisy machine, which causes pollution.

2.1. The Early Automotive

The early pioneers of the automobile were very little concerned with the aesthetics or social connotations of their crude self-propelled vehicles. They were practical mechanics and engineers preoccupied with the mechanical problems of adapting an engine to a personal means of transportation. In fact, most of the early inventors paid scant attention to vehicle design, being content to merely mount a motor on a light carriage or a bicycle.

In 1770, Frenchman Cugnot created the first steam car. Nevertheless, steam car had limited potential - heavy, slow and took a long time to preheat the water. It was actually worse than horse so that did not become popular.

Petrol cars finally appeared in the late 19th Century. In 1885, Gottlieb Daimler and Carl Benz created petrol internal combustion motorcycle and 3-wheeler respectively.

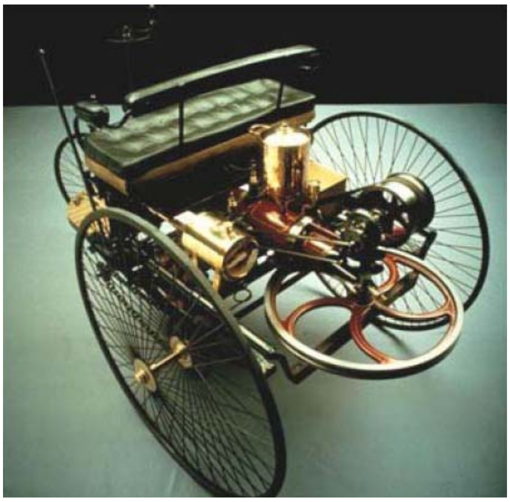


Figure 2.1. 1886 Benz Patent “Motorwagen” the first automotive.
(Source: WEB_1 2005)

Daimler's car was very raw, basically a wooden bicycle installed with his own motor. His son test drove it successfully. Benz's car appeared several months later but it included some advanced design such as battery-powered ignition and differential, though it could only reached 8 mph because the motor produced less than 1 hp.

Gottlieb Daimler, together with William Maybach, improves and changes the one-cylinder engine invented in 1872. From 1886 on, after having licensed the patent, Daimler sells his invention to several car manufacturers and starts his own plant producing self-propelled vehicles.

Daimler further put his world-leading engine into a horse carriage, this became the first 4-wheel motor car in the world.

French car-maker Panhard Levassor created the first front-engined car in 1891, then made the first Saloon (a car with enclosed cabin) four years later, which became standard until today.

2.2. Unique Automotive Form

Gartman (1994) mentions that the anachronistic carriage aesthetic of early automobiles was displaced in the middle of the first decade of the century by a more appropriate mechanical aesthetic. A major reason for this shift was the technical deficiencies of the buggy-inspired vehicles. These cheap, light cars were weakly constructed and lacked power, and consequently could not stand up to the stresses of daily use on rough roads. One buggy car, the 1-cylinder, $500 Brush Runabout, was popularly described as "wooden body, wooden axles, wooden wheels, wooden run." But an aesthetic deficiency also handicapped the carriage design - it had a "horse-wanted look." Without the horse, which lent a sense of power and horizontal direction to the vehicle, the motorized buggy seemed uneasily high and lacking a sense of propulsion.

Once the automobile was accepted as a machine in its own right, the aesthetic focus fell on the mechanics, which were no longer hidden but prominently displayed. According to Gartman (1994), these early automobiles also had a disjointed and discontinuous look, lacking any aesthetic unity between their elements. As one knowledgeable commentator stated: 'The cars of the 1885-1905 period had a generally untidy look. Each part seemed determined to live its own separate life - bonnet or hood, dashboard, front seats, rear seats or tonneau, mudguards, frame, wheels, axles and so on all grouped together in an arrangement that was seldom properly organized." They were conglomerations of unrelated shapes, with little evidence of effort to aesthetically ease the transition between the parts. Directing his or her eyes along the side elevation of a typical 1905 open touring car, the observer experienced a series of abrupt visual transitions or shocks. The horizontal line of the low hood abutted abruptly against the dashboard at a right angle. Then the eye leaped up the dash to the top line of the body, whose lack of doors quickly led the eye back down and around the cut-out entry to the front seat. Then the line of sight took a series of jumps up and down over the protruding seat backs before falling abruptly to the ground at the body's rear. And along this visual rollercoaster ride the observer also encountered a clutter of equipment and accessories - hand brakes, bulb homs, wicker baskets, tool boxes casually scattered over every square inch of surface area. The overall effect was a rather thrown-together look that could be disturbing and perplexing.

Despite their clumsy proportions and disjointed appearance, these early automobiles often had a certain visual appeal. The very complexity of shapes and textures could be entertaining. And although their components lacked aesthetic integration, when produced with high standards of workmanship these autos could attain a visual distinction. This was especially true of their bodies, which were often built by carriagemakers with the same painstaking care and attention to detail traditionally employed on exclusive horse-drawn vehicles (Gartman, 1994).

In 1908, Henry Ford adopted stream production method in Model T, thus greatly lowered the price of cars. This opened the first page of mass production.

Figure 2.2. 1927 Model Ford T.
(Source: WEB_1 2005)

From 1913 on, the mass production of cars, started by Henry Ford, shall be determinant for the massive use of these means of transport. Traffic increases and the first traffic signs appear. Up to 1927, 15 million Ford T are sold. With this mass-production, the car industry fosters technologic development, which combines precision, standardisation, exchange and synchronisation. All this also demanded a large-scale product promotion.

2.3. Aesthetic Integration

As the first decade of the twentieth century drew to a close, the aesthetic integrity that was originally confined to the separate parts like the body began to encompass the entire automobile, which began to lose its fragmented, disjointed look. Several factors initiated this aesthetic trend, which came to fruition in subsequent decades. First, chauffeur driven cars declined, leading to the predominance of owner-driven vehicles. This trend was due both to the spread of ownership down to the petite bourgeoisie or middle class, which could not afford chauffeurs, and the discovery by the very wealthy of the joys of driving. With the chauffeur gone, the class difference between driver and passengers evaporated, leading builders to conceive of the body as a unit rather than two class-specific modes of accommodation. There was now more concern for the comfort of the driver, spawning front doors, windshields, and front enclosures integral with the rear. A second factor favoring aesthetic integration was the vertical integration of automotive firms. As early as 1903 American automakers began to turn from the simple assembly of purchased parts to the manufacture of their own components, largely in order to ensure their quality. But a corollary of this integration was better coordination of the appearance of parts. The manufacture of components in one location allowed workers to coordinate their tasks through communication. This was especially true of chassis and body manufacture. As chassis producers began to add body and trim shops to their firms, the crude disjuncture between the body and the rest of the car began to fade. Automobiles were now designed as integral units, not as assemblages of separate bodies and chassis, and their appearance began to reflect this.

The aesthetic result of these factors was horizontal integration of the lines and forms of the automobile. The roller-coaster lines of the early open cars were gradually replaced by horizontal lines flowing straight from the radiator through to the rear. Between 1908 and 1911, structural changes induced by pressed-steel frames combined with aesthetic changes to emphasize the horizontal lines and bring previously disjunctive elements into a flowing linear continuity. The hood was raised, and its previously abrupt, right-angle juncture with the dash was eased by the addition of a taper dash or cowl, which sloped down to merge with the hood top and sides. And beginning about 1908, front doors were added, eliminating the U-shaped front entrances and raising these lines to the top of the body. Doors were usually mounted flush with the body surface, giving it a smooth, continuous contour. Further, the sides were gradually raised so the seats no longer protruded so far above the top of the open body. Passengers now appeared to be enveloped within rather than sitting on top of the car. The compound curves of the Roi-des-Belges open body gave way to flatter, simpler panels. And body sides and running boards were cleaned up by removing the clutter of accessories that previously broke up the continuity of horizontal lines.

Automobiles with these changes first originated in Europe around 1908 and were labeled torpedo or flush-sided bodies. The style spread to American manufacturers about 1911, with the all-important fore doors appearing on such popular makes as Oakland, Buick, and Cadillac in this year. Some automotive historians have suggested that these changes were introduced to cheapen the manufacture of cars, especially the bodies. These smoother, flatter body surfaces were probably easier to produce, paint, and finish than the elaborately curved panels of early touring cars. But their integration into a cohesive, pleasing whole was no simple task and required the skill of craftworkers, whose labor was rather dear (Gartman 1994).

In 1912, Cadillac invented electric motor starter, since then, car starting no longer needed someone to rotate the engine winder, thus women could drive by their own.

The changes resulting from the 1st World War shall be determinant to the development of cars. Mass production and standardisation of weaponry is then applied to the car industry.

Technical and formal improvements are relevant. The bodies, a wood structure coated with steel panels, are increasingly lower. All-steel body appeared in 1914 and became popular since the 20s. 4-wheel brakes are introduced.

During the '20 and '30, the car becomes popular and, at the same time, becomes a product, which means ostentation and sophistication. Rolls Royce, Bentley, Hispano-Suiza, Bugatti, Delage, Stutz and Duesenberg, among others, build high quality car bodies, which are tailor made by specialised companies. These are the famous cars that, during the '20, caused the admiration of the common citizen. During the '20, and later in the '50, publicity is mainly concerned in creating new consumption needs. Technical and formal features of cars are then related with social, psychological and physical characteristics of their users. When someone buys a car, he/she ponders not only on what he/she needs, but also on what he/she believes shall fit his/her image.

Automobile design during this period thus became increasingly bifurcated. Under the rigors of mass production, low-priced vehicles grew more rectilinear, fragmented, and homogeneous, while high-priced cars produced by craft methods became increasingly curvilinear, integrated, and distinctive. And these aesthetic differences assumed cultural meanings, symbolizing in consumption the differences between people in production. Cars bore testimony to class position, with luxury cars marking a commanding position removed from the necessities of degrading production and mass-produced vehicles marking a subjection to this deskilled, homogeneous production process. The class distinctions of work followed Americans home in their cars, exacerbating class conflict and preventing leisure from compensating for the dehumanizing demands of labor.

The main concern of every car manufacturer is to make this new means of transport accessible to everyone. Once this is accomplished, they have to keep on selling cars, by making obsolete their interiors, by creating and satisfying new needs of consumption through variety.

The '30 witness strong economical, political and social turmoiles. In order to reduce prices, car manufacturers decrease the number of models and prolong the lifetime of car series. Small production makes disappear.

During the '30, the appeal of speed leads the car designers to use low and long shapes as well as colours translating speed even when the car is parked. Inspired by aerodynamics, the streamline concept appears, having to do with the patterns of behaviour of a body perforating the air. In order to develop the design of cars, designers base themselves on water drops, fish shapes and bird wings.

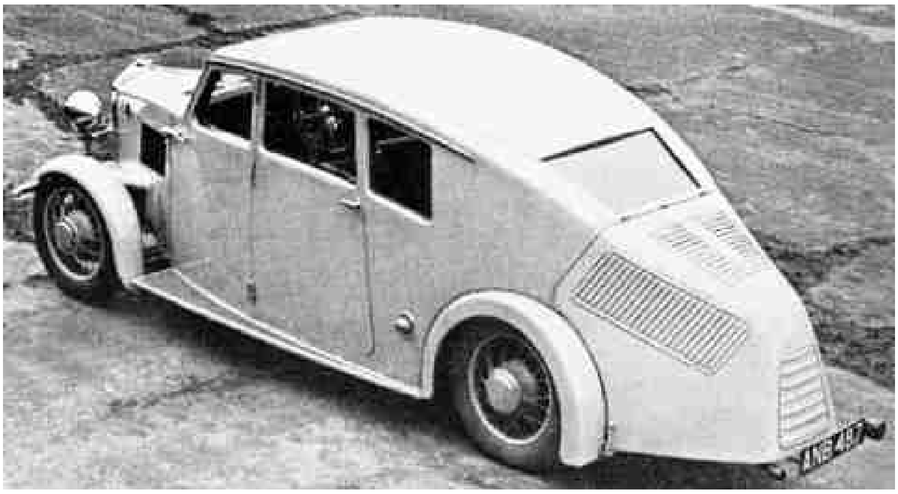


Figure 2.3. A rear quarter view of the 1934 RE Streamline.
(Source: WEB_2 2005)

Technically car reaches its maturity. Citoën launches in the market the famous 7 CV series. This model proves that it is possible to mass—produce a series of innovative and quality cars. This car has front drive and a monocblock structure, all made in steel. Its shapes, low lines, grant it stability and a good road adherence.

Figure 2.4. Citroen 7 CV.
(Source: WEB_3 2005)

Car design evolution is strongly associated with aeronautic and aerodynamic research. During the '50, however, in the United States of America, styling is pushed to extremes by a rather excessive and stylised interpretation of aerodynamics, aiming at creating products innovation.

Car design implies taking of account of several elements: function of the car, market, production, distribution, promotion, price reduction, and increase in safety, ergonomics and environmental concerns.

Symbol of modernity and well being, cars become the image of technical evolution for those nations producing them. The great European powers such as Germany, Italy, France and Great Britain fight for the first places in races and grant the car industry a high nationalistic character. Post war Europe shall find in the car industry an important economic development factor. Makes such as Fiat in Italy, Volkswagen in Germany, Citroën, Peugeot and Renault in France, Austin and Morris in England, shall decisively contribute for the re-launching of their countries in the world economy.

During the '50, car mass-production shall concentrate on the manufacturing of vehicles with a simple mechanics. The emerging middle class is looking for small cars allowing for an increasing autonomy and functionality.

Figure 2.5. Citroen 2CV.
(Source: WEB_4 2005)

VW "beetle", the 2CV, Renault 4, Fiat 600 and 500, Morris Minor, all these are examples of successful utilitarian models. In 1959, British engineer Alexander Issigonis designed a revolutionary car called Mini Minor, which established the standard for front-drive small cars (Figure 2.5, 2.6, 2.7).

Figure 2.6. Fiat 600.
(Source: WEB_5 2005)

Figure 2.7. 1959 Mini Minnor.
(Source: WEB_6 2005)

In the United States of America, due to the economic boom of that time, the situation is almost the opposite. Cars are bigger and bigger, more comfortable and luxurious and they consume great quantities of fuel (Figure 2.8).

Figure 2.8. 1954 Chevrolet Bel-Air Convertible.
(Source: WEB_7 2005)

Innovations appear in the accessories and design is associated to the idea of styling, an exaggerated interpretation of aerodynamics. The famous "fish tails" with bright colours become one of the symbols of American life style.

The '60 are years of economic stability. Full employment, better life conditions and the consequent appeal to consumption shall contribute for car mass-production.

The making and production of small utilitarian cars reach its peak. Thousands of Austin Mini/Morris and Fiats 600 and 500 are produced.

During the '70, people start worrying with the safety of passengers and with the growing air pollution produced by car exhaustion. Car becomes more uniform both in its external looks and in price, power and size. The era of the spontaneous car industry was coming to an end.

Figure 2.9. 1971 Volkswagen Golf.
(Source: Seiffert and Walzer 1991)

In 1971, Volkswagen Golf arouse the popularity of hatchback small cars. The rapid social, cultural and scientific evolution in areas such as the quality of life - both human and environmental - generated new concerns in developed countries. It is becoming more and more evident that pollution is a result of the massive use of car (Figure 2.9).

2.4. Technology, Environment, and Automotive Industry

Enter the 80s, electronics gave new life to modern cars. No matter mechanical parts (eg. engine management system, ABS), luxurious equipments (eg. memory seats, central lock) and the design / production process (eg. CAD / CAM), electronics involved in nearly all areas.

Environment and quality of life concerns are designed a new during the 90', including new concepts such as mobility and sustainable development. It is also during this decade that the need for rehabilitating urban public areas is recognised and further consolidated.

The destruction of the ozone layer causing climate changes can no longer be ignored. Restricting traffic flows turns out to be insufficient, mainly because production and economy growth of countries and people allow increasingly easier access to buying and using cars. It therefore becomes necessary to manage the sharing of urban areas both by people and cars, cars and public transports, by setting a new management of mobility and by improving services rendered by public transports.

In the 90s, due to the stricter regulations, cars became far more environmental-friendly. Safety was also greatly enhanced.

One of the opportunities a highly developed industry must explore to the fullest is product styling, especially when its production facilities are located in an expensive production area such as West Germany. The prestige of a product is increasingly determined by its aesthetic impact; in other words, the design of an automobile is essential and is often decisive for its success. In addition to technical qualities, styling can trigger the impulse to buy.

2.5. Inside the Automobile

The automobile design activity comprises the shaping of the automobile in all its visible aspects, in styling of the outer body shape and in graceful appointments of the interior; even the arrangement of the components in the engine compartment are included. Since direct sense perception acts strongly on the world of feelings, styling assumes a key function in the development of an automobile, Styling often determines individual acceptance or rejection of a given product even before technical features are evaluated (Seiffert and Walzer 1991).

Not only the automobile's exterior shape and interior comfort come to life as a result of good design, but also the engine compartment, even the shape of the floor pan, should be purposefully detailed and appealingly formed. These considerations are not entirely new. Some of the old-time automobiles delight us because engineering was made visible.

Nowadays, we are in the 3rd age of vehicle design era. With this era, manufacturers are begining to

- focus on technology (engineering and productions)
- focus on brand equity
- focus on consumer.

Recent years, automobile interior is developing faster than exterior and new sophisticated technology is being introduced faster. Models' life cycle is getting shorter for example; VW Golf.

- VW Golf Mark I to Mark II (1974 –1983) 9 years

- VW Golf Mark IV to Mark V (1997 –2003) 6 years

Figure 2.10. Changing in VW' s interior design.
(Source: WEB_8 2005)

For manufacturers, competition is fierce and profitability is low.

- Realignment of products and prices is occurring at twice the rate of a few years ago.
- Option changes are occurring three times more often than a few years ago and still increasing
- For some manufacturers, option prices are a huge profit source
- Interiors are becoming a far greater differentiator, and source of additional profit for the manufacturers
- There are more standart equipments than before
- New sophisticated technology is being introduced faster
- New technology filters down to lower segments much faster

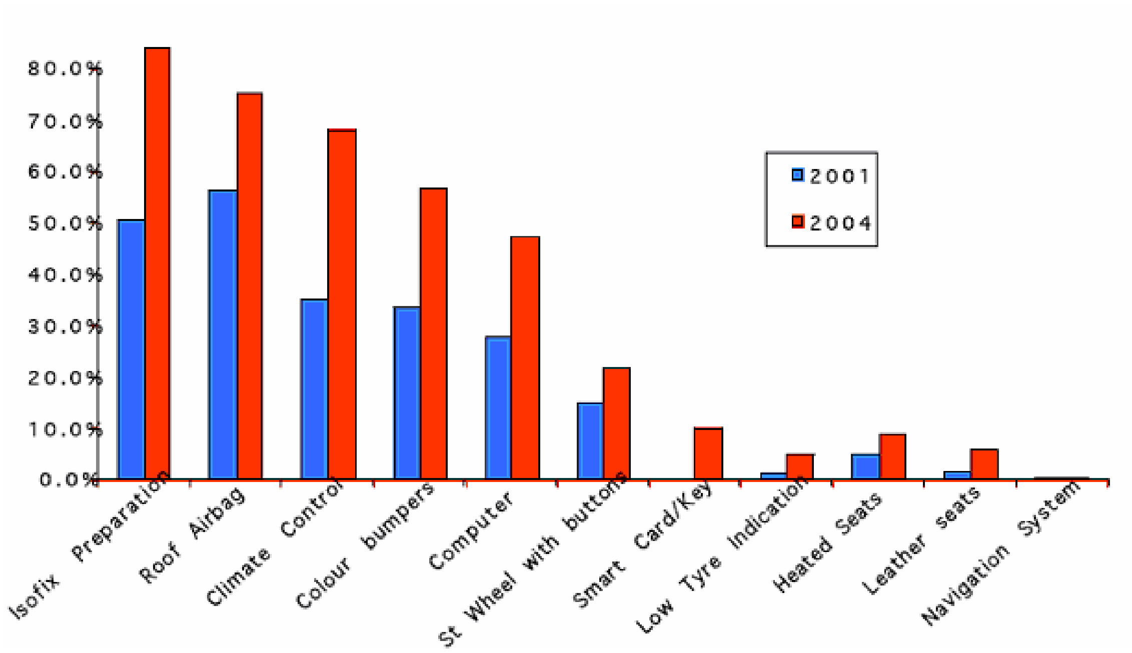


Figure 2.11. Diferrence in standart equipment in Germany.
(Source: WEB_8 2005)

Navigation systems can quickly become essential components of driving, especially in unfamiliar locations. They invoke strong feelings among those who use them, but alas, much in the same way we relate to our computers: love and hate seem to alternate.

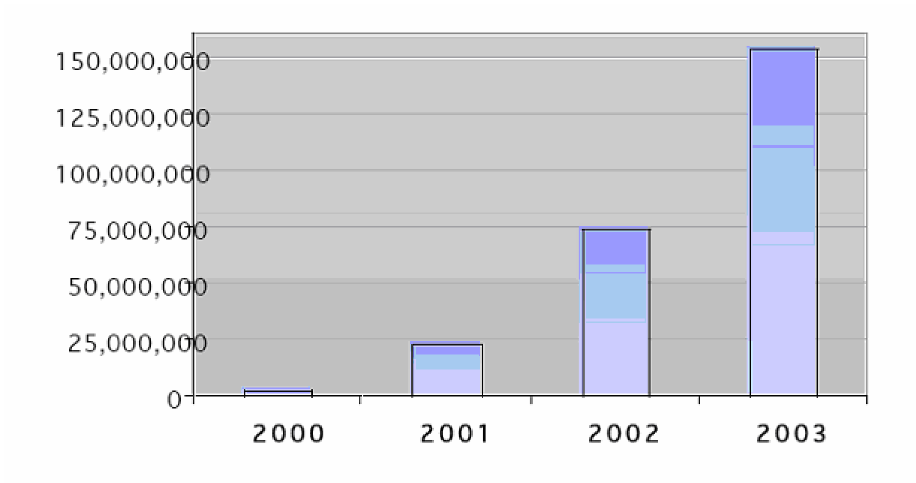
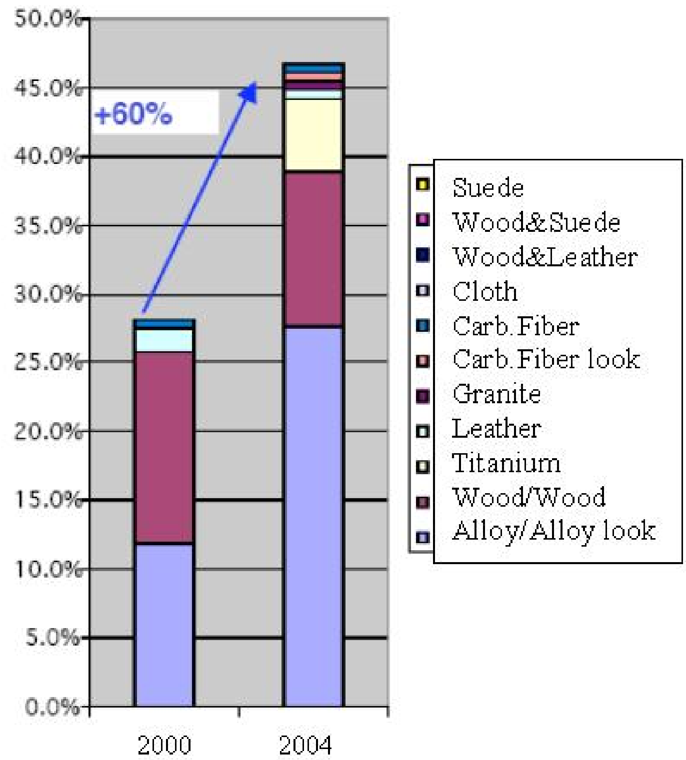


Figure 2.12. Revenue from purchase of navigation option in Germany.
(Source: WEB_8 2005)



Luxury Trim on Instrument Panel, reflected on Gearstick and Door Panels:

Alloy +230%

Wood - 20%

Leather - 50%

All new Suede, Cloth, Titanium, Carbon & Granite

now 10% of total market.

Figure 2.13. Standart Luxury Trim in Germany.
(Source: WEB_8 2005)

The dashboard will tend to look more and more like a computer output panel both because of the increased use of electronic instruments for information transmittal, and also because of the influence the technologically oriented environment has on the younger generation. To comply with the wish for comfort, the car interior will take on more the character of a living room with picture windows. Interior design has become the major area of strategic car design.

CHAPTER 3

USER CENTERED / INTERFACE DESIGN

3.1. Design as Communication

Design is a complex activity, and most of the objects, spaces, and even services that we interact with were designed by multiple people, sometimes in synchrony with one another, sometimes not. Each placement of an object, the choice of materials, the addition of hooks, handles, knobs, and switches, is both for utility and for communication. The physical placement and the perceptual appearance, sound, and touch all talk to the users, suggesting actions to be taken. Sometimes this conversation is accidental, but in the hands of good designers, the communication is intentional. Design is a conversation between designer and user, one that can go both ways, even though the designer is no longer present once the user enters the scene.

Design happens to be a rather unsettled field of human creativity, without critical method (and without methodic criticism), and without the means to construct one for itself. People who worked in typography, printing/printmaking, jewelry design, architecture, textile, heraldry, ceramics, fashion, and the arts started identifying themselves as designers less than a century ago. Design is a general concept, reflected in the underlying quality of objects, actions and representations which various people make possible in a given culture and within a value framework. To design means, among other things, to plan, to anticipate according to a devised course of events in view of a goal and under the influence of environment.

Semiotics, as a rational system for the analysis of communication and design problems, also provides a methodology for the evaluation of communication and design from the perspective of their functions. It allows the designer to:

- understand and effectively use optimal means of communication;
- generate and evaluate various answers to problems solved through design;

- choose technological means to solve problems;
- consider the dynamics characteristic of design.

The use of semiotic means of analysis and evaluation implies the need to integrate a signage system into the broader system of visual communication, making sure that it will perform according to its basic functions (as derived from service offered by a transportation authority): expressiveness, precision, user-friendliness.

People communicate using signs. Such signs can be simple or very complex, homogeneous or heterogeneous, sequential or configurational. Interface is the meeting place between two different entities that are supposed to come in contact, to be brought together, i.e., to communicate. It follows that interface has the nature of a sign. Interface is also a problem of human-to-human relations, especially in the context in which human contact and inter-influence become more and more mediated. Defining the sign as a mediating entity and semiotics as the theory and practice of mediation.

Based on these elements, we would like to introduce a generalized concept of design as interface: The product of design is the reality through which user and designer communicate. We should repeat that interface, no matter what kind, specifies the optimal set of signs for the interaction between two entities, be they animate or inanimate. In a limited sense, user interface specifies the action the user is supposed to take in order to access different parts of a system to the design of the conceptual model that is the basis of that particular system (WEB_9 2005).

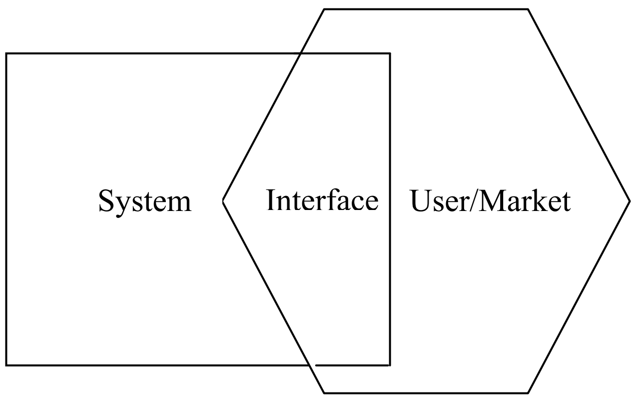


Figure 3.1. Generalized interface model.
(Source: WEB_9 2005)

Cars, radios, dishwashers, vending machines, etc. all require interface in order to be optimally used. Each requires a certain sequence of actions that allows for the pragmatics of using it. What makes things a bit more complicated in comparison to the most common social forms of interface through the intermediary of natural language (the most complicated semiotic system that we are aware, of) is the fact that *design interface is part of the designed object.* To use an analogy, it would be like receiving with every sentence we hear or read, instructions for understanding it, i.e., the code. Design is indeed a work of encoding and providing the key for the "reader." Sometimes design is quite hermetic; other times it can be direct to the degree of being simplistic, offending our sense of design.

Once we start to view design as a form of communication between designer and the user, we see that perceived affordances become an important medium for that communication. Designed affordances play a very special role. Now we see that the designer deliberately places signs and signals on the artifact to communicate with the user.

3.2. User Centered Design

Today's consumer have shifted from conventional commodities to novel experiences that satisfy not only their basic needs but also superior ones including sensorial, intellectual, emotional, and cultural needs. Creating novel '*experiences'* for consumers necessitates focusing on, besides their basic needs, deeper aspects of their lives, their emotions, aspirations, vice versa. Therefore, in a process of designing experiences for consumers, in-depth 'user research' appears to be the main source of knowledge. Besides utilizing user knowledge, the design process might also employ users in numerous phases of the design process including not only the evaluation phase but also conceptual and creative / generative phases. Utilizing users as a source of innovative knowledge and as creative individuals requires new techniques, methods, and tools.

Nevertheless, the emergence of user-centered design has naturally clarified the scene and brought together design practice and user research activity. The contribution of user-centered practices in the design activity has augmented the understanding of ‘user’ needs. As per Sanders (2001), the emergence of user-centered design has happened by a step-by-step contribution of user-centered practices in the practice of design. The gradual convergence of user-centered practices and design practice has initiated by the contribution of practices from ‘biological’ and ‘social’ sciences to the practice of design and augmented the understanding of user experience (Sanders 2001).

Sanders (2001) argues that the emergence of the user-centered approach to the design practice initiates with the contribution of ergonomics and human factors practices to the design practice those aim to meet the bodily needs of users. However, this approach recently covers the contribution of a broad range of practices to the design discipline and aims to meet a wide scope of emerging needs of users. Sanders (2001) outlines the development of the user-centered approach in terms of step-by-step contribution of user-centered practices to the design practice as follows:

- Fit to the body was emphasized in the field of ‘ergonomics’ or ‘human factors’.
- Fit to the mind was seen in the introduction of ‘cognitive ergonomics’, leading to new fields such as information design and interaction design in the 1980’s.
- Fit to the social aspects of human behavior came with the advent of ‘applied ethnography’ and ‘contextual inquiry’ in the 1990’s.
- Fit to the emotional domain is just now receiving attention, as seen in interest areas such as ‘affective human factors’.
- Fit to the dreams and aspirations of the people who will buy and use the goods and services that we design is the next step (Sanders 2001).

User-centered approach is not only a model providing need-related information to the design process, but also an understanding that focuses on user experience rather than the product or the design problem. According to Kelley (2001), before the emergence of the user-centered approach, the focus was purely on products and the users of the products were seen as “*stupid*.” He exemplifies this approach with the statement of an executive from the 1930s automotive industry as “*It’s not that we build such bad cars; it’s that they are such lousy customers.*” Moreover, Sanders (WEB_10 2005), identifies user-centered design as *“designing objects for users*.”

3.2.1. Approaches and Concepts in User-Centered Design

The design activity, its methods and sources, have also changed from depending on individual intuitions of designers to relying on 'collaborative' designing. Thackara (WEB_11 2005) suggests that designing is no longer a heroic activity that creation of products, services, experiences could be manipulated by "a design genius working in isolation" from people.

3.2.1.1. Design for Experiencing

The advancements in technology and industrial production have brought about unforeseen high-tech features and attractive qualities of today's products and services. However, enabling these high-tech features has also resulted in makingt them ordinary for the people using them. Therefore, people have become assessing 'intrinsic' qualities of products and services, rather than 'attractive' qualities that have already been granted (Marzano 2000). Consequently, today's commodities have lost their 'economic' value, those intend to satisfy people's basic needs, and replaced by higher values those mean to stimulate people's 'experiences' (Marzano 2000).

According to Arbak (2000), commodities constitute only tangible expressions of intangible 'experiences', given that "*the tangible qualities of the 'products' are simply expressions of the intangible experiences they provide for people.*" Arbak (2000) suggests that the output of the design activity is not only tangible products, but also "*the present and future experiences those products provide*." Alternatively, as per Marzano (2000), "*stimulation of both senses and intellect*" creates an experience, while their "*perception and understanding that determines whether the experience has been a positive or negative event in the eyes of the individual*." Therefore, Marzano (2000) argues that the only way to provide 'positive experiences' is through "*a better understanding of people's emotions, sensorial perceptions and cultural values.*" Correspondingly, Kelley (2001) suggests that addressing experiences comprise "*thinking verbs, not nouns*," that is focusing on experiences, rather than objects. He illustrates this argument with "*the goal is not a more beautiful store…it's a better shopping experience*" (Kelley 2001).

According to Sanders (2001, WEB_12 2005), 'design for experiencing' focuses on "*the whole user experience*", which comprises not only the present experience, but also past and future experiences of user. On the other hand, Thackara (2001) argues that 'experiences' could not be designed, where the design activity could only provide elements of products, such as interfaces, environments, and so on that offer the experience. Consequently, Sanders (WEB_10 2005) suggests that 'design for experiencing' could only be achieved is user's whole experience that comprise past, present and potential experiences with a product or service is accessed, therefore these experiences could be utilized as the source of inspiration in the design activity.

3.2.1.2. Co-Design or Collaborative / Participatory Design

The developments in user-centered approach and the focus on 'user experience' have also resulted in a new paradigm, which is based on collaboration with users in the beginning of the design process, namely 'co-design', 'collaborative design', or 'participatory design'. The emergence of this paradigm mainly relies on the need for an in-depth understanding of users' experiences and aspirations in order to "*address the real needs or fulfill the dreams of people*" (Sanders 2001).

Martin and Schmidt (2001) mention "*participatory design is founded on the belief that users are creative and can play an active role in the design process*" and argue this paradigm to be based on designing not only 'for' users, but also 'with' them. The main objective of collaboration with users in the design process is to gain an in-depth understanding of users' experiences and dreams. As per Martin and Schmidt (WEB_13 2005), innovations would be successful since they are derived from the real experiences and aspirations of users. Correspondingly, Thackara (WEB_11 2005) argues that designing 'with' people, not 'for' them, "*can bring the whole subject of 'user experience' literally to life.*" From this perspective, according to Thackara (WEB_11 2005), "*success will come to organizations with the most creative and committed customers*." In the same way, Marzano (2000) suggests that the only way to provide people meaningful products is to involve them to the new product development process.

3.2.1.3. New Roles within New Approaches

The developments in the user-centered approaches and the emergence of participatory / collaborative approaches also bring about a change in the role of both the users and designers through the design process. Consequently, within the emerging participatory / collaborative approach, all the stakeholders of the collective design activity are expected to be creative, where the role of the designers are to create scaffolds that users could easily express their creativity and to truly empathize the experiences and aspirations of the users utilizing a new language through communicating with them. Moreover, with new approaches and the changes in the roles of the participators of the design process, the source of innovation of the design activity appears to become more relying on the creativity and needs of the users.

3.2.1.4. Postdesign

All above-mentioned approaches and concepts bring about changes in the sources, tools, and methods of the design activity and the roles of both the users and practitioners, whereas “postdesign” emerges as a new “mindset” that institutionalize and converge the new participatory / collaborative approaches and the developments in the design activity.

Postdesign is understanding illustrates a new domain where all people are creative and can express and communicate their ideas and feelings easily. Within this framework, the role of design practice is also changing towards an effort to build an appropriate ‘language’ for people to express and communicate themselves. In this sense, design practice entails a collective approach, the collaboration of interdisciplinary design and research practitioners and ordinary people (nonpractitioners) to work together in creating a collective language.

3.2.2. New User-Centered Methods for Design Innovation

The recently growing importance of 'design' in achieving innovation and the emergence of 'design innovation' paradigm have brought about significant changes in design methods and stimulated to the emergence of new methods. Additionally, one more reason that makes these methods novel is that they have accessed the practical domain of the design discipline recently.

The emergence of user-centered approach and the developments in the user-centered design domain has led to emergence of several methods in time. These methods are mostly based on understanding 'user needs' in order to create user-related knowledge to the design activity. However, some of them include different levels of collaborative approaches whereas some others comprise modifications of conventional market research activities.

3.2.3. Involving Users in the Design Process

According to Feeney (1996) traditional ergonomic methods for improving usability in product design has been to involve users in the design process. This had resulted in a number of approaches being adopted, all of which can be grouped into two main categories:

a) getting information from users or potential users in order to incorparate their needs and wants into the design of a product.

b) collecting informations from users on a products usability once it has been conceived

The concept of the user as a partner in the design process may , for many designers, be difficult to accept. In many ways howerver, the user has a valuable and in some respects, a unique experience with the product. Users have differing characteristics and needs an often behave differently from each other. For example it could be argued that people who have had an accident with a product resulting in an injury have experienced an interaction with that product which different to any other persons'.

One important criteria for involving users in the design process is that they are informed about how products are designed, manufactured and sold and what are the financial and other constraints imposed on producers. This is not to say users need to be educated in the disciplines of engineering, design, marketting etc., but they should be informed sufficiently to understand the viewpoint of such disciplines and be able to communicate in a constructive manner. The emphasis here should not be on just learning about how products are produced but to be able to objectively question whether doing it ' the way we have always done it' is necessarily the only way.

There are many difficulties to be faced when involving product users in the design process. Many of them however are of a basic nature and arise as a result of traditional attitudes on the part of the manufacturer and designer rather than with practical problems. Involving users in a real way means that some of the decision making has to be developed. This may present problems of those who are traditionally the sole decision makers in the design process. It may also pose a commercal risk for the company. One of the continuing problems facing the design review team was that the wishes of users to be creative was opposed by the designers who felt they were being unrealistic in their demands and did not appreciate the constraints imposed by the design and manufacturing system. To a large extend this was indeed due in part to the ysers lack of understanding of the system but also the lack of critical evaluation on the designers part of the suggestions being put by the users. A strong conclision from this was that there needed to be further examination of how the different experts can pool their knowledge and also have a more open mind regarding changes to the design however unrealistic they may at first seem.

At a practical level several problems arrose. Although the majority of the panel participated in all the important events, their availability could not always be guaranteed. The process can involve a considerable time commitment and suitable financial remuneration must taken into account when deciding to embark on such a procedure. Furthermore it was apparent that experienced users have very strong views on product features which sometimes conflict with research evidence. This can create problems for the designers.

The users involved in the design process were therefore already very familiar with the technology of the product and with user behavior with the procudt. It is recognised therefore that were the product to be ebtirely new with no specific identifiable users the process described may not be applicable and make take an entirely sifferent from with perhabs more emphasis on traditional design methods ie where the designer 'sets the agenda'. The experience may however encourage other researches to pursue models for such an application.

Whilst there are many problems to be overcome, in involving users in the design process, this case study illustrates that many real benefits can be gained for the producer, for designer and for the ultimate users of the product (Feeney 1996).

3.3. Supporting the Design of User Interfaces

There are several reasons why user interface designers should be empowered with high level tools to facilitate design decisions and support user-centered, ergonomic design of user interfaces.

First, it is argued that the accessibility of user interfaces in the emerging Information Society is mainly a design consideration which should be systematically supported.

Secondly, the need for compliance with standarts will increasingly influence design activities requiring expert articulation of design knowledge and artifacts.

Finally, the increasing pressure from the user community for more usable system has necessitated the consolidation of existing results in Applied Ergonomics and Human Factor to provide the body of knowledge required to facilitate a user-centered approach to system development. Following these trends, it becomes evident that the design, development and evaluation of user interfaces for all users links with research from several disciplins in order to address different design dimentions and objectives, including (but not limited), design assistance, usability engineering, standarts compliance, incorporating guidelines into deisgn life cycles, design assessment components and design critiquing (Stephanidis and Akoumianakis 1996).

3.4. Designing for All Users

It is believed that in the emerging interaction-intensive paradigm for Human-Computer Interaction. Universal accessiblity and high quality of interaction will pre-dominate, as new usability requirements. Unfortunataly, the present generation of user interface development tools, but also existing techniques for usabilty evaluation do not support design for all users. For instance, consider the requirement that a user interface shoul be accessible by different user groups. This general requirement which is expected to increasingly become an essential property of all interactive system, is seldom addressed compresensively by any of existing ergonomic guidelines and criteria. On the other hand, techniques such as user inteface adaptability or user interface adaptivity, at present,offer limited support towards the above requirement. As an example of the implications of this shorthcoming, let us consider a hypothetical scnerio whereby an interface is equipped with tools which allow the user to tailor the interaction with the system (adaptanilty), but also with user modeling components that support adaptivity. Since the interface is built using an existing development tool (i.e. MS-Windows, OSF), it is not directly accessible by a disabled computer user. Consequently, since no interaction can be initiated (a) no adaptibility can be realised by this user unless a facilitator undertakes the responsibility of this task. And (b) no adaptivity can be supported as no assumptions about the user can be delivered. It follows, therefore that the appropriation of the benefits of adaptability and adaptivity can only be observed for certain usre gruops, which implies that the requirement for universal accsessibility cannot be met. From the above it is evident that today there are no tools to support the development and maintenance of user interfaces accessible by different user gruops, while existing techniques for user interface adaptation fail to effectively address such a requirement. It is therefore argued that the development of a comprehensive toolset which will take full account of the required methods can provide the necessary support to guide designers towards system which are aware of their target user gruop, co-operative, tailorable, adaptable and adaptive depending on the interaction context (Stephanidis and Akoumianakis 1996).

3.5. Interactive Properities

Manufacturing companies that operate in a global business environment face challenges and opportunities to develop their business by providing a variety of attractive products to the market in an environment where speed and agility are essential. The attractiveness of a product depends strongly on how we perceive the product with all our senses in relation to the expected performance of the product. This normally means that the technical functional requirements and the cost constraints must be fulfilled. But, sometimes even more important, the product must also have “something more” properties of a semiotic, ergonomic and/or aesthetic nature. Consequently, a holistic view is necessary in the product realization process and both the technical and the “something more” aspects must be considered. We can name the “something more” properties interactive properties.

The perceived use of a product by a human being relies on subjective understanding to a great extent. We therefore have to find ways to model the "hard" and the "soft" requirements, the technical and the interactive properties implemented in a product, and their relations. Interactive and technical functional surfaces and how they fit into a general modeling principle of technical systems are elaborated on. The general modeling principle includes both previously presented technical interface models and interface models of interactive functions.

The general industrial demands on the product development process are to reduce the development time, improve the product quality, and reduce the corporate cost. As a direct consequence, industry is changing from a manufacturing economy to a digital economy, in which the processing of product knowledge plays an important role (Lange 2001) and there is increased interest in platform-based product development. Product platform development includes the tricky task of answering questions on how to handle variety, how to structure products, and how to structure the associated digital models of the products. In addition, methods and techniques for handling different system structures and different models of these structures must be developed and thoroughly tested.

According to Lange (2001), products are designed by someone to be perceived by someone. Lange’s research concentrated on design synthesis rather than on design analysis, which is the more common focus. He came to the conclusion that design is an act of semiosis and adopted “a designer-centered perspective of the design activity where it is the individual who has a perception of a product that shall be created.” It also takes a human to perceive value in the attractiveness of a product. We thus have to consider human aspects both as designer and as user.

The attractiveness of a product is normally related to its aesthetics. However, this statement is an oversimplification, since the attractiveness of the product is related to how we perceive the product with all our senses in relation to what we expect to get from the product. This means that the technical functional requirements and the cost constraints must be fulfilled, but it also often means that the product must have “something more,” some syntactic, semantic, ergonomic, or aesthetic properties. Consequently a holistic view is necessary in the product realization process and both the technical and the “something more” aspects must be considered.

All product realization activities benefit from a holistic approach. Both the technical and the “something more” aspects must be considered simultaneously. We can name the “something more” properties “interactive properties.” Furthermore, modeling and simulation of products for their whole life is becoming increasingly important. We therefore have to find ways to model both the technical and the interactive properties of products.

3.5.1. Technical and Interactive Functions

The word "function" appears in many different situations, with different meanings. Here we focus on the functions of physical products. Product function is normally something that the product does or is intended to do.

Warrel (2001) devided functions into technical functions and interactive functions. Technical functions are internal product functions while interactive functions are human-product functions.

Technical functions are associated with the flow, transformation, and storage of energy, materials, and information in the product. Typical basic technical functions include storing, transporting, transforming, supporting, and preventing something.

These basic functions can also be expressed using synonyms or more natural formulations, such as enabling something to open or allowing something. A technical function can be active, for example when it involves transporting or transforming something, or passive, for example when it involves supporting something.

Interactive functions are associated with the interaction between the user and the product and communicate the usability and the attractiveness of a product (Warrel 2001). They can be decomposed into *ergonomic functions, semantic functions,* and *syntactic functions*. Syntactic and semantic functions are *communicative functions*. An ergonomic function captures the relation between a product and the physical and physiological capability of the human body. A semantic function captures how products or parts of the product communicate their purpose to the user. Syntactic functions capture how the form of a product, or of part of a product, are perceived by humans. It is often difficult for engineers to clearly distinguish between a semantic and a syntactic function. Furthermore, semantic and syntactic functions are often interrelated and act in parallel.

3.5.2. Technical Systems and Functional Interfaces

A technical product can be viewed as a system, which can be defined as a set of subsystems or elements that are interrelated to each other and to the whole so as to achieve a common goal, or function. Many subsystems are assemblies of machine elements. The technical function of a component often relies on mechanical contact relations within the component and between the component and surrounding components of the system, or on interaction relations between the component and the environment.

Sellgren (1999) defines an interface as an attachment relation between two mating faces. A mating face is typically a surface with an intended contact function on a component. We can refer to surfaces whose main purpose to interact with other surfaces or with a human as functional surfaces. *Functional interfaces of a product are the interfaces by which the different technical and interactive functions are actively performed when the product is in use.* Consequently, we can modify the original definition of a (functional) interface as follows:

An interface is an interaction relation between two functional surfaces.

This definition of an interface easily embraces all technical functional surfaces within the system and those in the environment that interact with the system. Furthermore, if we represent the human side of the human–product (or man-machine) interaction as an interactive functional surface, we can include all the interactive functions in the definition as well.

In summary, the following types of interfaces can be identified:

- *Technical interface* – a technical functional surface in or on a technical system that interacts with another technical functional surface within the technical system or in the environment
- *Interactive interface* – an ergonomic or communicative functional surface on a technical system that interacts with a human through one of his or her senses.

3.5.3. Human – Computer Interaction

Effective design of human-computer systems requires the designer to have an understanding not only of the technical components of the system, but also of the human components. As an aid to understanding, computers are conventionally modelled as a combination of a central processor and its associated memory along with an input/output controller to communicate with the peripheral components and the outside world. The operation of the computer and its components carefully understood and the model can therefore be fully denned.

Ideally, for the purposes of engineering design, it would be desirable to model the human part of the overall system in the same way. Unfortunately, humans are much less predictable, consistent and deterministic than computers, and thus defining a general model for the human part of the system is not possible given the current understanding that exists of the human processor's operation.

Instead, a number of more fragmentary and incomplete models of the human as an information processor have been proposed, each of which can be applied in restricted circumstances. These models have been derived from hypotheses proposed by cognitive psychologists and reinforced by empirical exploration within the field of experimental psychology. Over a period of time, their robustness and range of application has been established, with the result that they now form useful predictive tools in the design of human-computer systems. However, although the models accurately depict first-order effects, analysis at a more detailed level usually reveals limitations and inconsistencies. The models are therefore primarily useful in predicting gross behaviour, but suppress detail.

In general, the most accurate, detailed and specific models relate to those aspects of human performance which can be most easily tested. Thus the characteristics of the human senses (particularly vision and hearing) are well established, whereas those aspects of the human processor which can only be observed indirectly (such as short- and long-term memory) are less clearly understood. In the following sections, the various components of the human processor are considered in more detail, and their principal capabilities and limitations presented (Dowton and Jones 1993).

3.5.4. Human Senses

The main human senses are vision, hearing, touch, smell and taste. In interactive computer systems, vision and hearing are by far the most frequently used, while touch, smell and taste are used to a lesser extent but may be useful in input/output devices for the handicapped where the primary senses are missing or impaired.

a. Vision

For the normally sighted person, vision is by far the most powerful sense. Psychologists have argued that the human visual system is designed to produce organized perception in terms of motion, size, shape, distance, relative position and texture. Because we are used to viewing three-dimensional objects, the visual system attempts to interpret all stimulation reaching the eyes as if it were reflected from a real scene in three dimensions even when we are viewing a flat, two-dimensional surface.

b. Hearing

For normally sighted and hearing people hearing is the most importantsense after vision in any computer interaction. Most people can detect sound in the frequency range

20 Hz up to 20 000 Hz but both the upper lower frequency limits tends to deteriorate with age and health. ring is more sensitive within the range 1000-4000 Hz, which in musical terms corresponds approximately to the top two octaves of the piano keyboard.

As well as frequency variation, sound can also have loudness variation. Defining the threshold of hearing as 0 dB, then a whisper registers as 20 dB and normal conversation registers between 50 dB and dB. Ear damage is likely to occur if the sound exceeds 140 dB. The ear is insensitive to frequency changes below about 20 dB (that is, below whisper). The sensitivity to both frequency and loudness varies from person to person and indeed for the same person from time to time, depending upon what level of sound they have been exposed to in the recent past. For example, when a person has been subjected to a fairly high level of constant background noise (as often occurs in factory environments) their sensitivity to changes in frequency and loudness is reduced for a while after they leave the noisy environment. The duration of this deterioration depends on the magnitude and duration of the initial exposure.

Hearing impairment is a relatively common problem which is often umderestimated as it is not always as apparent as vision impairment, but is estimated to affect around 10 per cent of the population overall. It is particularly prevalent among the old.

Although sound is the second most important medium for conveying infonnation to the user from a computer system, it can also be a cause of great distraction and annoyance. Because sound is such an invasive midium, it should be used sparingly and with a great deal of caution in the design of human-computer systems.

c. Touch

For computer interaction purposes, the sense of touch ranks third after vision and hearing. However, for the blind it has a higher importance and is therefore useful in aids for the disabled. It is also useful in areas of high auditory or visual noise where an additional channel is needed to attract the user's attention. For example, there are paging systems which vibrate to attract the wearer's attention. The fingertips are very sensitive to changes in pressure but as with any physical contact this pressure sensation diminishes with constant application (as long as the pressure sensation is below the pain threshold).

Although touch is not used a great deal consciously in human-computer interaction, tactile feedback conveys important subconscious information. Touch is also closely associated with ergonomic design aspects of a system. For example, when using a keyboard or switch it is very disconcerting if there is no obvious tactile or audible sensation that the switch has been operated. It is not uncommon for computer operators to complain that they do not like the 'feel' of a particular keyboard. These complaints can be associated with the position and shape of the keys but are also directed at keyboards which require too much or too little pressure to operate the keys or have a 'soggy' feel to the key action. If there is no obvious visual or auditory indication of the switch being operated then touch is the next most likely means of providing that feedback.

d. Taste and Smell

Taste and smell are not particularly useful in human-computer interface design and because they are not among our primary senses they are poorly developed and not very accurate in most people. In addition, taste and smell are highly dependent upon health. However, these senses can be trained, and there are a number of people who have very highly developed taste and smell.

CHAPTER 4

HUMAN FACTORS AND ANATOMY

Ergonomic, anthropometry, anatomy play an important role in the design and evaluation of seat and display concepts. The rapid growth in the application of new technology has posed as many queries for the designer and engineer as it has provided design opportunities. Ergonomists have addressed the queries arising from the interface between the display and the user and can work with the designers and engineers towards solutions.

4.1. History of Human-Machine Systems

One of the characteristics of Homo sapiens is the ability to make and use tools; even in the simplest human worksystem, it can be taken as axiomatic that a machine of some sort will be used.

In hunter-gatherer societies, the level of technology is low but the social bonds between people and the knowledge of the environment are well developed. This is appropriate since the survival of these people depends on cooperation and the ability to move freely around large areas of unoccupied land searching for food and water. Possessions are therefore lightweight and made out of readily available materials. In technologically more advanced societies, the emphasis may shift toward machines and more complex material possessions but is often accompanied by a corresponding reduction in the complexity of social interaction and knowledge of the environment.

The geometry necessary for understanding ellipses and parabolas was worked out by the Greek mathematician Apollonius in the third century B.C. purely as a theoretical exercise, as was most Greek mathematics and philosophy. One thousand years later, in medieval times, the opinion about most Greek mathematics and philosophy was that it was of little use, and for most of history, the social, economic, and intellectual climate did not stimulate thinkers to find uses for it. In fact, Apollonius's work bore fruit only in the sixteenth and seventeenth centuries when it turned out to be essential to understand the behavior of the planets and of projectiles such as artillery. Boole was a nineteenth century country clergyman whose invention of Boole an algebra turned out to be important in twentieth-century computer science. Finally, we can consider the advances in microelectronics and miniaturization which were essential for the success of the U.S. space program but also had a profound effect on the design of many consumer products as unexpected spin-offs from the main enterprise.

The tendency to overemphasize the role of science is well illustrated by the controversy over the invention of the miners' safety lamp in the nineteenth century. The problem of explosions in mines caused by the ignition of gases by naked lights was solved independently by the eminent British chemist Sir Humphrey Davy and by George Stephenson, the pioneer of the railways in Britain. Stephenson received little education and achieved only a rudimentary level of literacy at the age of 17. Not surprisingly, Davy was initially credited with the invention of the lamp (which was named after him). Stephenson's sponsors soon laid their claim (the "Geordie" lamp, developed by Stephenson, had been in use for some time) and Stephenson eventually received recognition.

It can be argued that a knowledge of science was not needed to discover the principle behind the safety lamp or to implement it in a prototype. It may well have been the case that Davy, thanks to his knowledge of chemistry, formal education, and scientific vocabulary, would have been better able to explain why the lamp worked. As is often the case, the superiority of science over intuition may be overestimated when explanation is confused with invention.

For much of history, the scientific and technical knowledge which was available to society was not used to improve the design of work systems. The ancient Greeks who invented mathematics and philosophy also developed pumps, astronomical calculators (preempting Babbage by almost two thousand years), and a primitive steam engine (Heron's "aerolabe"), but these were regarded as curiosities and their industrial potential was never exploited. Plato described the principle of work specialization and its advantages as follows:

> . . . more things are made and they are made better and more easily when each man does the work to which he is suited.

But the necessary integration of this idea with the application of science and technology in work design had to wait more than two thousand years. Some historians attribute this neglect to the social and economic effects of the use of slave labor in the ancient world, which meant that free citizens had no interest in physical work and looked upon it with disdain. It is interesting to note that one of the foundations of F. W. Taylor's scientific management was the insistence that increased output, lower product prices, *and* higher wages went together as part of the scientific management of industrial enterprises.

When deforestation caused the ancient Greeks to use stone as a building material, they were slow to exploit the new possibilities for construction it offered. Although they were aware of the advantages of the arch and the vault over the column and the lintel, they continued to build in stone using designs appropriate to construction in wood (the Parthenon is a famous example). On those occasions when scientific and technological skills were exploited, such as in civil engineering, the design of viaducts, town planning, etc., the results were impressive, judging by the many extant constructions.

Necessity is said to be the mother of invention, but it also appears to be the force which drives the large-scale application of different disciplines in an integrated way to achieve a common goal. The assembly line is sometimes credited to Henry Ford, but in the fifteenth century, the Venetian republic, then the main European maritime power, had a line for refitting its ships. Vessels were floated along the line while groups of workers at fixed stations performed specific operations.

The main factors which gave rise to the industrial revolution in Britain (1780-1860) were social and economic rather than scientific:

- Steady economic and population growth in the preceding centuries and an energy crisis resulting in the substitution of coal for wood.
- Increased agricultural activity due to improved land use and crop rotation. The size of the nonagricultural workforce grew. For much of British history prior to this time, the labor of two people was needed to provide enough food for three. This placed severe limitations on the size of the nonagricultural workforce.

- Better access to education, particularly for the middle and lower classes.
- Improved economic organization on a national scale.
- Emergence of a belief in work as an end in itself and the moral duty of thrift, moderation, and prudence.

The Napoleonic wars accelerated the trend toward industrialization even further by causing an increase in the price of fodder for horses. Mine owners looked to the development of railways using steam locomotion as a cheaper method of transporting coal.

This is not to suggest that developments in physics and chemistry due to Galileo, Newton, Boyle, and others were not important. Watt, the developer of the steam engine, is known to have had a keen interest in physics, particularly the gas laws. The Royal Society was established in Britain in 1660 to guide and strengthen scientific inquiry and the Royal Society of Arts, created in 1754, offered prizes for solutions to technical problems. Although these institutions can be seen as symptomatic of an intellectual climate receptive to scientific inquiry and the solution of practical problems, very few of the really important technical developments of the era arose out of these efforts. In fact, much of the technology (as well as the science) needed to start an industrial revolution had been in existence for centuries and just needed adapting to the new applications. For example, the techniques for fabricating cylinders for steam engines were adapted from those developed previously to bore cannon. The casting of cannon, in turn, made use of expertise gained centuries previously in the casting of church bells. What is significant, however, is that the spirit of inquiry which had always existed was directed to the design of worksystems and the solutions of practical problems. Scientists and thinkers were willing to "get their hands dirty" and find ways of applying their scientific knowledge for practical purposes.

As has already been stated, one of the characteristics of the development of industry over the last hundred years or so has been the application of more and more sciences to the design and analysis of worksystems in an attempt to improve them. Even apparently mundane occurrences can be better understood by the systematic application of basic principles and theories, but only if people are willing to do so. There is currently concern about global problems such as population growth, possible ill effects of accumulation in the atmosphere of carbon dioxide from the combustion of fossil fuels, and the future availability and affordability of energy sources. These concerns may give rise to profound changes in the technological base of advanced societies and the way this technology is used.

Much scientific knowledge about humans is available. It is, and will continue to be, the responsibility of the ergonomist to ensure that, where possible, this knowledge is applied to the study, design, and improvement of worksystems.

Ergonomics is a multidisciplinary subject which can be applied to the study and design of the human component of worksystems. Its areas of application are not limited by the particular technology or by the scale of the system. Ergonomics provides a standardized approach to the analysis of worksystems with the emphasis on the interactions between humans and machines. It has some areas of overlap with work study but is more scientific (and sometimes less quantitative) in approach. Its related disciplines are industrial medicine, industrial engineering, industrial psychology, and systems design and analysis.

Historically, ergonomics can be seen to have arisen as a response to the need for rapid design of complex systems. As technology becomes more complex and worksystems operate under increasingly severe constraints, good ergonomic design becomes increasingly important. Thus, "technology push" can be identified as one of the main factors influencing the direction and growth of the subject. The modem ergonomist has an important role to play as a source of scientific information about humans (a scarce commodity in many organizations), as a generator of knowledge about the human component of a worksystem, and as a member of a design team (Bridger 1995).

4.2. Human Factors and Ergonomics

In Britain, the field of ergonomics was inaugurated after the Second World War (the name was invented by Murrell in 1949 despite objections that people would confuse it with economics). The emphasis was on equipment and workspace design and the relevant subjects were held to be anatomy, physiology, industrial medicine, design, architecture, and illumination engineering. In Europe, ergonomics was even more strongly grounded in biological sciences. In the United States, a similar discipline emerged (known as "human factors"), but its scientific roots were grounded in psychology (applied experimental psychology, engineering psychology, and human engineering).

4.2.1. Modern Ergonomics

Modem ergonomics contributes to the design and evaluation of worksystems and products. Unlike in earlier times when an engineer designed a whole machine or product, design is a team effort nowadays. The ergonomist usually has an important role to play both at the conceptual phase and in detailed design as well as in prototyping and the evaluation of existing products and facilities (Bridger 1995).

Ergonomics is about ensuring a good fit between people, the things they do, the objects they use and the environments in which they work, travel and play. Human factors (or human factors engineering) is an alternative term for ergonomics, and is more commonly used in the USA. Ergonomics needs to be considered in the design of virtually any product, system or environment. Failure to do so may lead to designs which do not fit the physical, psychological or sociological needs of the users, leading to ineffective, inefficient or unsafe designs, which are unlikely to be commercially successful.The human sciences of psychology, anatomy and physiology provide information about the abilities and limitations of people, and the wide differences that exist between individuals. People vary in many ways: body size and shape, strength, mobility, sensory acuity, cognition, experience, training, culture, emotions, etc. Ergonomists are trained in analytical techniques which enable the full extent of these user characteristics and individual differences to be considered when influencing the design process. Good designers are trained to consider the people who will use the products, systems and environments they design, but they also have many other factors to consider. All too often, commercial or time pressures mean that ergonomics principles are compromised or not given adequate priority until too late in the design process. However, in recent years, crowded and competitive markets, raised consumer expectations, and new legislation have lead to a more rigorous application of ergonomics. Fundamental themes of ergonomics, such as 'user-centred design', 'userfriendly', 'inclusive design' and 'usability' have become buzz-words within the design industry. Far from being a constraint on creativity, ergonomics methods can be applied at the earliest stages of the design process, defining user needs and identifying opportunities for innovation. Some design consultancies employ qualified ergonomists and many other design groups work closely with specialist ergonomics consultancies. Large manufacturers, such as Ford, Philips and Nokia employ ergonomists to work alongside their in-house design teams. Most design projects involve multidisciplinary teams, including designers, engineers, marketing researchers, brand managers and, increasingly, ergonomists. Ergonomics is a broad subject area and is applied in many areas of industry, commerce and government. It can be considered under three broad headings (Pheasent 1988):

- Physical ergonomics: Concerned with human anatomical, anthropometric, physiological and biomechanical characteristics as they relate to physical activity. The relevant topics include controls and displays, working postures, manual handling, repetitive movements, work-related musculoskeletal disorders, workplace layout, safety and health, lighting, and the thermal and acoustic environment.
- Psychological ergonomics: Concerned with mental processes, such as perception, cognition, memory, reasoning and emotion, as they affect interactions amongst people and with products, systems and environments. The relevant topics include mental workload, cognition, decision-making, skilled performance, human-computer interaction, human reliability, work stress, training, cultural differences, attitudes, pleasure and motivation.
- Organisational ergonomics: Concerned with the optimisation of sociotechnical systems, including their organisational structures, policies, and processes. The relevant topics include communication, staff resource management, work design, design of working times, teamwork, participatory design, community ergonomics, co-operative work, new work paradigms, organisational culture, virtual organisations and quality management.

4.2.2. Human-Machine Systems

The human-machine model and the worksystems framework provide a standardized, albeit empirical, way of describing worksystems, irrespective of the application area and independently of any particular core science of ergonomics. They can be used to generate checklists and methodologies for evaluating prototypes or existing systems. It is often the case that some of the design issues in a particular system will stand out more than others and perhaps receive undue attention from the design team. A standard format for describing worksystems forces the ergonomist to consider all the issues, at least in the early stages.

The two most important first steps when using the human-machine model are to describe the technology and to describe the user or operator. Machines are normally well described, and plenty of information in the form of manuals and textbooks is available. Designers of human-machine systems normally operate with much less detailed and less formal information about people and make assumptions about people in a way that they would never do about machines.

A major task of the ergonomist is to describe the human at all levels appropriate to the particular system.

This task can entail a physical description in terms of user dimensions and abilities, including physiological factors such as age and fitness and their implications for human function. It also entails a psychological description, which includes details of operator/user skills, knowledge, experience, and motivation, and may include detailed considerations such as preferred ways of working, jargon, etc.

4.2.3. System Design and Human Behavior

After many years, research in ergonomics and its related disciplines has yielded standards and guidelines for tighter control of working conditions. The most common areas are lighting design, noise control, the indoor climate, the design of manual handling tasks, and seating.

Although it is necessary for the modem ergonomist to know about these controls and to be able to apply them to the design of systems, this is not sufficient. The professional ergonomist must fully understand the rationale for a particular control, the scientific principles on which it is based, the consequences of misapplication, and any limitations in the knowledge used to specify the control itself. A major emphasis of the present text is to enable the novice to develop a deeper understanding of this type of information.

Standards change over time and vary between countries, so there is little use in the ergonomist's learning them by rote. More importantly, the ergonomist must know *when* to look for this type of information, *how* to find it, and *how to* apply it.

As per Bridger (1995), the ergonomist must also be able to specify appropriate human behaviors and actions in the operation of a system. Much of the existing literature allows such specification to be done on a default basis. Ergonomists are good at deciding how tasks shouldn't be designed—either because of danger or health hazards or high probability of human error which will reduce the reliability of the system. The more positive approach requires that implementable human behaviors be specified at the design stage, which will result in the system's functioning at a specified level. Empirical techniques such as task analysis and description enable human behavior in the operation of systems to be studied systematically. However, there is a lack of formal procedures for specifying behavior, although attempts are being made to integrate human factors and systems engineering in a formal way.

4.2.4. Generation and Implementation of New Concepts

According to Bridger (1995), the design of the human-machine interface is the classical point of departure for the application of ergonomics. A very large body of literature is available to assist designers with the design of the user interface. The ergonomist has an important role to play at the concept generation stage in trying to anticipate what the demands of the new system will be and how they will affect operators. Organizations sometimes exhibit a certain inertia, which manifests itself as a desire to "do things in the way we've always done them." The ergonomist must analyze the reasons for current or proposed designs and suggest improvements and alternative concepts. Technological advances now offer many new concepts for the design of interfaces which are radical departures from traditional methods. Control of machines by voice and the use of synthetic speech as a display are examples. Computer-generated two- and three-dimensional graphic displays offer designers much more flexibility and capacity for information display than their electromechanical counterparts. Such displays have application in the aerospace and process industries and in the design of everyday products such as the automobile dashboard.

It is necessary to develop a sensitivity to the cost-benefit implications and practicalities of new design ideas. This is particularly true when an existing system is being improved. Several schemes exist so that recommendations for ergonomic improvements can be prioritized. The category chosen for a recommendation depends on the need for change, as perceived by the ergonomist, and the implementation costs in terms of money, time, expertise, impact on day-to-day running, etc. One way of prioritizing recommendations (used, for example, by the University of Vermont Rehabilitation Engineering Center) is as follows:

- Implement recommendation immediately (e.g., there is a serious design flaw threatening employee health or system reliability, or there is contravening legislation).
- Implement recommendation soon (e.g., the current way of working is unsatisfactory, but there is no immediate danger).
- Implement when equipment is shut down (e.g., if stoppages are expensive and there is no immediate danger, wait until the system is shut down for regular maintenance or repair and then implement the idea).
- Implement when cost-benefit ratio is acceptable (e.g., wait until the financial situation improves or implementation costs are lower).
- Implement when equipment is built or purchased (e.g., phase in new products or items on a replacement basis as old ones are discarded).

4.3. Anatomy, Posture, and Body Mechanics

It is easy to overlook the fact that the human body is a mechanical system which obeys physical laws. Many of the postural and balance control mechanisms, essential for even the most basic activities, operate outside of conscious awareness. Only when these mechanisms break down—as when we slip or lose balance—are we reminded of our physical limitations. An understanding of these limitations is fundamental to practically all applications of ergonomics.

The skeleton plays the major supportive role in the body. It can be likened to the scaffolding to which all other parts are attached, directly or indirectly. The functions of the skeletal and muscular systems are summarized in the bellow:

Skeletal system	*Muscular system*
1. Support body	1. Produce movement of the body or
2. Protection (the skull protects the brain and the rib cage protects the heart and lungs)	2. Maintain posture
3. Movement (muscles are attached to bone and when they contract, movement is important produced by lever action of bones and joints)	3. Produce heat (muscle cells produce heat as a by-product and are an mechanism for maintaining body temperature)
4. Homopoiesis (certain bones produce red blood cells in their marrow)	

Like any other mechanical system, the body may be stable or unstable and is able to withstand a limited range of physical stresses. Stresses may be imposed both internally or externally and may be acute or chronic. The function of the ergonomist in the study of such stresses is to use principles of anatomy and biomechanics to design the working environment in order to minimize undue stress, preserve the health of the workforce, and improve task performance (Bridger 1995).

4.3.1. Some Basic Body Mechanics

The basic limiting condition for postural stability is that the combined COG (the combined center of gravity) of the various body parts is within the base of support described by the position of the feet (assuming no other external means of support). The main parts of the axial skeleton must be positioned vertically above the base of support. Ideally, the lines of action of the masses of the body parts should pass through or close to the relatively incompressible bones of the skeleton (Figure 4.1). The jointed skeleton thus supports the body parts and is itself stabilized by the action of muscles and ligaments which serve merely to correct momentary displacements of the mass centers from their bony supports. In a rather crude analogy, the skeleton can be likened to an articulated tent pole with guy ropes (postural muscles) on every side. The fabric of the tent corresponds to the soft tissues of the body. Any displacement of the COG of the structure in a given direction leads to tension in the guy ropes on the opposite side. Ligaments can be likened to the springs and rubber fittings which stabilize the articulations of the tent pole, and tendons to the ends of the guy ropes where they insert into the poles. The skeleton is the tent pole, the muscles are the guy ropes, and the soft tissues are the canvas (Figure 4.1.).

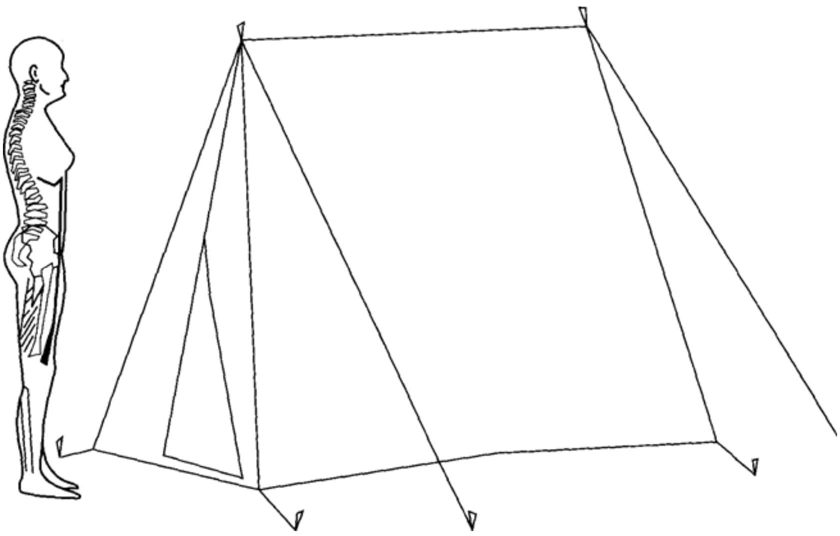


Figure 4.1. The tent analogy.
(Source: Bridger 1995)

4.3.1.1. Stability and Support

A stable posture can be maintained only if the various body parts are supported and maintained in an appropriate relation to the base of support, such as the feet or the squab of the seat. The size of the base of support determines not only the stability of the body but also the postures which can be adopted.

For the body to be in a condition of static equilibrium:

- Upward forces (from floor) must equal downward forces (body weight plus any objects held).
- Forward forces (e.g., bending forward) must equal backward forces (extension of back muscles).
- Clockwise torques (e.g., from asymmetric loads) must equal counterclockwise torques (back and hip muscles).

Ideally, the skeleton should play the major role in supporting the various body parts since this is its function. However, muscles, ligaments, and soft tissues can also play a role but at a cost of increased energy expenditure, discomfort, or risk of soft tissue injury.

4.3.1.2. Some Aspects of Muscle Function

The function of skeletal muscles is to exert tension between the bony points to which they are attached. Tension is exerted when a muscle changes from its resting to its active state in response to impulses from the central nervous system. The maximum tension a muscle can exert depends on its maximum cross-sectional area and also its length (as described below).

The term "muscle contraction" refers to the physiologically active state of the muscle, rather than its physical shortening. Muscles are able to contract eccentrically, isometrically, and concentrically:

- *Eccentric contractions.* The muscle lengthens while contracting.
- *Isometric contractions.* The muscle length remains constant during contraction.
- *Concentric contractions.* The muscle shortens while contracting.

4.3.2. Anatomy of the Spine and Pelvis Related to Posture

The spine and pelvis support the weight of the body parts above them and transmit the load to the legs via the hip joints. They are also involved in movement. Almost all movements of the torso and head involve the spine and pelvis in varying degrees. The posture of the trunk may be analyzed in terms of the average orientation and alignment of the spinal segments and pelvis (Bridger 1995).

Driving postures used by drivers should take into consideration musculoskeletal and biomechanical factors, and ensure that all driving tasks are conducted within a comfortable reach range. The posture of the seated person is dependent on the design of the seat itself, individual sitting habits and the work to be performed. Seated postures are defined as the body position in which the weight of the body is transferred to a supporting area - the ischial tuberosities of the pelvis and their surrounding soft tissue. The biomechanical considerations of seated postures include the spine, arms, and legs. The muscles at the back of the thighs influence the relative position of the spine and pelvis. The location and slope of the work area influence the position of the neck, shoulders, and upper extremities, when an individual is in a seated posture. Therefore, along with the seat itself, it is essential that the work to be performed be taken into consideration. However, there are several factors which help to minimize musculoskeletal stresses. It is generally accepted that

a) the seat should permit shifting or changing of a seated posture;

b) a large adjustable back support should be provided;

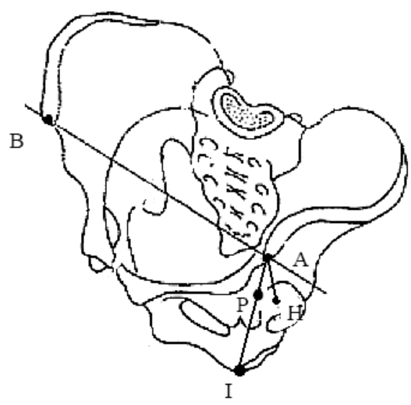
c) seat surfaces should be accommodating, but not spongy, in order to accommodate the forces transmitted on it;

d) adjustments in seat height and angles be easy.

All of these features contribute to good seated posture. Additionally, providing a biomechanically improved seated workstation requires consideration of the size variation in the workforce population and that prolonged static muscle exertion be minimized to prevent muscle fatigue. The weight of the human body must be supported without creating high, localized points of pressure.

Seated posture can be accurately described when the position of the pelvis is accurately measured. The pelvis is one of the most difficult body segments to measure due to the amount of tissue overlaying it and the fact that it is a very private area of the body. To the automobile seat manufacturer, three points on the pelvis are of great importance: H-point (hip joint location) D-point (ischial tuberosity) and ASIS (anterior superior iliac spine). H-point is most important for vehicle packaging, D-point is important for comfort and safety of the occupant and the lap belt is most effective for holding the pelvis in the seat during a crash if it is below the ASIS (WEB_6 2005).

The H-point, or average location of the hip joint in the compressed seat of a vehicle, is now officially defined by the use of standardized two or three-dimensional mannikins. These were originally the subject of a Society of Automotive Engineers Standard (1974) and have subsequently been adopted in international standards (ISO 3958, ISO 6549).



the left ASIS point (**A**),

the right ASIS point (**B**),

the left ischial tuberosity (point **I**).

Figure 4.2. The human pelvis and the landmarks used to estimate H-point.
(Source: WEB_14 2005)

4.4. Anthropometric Data

Anthropometric data are used in design standards for new systems and in the evaluation of existing systems in which there is a human-equipment interface. The purpose of the data is to ensure that the worker is comfortable and efficient in performing work activities and in the use of the equipment. Traditionally, anthropometric data used by industrial designers has come from military studies.

Military males are healthy and young. Because there is some selection in the military population, the anthropometric measurement extremes found in the industrial population differ from those found in the military population. For example, the very overweight or the very small person may be seen more frequently in the industry population, than in the military population. In the past, males driver dominated. Today is comprised of males and females between the age of 17 and 70 who may have chronic illnesses and/or functional capacity losses. In addition, the demographics of the driver population are dramatically changing with significant increases in racial and ethnic diversity in globe (Waller and Green 1997).

The word "anthropometry" means measurement of the human body. It is derived from the Greek words *anthropos* ("man") and *metron* ("measure"). Anthropometric data are used in ergonomics to specify the physical dimensions of workspaces, equipment, furniture, and clothing so as to "fit the task to the man" and to ensure that physical mismatches between the dimensions of equipment and products and the corresponding user dimensions are avoided (Bridger 1995).

4.4.1. Anthropometry and Its Uses

According to Bridger (1995), clearly the natural variation of human populations has implications for the way almost all products and devices are designed. Some obvious examples are clothes, furniture, and automobiles. Anthropometric data can be used to optimize the dimensions of a diverse range of items—the length of toothbrush handles, the depth and diameter of screwtops on jars and bottles, the size of tools in tool kits supplied with automobiles, and almost all manual controls, such as those that are found on televisions, videocassette recorders, radios, etc.

Body size and proportion vary greatly between different population and racial groups—a fact which designers must never lose sight of when designing for an international market. U.S. manufacturer hoping to export to Central and South America or southeast Asia would need to consider in what ways product dimensions optimized for a large U.S. and probably male user group would suit Mexican or Vietnamese users, who belong to one of the smallest population groups in the world.

It is usually impracticable and expensive to design products individually to suit the requirements of every user (although this is a recent development in the history of design). Most are mass-produced and designed to fit a wide range of users—the custom tailor, dressmaker, and cobbler are perhaps the only remaining examples of truly user oriented designers in western industrial societies.

In the design of mass-produced items the task of the ergonomist is first to characterize the way a product is to be used and then to identify the issues which might affect usability—including the constraints which are imposed on the design by the anthropometry of the user population. From this, anthropometric dimensions appropriate to the design of the particular product can be specified. Second, the necessary data from the corresponding consumer/user group are obtained for use in dimensioning either the product itself or its range(s) of adjustability.

4.4.2. Types of Anthropometric Data

4.4.2.1. Structural Anthropometric Data

These are measurements of the bodily dimensions of subjects in fixed (static) positions. Measurements are made from one clearly identifiable anatomical landmark to another or to a fixed point in space (e.g., the height of the knuckles above the floor, the height of the popliteal fossa, or back of the knee, above the floor, etc.). Some examples of the use of structural anthropometric data are to specify furniture dimensions and ranges of adjustment and to determine ranges of clothing sizes. Figure 4.3 shows structural variables which are known to be important in the design of vehicles, products, workspaces, and clothing. Figure 4.4 shows examples of vehicle dimensions which would require user anthropometry to be specified (Bridger 1995).

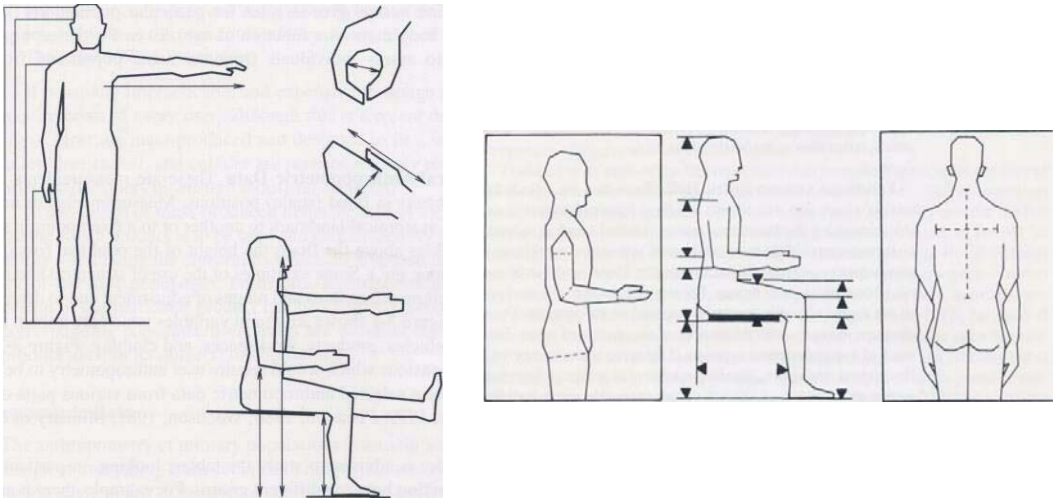


Figure 4.3. Some common structural anthropometric variables.
(Source: Bridger 1995)

4.4.2.2. Functional Anthropometric Data

These data are collected to describe the movement of a body part with respect to a fixed reference point. For example, data are available concerning the maximum forward reach of standing subjects. The area swept out by the movement of the hand can be used to describe "workspace envelopes"—zones of easy or maximum reach around an operator. These zones can be used to optimize the layout of controls in panel design. The size and shape of the workspace envelope depends on the degree of bodily constraint imposed on the operator. The size of the workspace envelope increases with the number of unconstrained joints. For example, the area of reach of a seated operator is greater if the spine is unencumbered by a backrest and can flex, extend, and rotate. Standing reach is also greater if the spine is unconstrained and greater still if there is adequate foot space to enable one or both feet to be moved. Somewhat counter-intuitively, one way to increase a worker's functional hand reach is to provide more space for the feet (Bridger 1995).

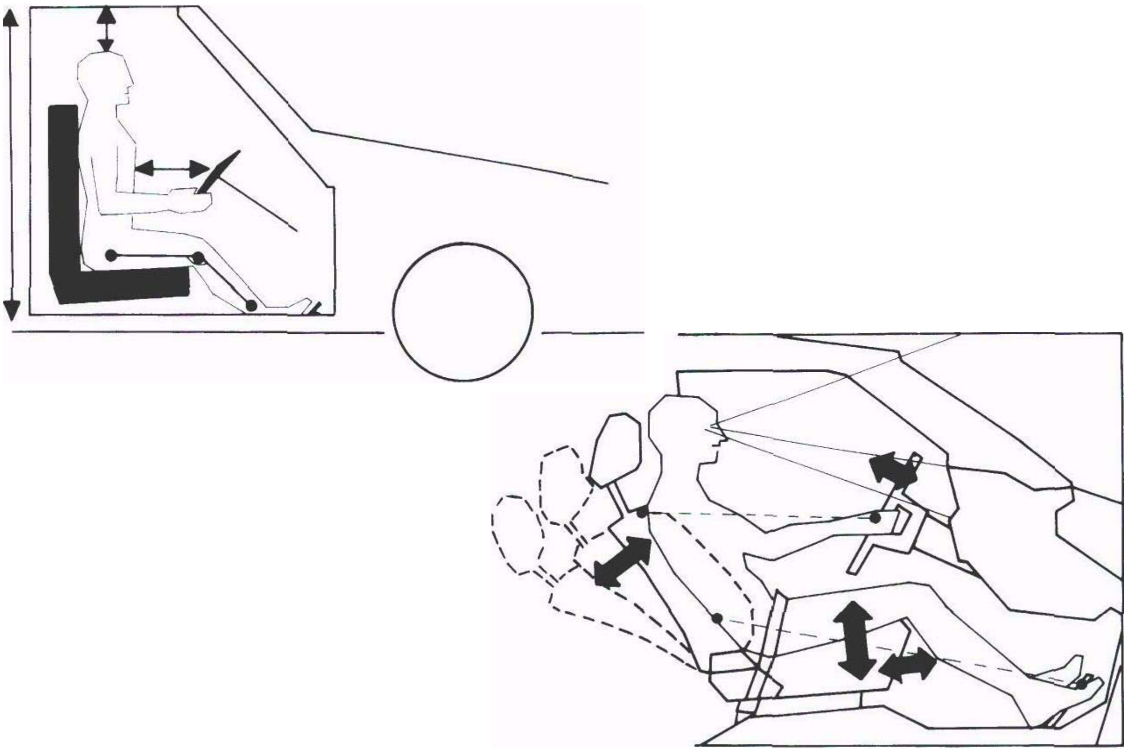


Figure 4.4. Dimentions which are determined using anthropometric considerations. (Source: Bridger 1995).

Data on static measurements can effectively serve certain design purposes that relate to circumstances in which people do in fact tend to stay put, such as in some chairs and seats, or in which mobility is relatively minimal. In most circumstances in life, however, people are not inert (not even when sleeping). The focus of dynamic anthropometry is on operational measurements of the human body while its inhabitant is performing some function. Figure 4.5 illustrates the *dynamic* aspects of an operation, that of driving a vehicle, as contrasted with the less realistic *static* aspects of vehicular cab design (which tend to emphasize the physical *clearance* between the driver and the features of his physical environment).

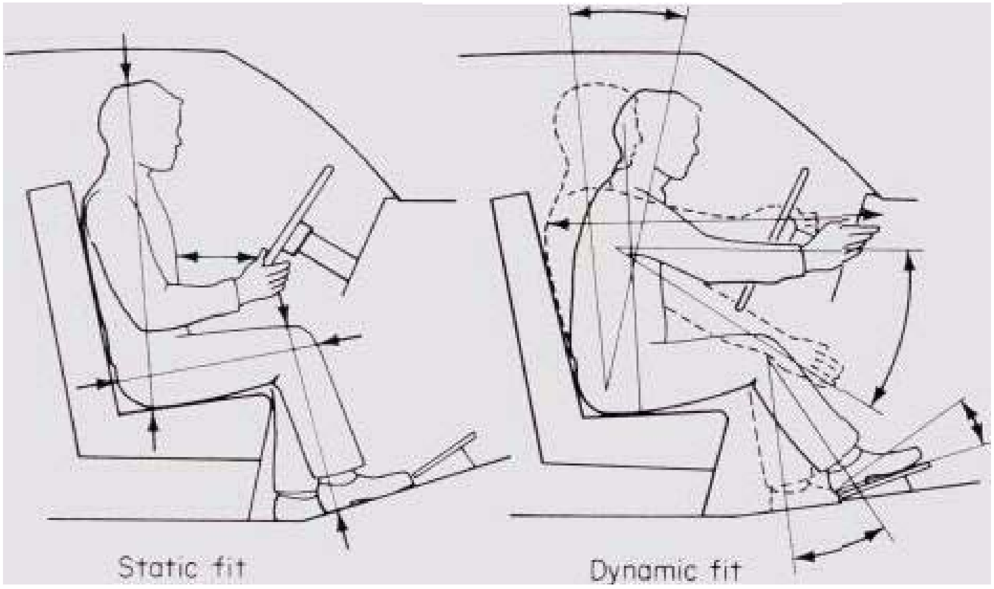


Figure 4.5. Illustration of a static versus dynamic fit in the context of cab design. (Source: Bridger 1995)

Probably a central postulate of dynamic anthropometry relates to the fact that in performing physical functions, the individual body members normally do not operate independently, but rather in concert. The practical limit of arm reach, for example, is not the sole consequence of arm length; it is also affected in part by shoulder movement, partial trunk rotation, possible bending of the back, and the function that is to be performed by the hand. These and other variables make it difficult, or at least very risky, to try to resolve all space and dimension problems on the basis of static anthropometric data (Bridger 1995). An impression of the manner in which the body members interact in performing some function is shown in Figure 4.6, this particular example showing the pattern of body movements involved in the shot put. Pattern of body movements in the shot put, sequence of posture, and a pattern of force application directed toward getting the maximum throw and maintaining body control to stay within the throwing ring.

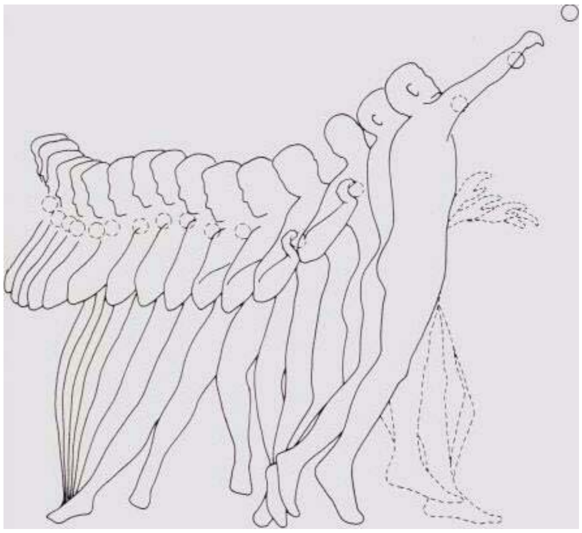


Figure 4.6. Pattern of body movements in the shot put.
(Source: Bridger 1995)

4.4.2.3. Newtonian Anthropometric Data

Such data are used in mechanical analysis of the loads on the human body. The body is regarded as an assemblage of linked segments of known length and mass (sometimes expressed as a percentage of stature and body weight). Ranges of the appropriate angles to be subtended by adjacent links are also given to enable suitable ranges of working postures to be defined. This defining enables designers to specify those regions of the workspace in which displays and controls may be most optimally positioned (Bridger 1995). Newtonian data may be used to compare the loads on the spine from different lifting techniques.

4.4.3. Principles of Applied Anthropometry in Ergonomics

Anthropometric variables in the healthy population are usually considered to follow a normal distribution ; as depicted in (Figure 4.7).

4.4.3.1. The Normal Distribution

For design purposes, two key parameters of the normal distribution are the mean and the standard deviation. The mean is the sum of all the individual measurements divided by the number of measurements. It is a measure of central tendency. The standard deviation is calculated using the difference between each individual measurement and the mean. It is a measure of the degree of dispersion in the normal distribution. Thus, the value of the mean determines the position of the normal distribution along the x-axis (the horizontal axis). The value of the standard deviation determines the shape of the normal distribution. A small value of the standard deviation indicates that most of the measurements are close to the mean value (the distribution has a high peak which tails off rapidly at both sides). A large value of the standard deviation means that the measurements are scattered more distantly from the mean. The distribution has a flatter shape.

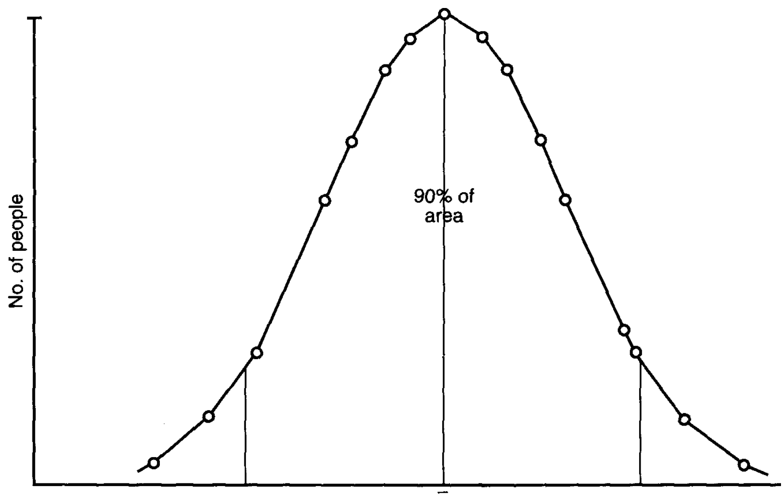


Figure 4.7. The normal distribution.
(Source: Bridger 1995).

Ninety percent of the measurements made on different people will fall in a range whose width is 1.64 standard deviations above and below the mean

In order to estimate the parameters of stature in a population (the mean and stand; deviation), one must measure a large sample of people who are representative of that population (e.g., central African females, male Amazonian Indians, U.S. female bus drivers). The mean and standard deviation can be calculate with the formulas. Estimates of population parameters obtained from calculations on data from samples are known as sample statistics.

The distribution of stature in a population may be used to exemplify the statistical aproach to design. The assumption that stature is normally distributed in the population together with the estimates of the mean and standard deviation, enables stature to characterized in a quantitative manner. An important characteristic of the normal distribution is that it is symmetrical—as many observations lie above the mean as below it in the graphic terms of the figure, as many observations lie to the right of the mean at he left). If a distribution is normally distributed, 50 percent of the scores (and thus individuals from whom the scores were obtained) lie on either side of the mean.

This simple statistical fact applies to very many variables, yet it is often ignored misunderstood by both specialists and laypeople alike. It is common to hear statements such as "your child is below average height for his age" or "you are above average weight for your height" both pronounced and perceived in a negative way. The statistical reality is that half of any normally distributed population is either above or be "average." In itself, this fact has no negative or positive connotations. What *is* important is how *far* or how *different* from the mean a particular observation is. Observations which are different from the mean become rarer as the "distance" increases. The distance of an observation from the mean is usually measured in standard deviations—we can talk about an observation's being a certain number of standard deviations greater or less than the mean.

An important consequence of standard deviations is that it is unwise to design for "Mr. or Ms. Average," a mythical person with the mean stature. As can be seen, very few individuals will be *exactly of* "average" height, and therefore it is necessary to design to accommodate a range of people—preferably those both above and below the mean (Bridger 1995).

4.4.3.2. Estimating the Range

The standard deviation contains information about the spread of scores in a sample. It is known, for a normal distribution, that approximately two-thirds of the observations in the population fall within 1 standard deviation above and below the mean. Thus, for a population with a mean stature of 1.75 meters (m) and standard deviation of 0.10 m, approximately two-thirds of the population would be between 1.65 and 1.85 m tall. The remaining third would lie beyond these two extremes.

Using the standard deviation and the mean, one can calculate estimates of stature below which a specified percentage of the population will fall. Prom the mathematics of the normal distribution, the area under the normal curve at any point along the x-axis can be expressed in terms of the number of standard deviations from the mean. For example, if the standard deviation is multiplied by the constant 1.64 and *subtracted* from the mean, the height below which 5 percent of the population falls is obtained. If 1.64 is *added to* the mean, the height below which 95 percent of the population falls is obtained. These are known as *the* 5th and 95th percentile heights. The 1st and 99th percentile heights are obtained when the constant 2.32 is used.

Using the mean and standard deviation of an anthropometric measurement and a knowledge of the area under the normal curve expressed as standard deviations from the mean, one can estimate ranges of body size which will encompass a greater and greater proportion of individuals in a population. Thus, given the mean and standard deviation of any anthropometric variable, one can compute a range of statures, girths, leg lengths, etc., within which a known percentage of the population will fall (Bridger 1995).

4.4.3.3. Applying Statistics to Design

As per Bridger (1995), statistical information about body size is not, in itself, directly applicable to a design problem. First, the designer has to analyze in what ways (if any) anthropometric mismatches might occur and then decide which anthropometric data might be appropriate to the problem. In other words, the designer has to develop some clear ideas about what constitutes an appropriate match between user and product dimensions. Next, a suitable percentile has to be chosen. In many design applications, mismatches occur only at one extreme (only very tall or very short people are affected, for example) and the solution is to select either a maximum or a minimum dimension. If the design accommodates people at the appropriate extreme of the anthropometric range, less extreme people will be accommodated.

4.4.3.3.1. Minimum Dimensions

A high percentile value of an appropriate anthropometric dimension is chosen. In the de sign of a doorway, for example, sufficient head room for very tall people has to be provided, and the 95th or 99th percentile (male) stature could be used to specify a minimum height. The doorway should be no lower than this minimum value, and additional allowance would have to be made for the increase in stature caused by items of clothing such as the heels of shoes, protective headgear, etc.

Seat breadth is also determined using a minimum dimension—the width of a seat must be no narrower than the largest hip width in the target population (Figure 4.8). Minimum dimensions are used to specify the placement of controls on machines, door handles, etc. Controls must be sufficiently high off the ground so that tall operators can reach them without stooping, i.e., no lower than the 95th percentile standing knuckle height. In the case of door handles, the maximum vertical reach of a small child might also be considered (to prevent young children from opening doors when unsupervised).

Circulation sace must be provided in offices, factories, and storerooms to allow for ingress and egress of personnel and to prevent collisions. In a female or mixed-sex workforce, the body width of a pregnant woman would be used to determine the minimum. About 60 centimeters (cm) of clearance space is needed for passages, the separation of machines, and the distance of furniture from walls or other objects in a room.

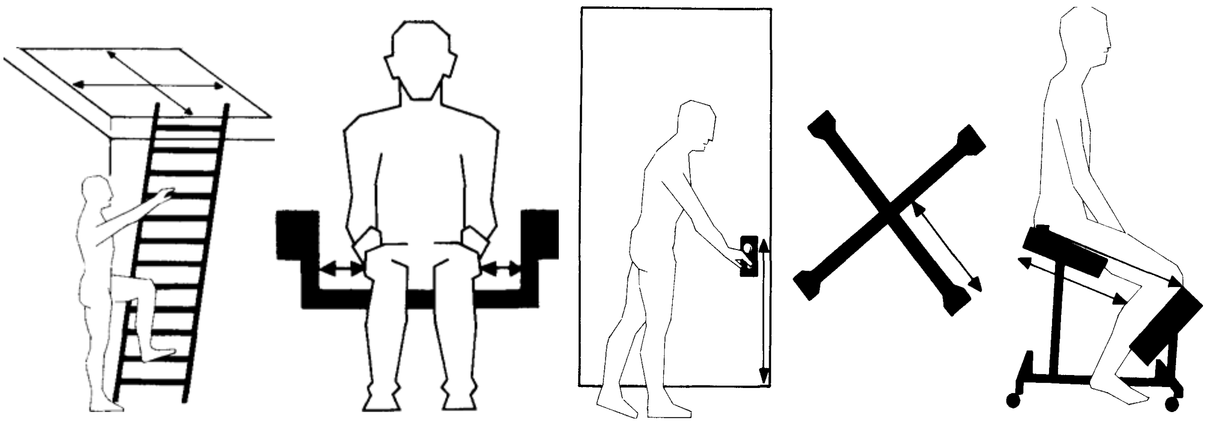


Figure 4.8. Some minimum dimensions.
(Source: Bridger 1995)

The height of a doorway must be no lower than the stature of a tall man (plus an allowance for clothing and shoes). The width of a chair must be no narrower than the hip breadth of a large women. A toothbrush must be long enough to reach the back molars of someone with a deep mouth. An escape hatch must be wider than the shoulder width and body depth of a large person. A door handle must not be lower than the highest standing knuckle height in a population so that all users can open the door without stooping. The distance from the kneepad to the back of the seat of a "kneeling chair" must exceed the longest buttock-knee lengths in the population of users. The length of a wheel brace must provide sufficient leverage for a weak person to generate sufficient torque to loosen the wheel nuts.

4.4.3.3.2. Maximum Dimensions

A low percentile is chosen in determining the maximum height of a door latch so that the smallest adult in a population will be able to reach it. The latch must be no higher than the maximum vertical knuckle reach of a small person. The height of nonadjustable seats used in public transport systems and auditoriums is also determined using this principle—the seat must be low enough so that a short person can rest the feet on the floor when using it. Thus, the seat height must be no higher than the 1st or 5th percentile popliteal height in the population (Figure 4.9). gives examples of some maximum allowable dimensions.

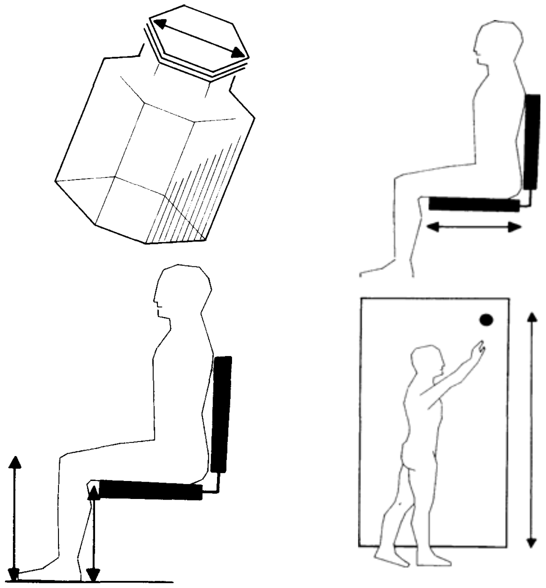


Figure 4.9. Some maximum allowable dimensions.

(Source: Bridger 1995)

A door lock must be no higher than the maximum vertical reach of a small person. Seat heights and depths must not exceed the popliteal height and buttock-knee lengths of small users. Screw-top lids must be wide enough to provide a large contact area with the skin of the hand to provide adequate friction and so that pressure "hot spots" are avoided. However, the lids must not exceed the grip diameter of a small person.

4.4.3.3.3. Cost-Benefit Analysis

Sometimes it is not necessary to use anthropometric data because there may be no cost; incurred in designing to suit everyone (a doorway or entrance is a hole and the bigger it is, the less building materials are used). However, there are often trade-offs between the additional costs of designing to suit a wide range of people and the number of people who will ultimately benefit. As can be seen from the normal distribution, the majority of individuals in a population are clustered around the mean and attempts to accommodate more extreme individuals soon incur diminishing returns since fewer and fewer people are accommodated into the range.

As an example, let us suppose that the minimum height of a car interior has to be specified. Increases in roof height increase wind resistance and construction cost but provide head clearance for tall drivers. Thus, there are both costs and benefits of building cars with plenty of headroom for the occupants. If the mean sitting height for male is 90 cm with a standard deviation of 5 cm, a ceiling height of 91 cm (measured from the seat) will accommodate 50 percent of drivers with 1 cm clearance to allow for clothing or hair (except hats). An increase in ceiling height of 5 cm will accommodate a further 34 percent of drivers so that a total of 84 percent are now catered for. A further increase of 5 cm will accommodate an extra 14 percent of drivers, bringing the total to 9; percent. However, a further increase of 5 cm will accommodate only an extra 2 percent of drivers in the population. Because this 2 percent probably represents a very small number of potential customers, the additional costs of accommodating their anthropometric requirements into the design of every car built become significant. It may be more cost-effective to exclude these individuals in the generic design but retrofit the finished product to accommodate one or two extremely tall buyers (for example, by making it possible to lower the seat slightly).

This example should illustrate why the 5th and 95th percentiles of anthropometric variables are often used to determine the dimensions of products. Ninety percent of potential users are accommodated using this approach and further sizable alterations will accommodate only a small number of additional users—the point of diminishing returns has been reached.

Anthropometric data must always be used in a cautious manner and with a sound apreciation of the design requirements and the practical considerations. In particular, the designer should try to predict the consequences of a mismatch—how serious they would be and who would be affected. The height of the handle of a door leading to a fire escape in an apartment building dramatizes the seriousness of such mismatches: It is essential that a very wide range of users—including children—be able to reach and operate the handle in an emergency. The design of passenger seats for urban transportation systems is also important—although somewhat more mundane. Because the seats are used regularly by a very wide range of users, even small imperfections will affect the comfort of a very large number of people every day. In the use of anthropometric data, the selection of a suitable cutoff point depends on the consequences of an anthropometric mismatch and the cost of designing for a wide range of people. One of the ergonomist's most important tasks is to predict and evaluate what any mismatches are going to be like. It is not normally sufficient only to specify the required dimensions without considering other aspects such as usability and misuse (Bridger 1995).

4.4.4. Applications of Anthropometry in Design

In bellow gives examples of some common anthropometric variables and how they are used in ergonomics.

- *Standing eye height:* Height above the ground of the eye of a person standing erect. Can be used as a maximum allowable dimension to locate visual displays for standing operators. The displays should not be higher than the standing eye height of a short operator so that short operators do not need to extend the neck to look at displays.

- *Standing shoulder height:* Height of the acromion above the ground. Used to estimate the height of the center of rotation of the arm above the ground and can help specify the maximum allowable height for controls so that short workers need not elevate the arms above shoulder height to operate a control.
- *Standing elbow height:* Height above the ground of the elbows of a person standing erect. Used to design the maximum allowable bench height for standing workers.
- *Standing knuckle height:* Height of the knuckles above the ground. Used to determine the minimum height of full grip for a standing operator. Operators with high standing knuckle heights should not have to stoop when grasping objects in the workplace.
- *Standing fingertip height:* Height of the tips of the fingers above the ground. Used, as above, to determine the lowest allowable position for controls such as switches.
- *Sitting height:* Distance from the seat to the crown of the head. Can be used to determine ceiling heights in vehicles to provide clearance for users with tall sitting heights.
- *Sitting elbow height:* Height of the elbows of a seated person above the chair. Used to determine armrest heights and work surface heights for seated operators.
- *Popliteal height:* Height of the popliteal fossa (back of the knee) above the ground. The 5th percentile popliteal height may be used to determine the maximum allowable height of nonadjustable seats. The 95th percentile popliteal height may be used to set the highest level of adjustment of height-adjustable seats.
- *Knee height and thigh depth:* Taken together, these variables specify the height above the floor of the upper thigh of a seated person. Can be used to determine the thigh clearance required under a table.

- *Buttock-popliteal length:* Distance from the buttocks to the back of the knee. Used the determine the maximum allowable seat depth so that seat depth does not exceed the buttock-popliteal length of the short users.
- *Shoulder width:* Widest distance across the shoulders. Used to determine the minimum width of narrow doorways, corridors, etc. to provide clearance for those with wide shoulders.
- *Hip breadth:* Widest distance across the hips. Used to determine the space requirements necesesary for clearance and, for example, the minimum width of seats to allow clearance for those with wide hips.
- *Abdominal/chest depth:* Widest distance from a wall behind the person to the chest/abdomen in front. Used to determine the minimum clearance required in confined spaces.
- *Vertical reach (sitting and standing):* Highest vertical reach. Used to determine maximum allowable height for overhead controls so that they are reachable by the shortest users.
- *Grip circumference:* Internal circumference of grip from the root of the fingers across the tip and to the palm when the person is grasping an object. Used to specify the maximum circumference of tool handles and other objects to be held in the palm of the hand. Handle circumferences should enable those with small hands to grasp the tool with slight overlap of the thumb and fingers.
- *Reach:* The dimensions of the reach envelope around an operator can be used to locate controls so that seated operators can operate them without having to lean forward away from the backrest or twisting the trunk and standing operators can operate them without forward, backward, or sideways inclination of the trunk. Arm movements should be kept in the normal work area to eliminate reach over 40 cm for repeated actions. These data are applicable to the design of all vehicle cockpits and cabs.

4.4.5. Designing for Everyone

According to Bridger (1995), the problem of designing to suit a range of users can be approached in several different ways.

4.4.5.1. Make Different Sizes

In clothing and school furniture design, a common solution is to design the same product in several different sizes. Anthropometric data can be used to determine a minimum number of different sizes (and the dimensions of each size) which will accommodate all users. Mass production or long production runs often bring economies of scale in product design through reduced retooling and stoppages. Mass production usually has economic benefits and demonstrates why it is important to determine the minimum number of sizes in a product range which will accommodate most of the users in the population in question.

4.4.5.2. Design Adjustable Products

An alternative approach to product design is to manufacture products whose critical dimensions for use can be adjusted by the users themselves. A first step is to determine what the critical dimensions for use are. The next step is to design the mechanism of adjustability with the emphasis on ease of operation. Finally, some instructions or a training program may be necessary to explain to users the need to adjust the product and how to adjust it correctly.

In seated work, for example, the height of the seat and desk are critical dimensions for seated comfort. The seat height should be no higher than the popliteal height of the user so that both feet can be rested firmly on the floor to support the weight of the lower legs (otherwise the soft tissues on the underside of the thigh take the weight and blood circulation is impeded as a result of compression of these tissues). Secondly, the desk height (or middle row of keys on a keyboard) should coincide with the user's sitting elbow height. Since popliteal height and elbow height do not correlate strongly in practice, adjustable seat and desk heights are needed.

Anthropometric data provide the designer with quantitative guidelines for dimensining workspaces. However, a number of precautions are needed if data are to be used correctly:

1) Define the user population and use data obtained from measurements made on that population.

2) Consider factors that might interfere with the assumption of normal distribution of scores. For example, in some countries, stature may be negatively skewed because many individuals do not attain their potential stature because of disease or malnutrition.

3) Remember that many anthropometric variables are measured using seminude subjects. Allowance for clothing is often necessary when designing for real users. Centimeter accuracy is usually appropriate because the effect of clothing on the estimates ofuser anthropometry can never be accurately predicted. These considerations are particularly important when using data on stature and leg length—allowances for heel heights of 5 cm or more may be needed, depending on the user population and current fashions of dress. The effect of clothing also depends on climate—the colder the climate, the more bulky the clothing and the greater the importance of allowing for this factor in design.

In practical design situations, the data required for a particular body dimension or population may not be available. However, techniques are available for estimating unknown dimensions and the literature on anthropometry can still be of use to the designer in drawing attention to the various body dimensions which need to be considered in the design and the types of human-machine mismatches which could occur. Anthropometry can provide the designer with a very useful perspective on usability issues at the very early stages of the design process. Later, the designer might then take a more empirical approach and test out prototypes using a small sample of users from the extremes of the anthropometric range.

CHAPTER 5

DESIGN CONCEPT

The occupational physical factors of postural stress, muscular effort and long term exposure to whole-body vibration were consistently associated with driving motor vehicles for extended periods of time. The prevention of musculoskeletal disorders is achieved by interventions which reduce the probability and severity of injuries. The primary interest in the driver's environment is the relationship between the driver's seat, steering column and wheel.

The design of the driver's environment must not just take into consideration the tasks performed by the driver. The design must also consider the physical characteristics of the driver and the accommodations required that permit the full range of seat adjustments. Although the functional design relationships are significantly useful in the driver environment, little work has been done in this area.

The general objectives of the design methodology are to develop a work station which will accomodate the population extremes with minimum mechanical adjustment. Other objectives include: visibility, reach, comfort, and adjustability.

The driver environment is the area in which the driver directly controls the operation of the car and interacts with interior of automobile and other pasengers. To understand the casual factors of musculoskeletal injury and discomfort to the driver, the relationship between the driver's seat, steering column and wheel, and pedals in the workstation must be understood. It is the use and relationship of the seat, steering wheel, and pedals that influence the driver's posture. Information from anthropometric data and about human biomechanical capabilities ensures functionality in terms of safety, performance, and ease of use.

5.1. General Safety Requirements

A vehicle must be designed cunstructed using materials and components that are fit for their purpose; and be safe to be operated on the road. The condition of interior fittings, controls, and surfaces in the passenger compartents of a motor vehicle must be mantained so that the likelihood of injury to occupants is minimized (WEB_15 2005).

5.2. Zones of the Car Interior

Interior of a car is systematically arranged into three cell zone (WEB_15 2005);

I. A-Zone Areas: The A-Zone of a vechile occupant cell is the area inside

- an arc swung in a forward direction from the h-point using either body frame, or H-point template as shown in Figure 5.1 with the seat in its mid point position if adjustable, from the seatback in normal driving position to the seat base of:
    - where web-clamp retractor lap and diagonal or four-point harness seatbelts are fitted, a 700 mm radius (Figure 5.3)or,
    - where seatbelts of types otherthan those are fitted, a 900 mm radius (Figure 5.3); and

Distance '1' is for relatively firm seat cushions which compress very little with occupant weight.

Distance '2' is for relatively soft seat cushions which compress by 20 mm or more with occupant weight

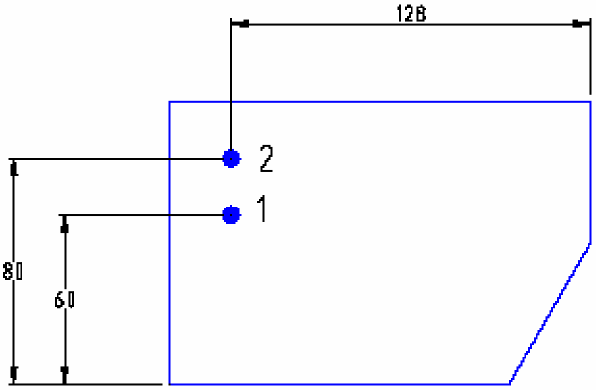


Figure 5.1. H-point template
(Source: WEB_15 2005)

Drivers' eye positions are the subject of a standard of considerable ingenuity which describes the construction and use of ‘eyellipses'.These are elliptical contours in side elevation and plan which are not direct representations ot the bivariate normal distribution of eye position although they are mathematically derived from it. Hence, the 95%ile eyellipse does not include 95% of eye positions. Rather, it has the property that any line drawn tangent to its upper edge will have 95% of eye locations below it and 5% above it (and vice versa for the lower edge). In their standard form the eyellipses can only be employed in conjunction with the H-point devices—however, once this difficulty is overcome there is no reason why they should not have extensive application in fields other than automotive design.

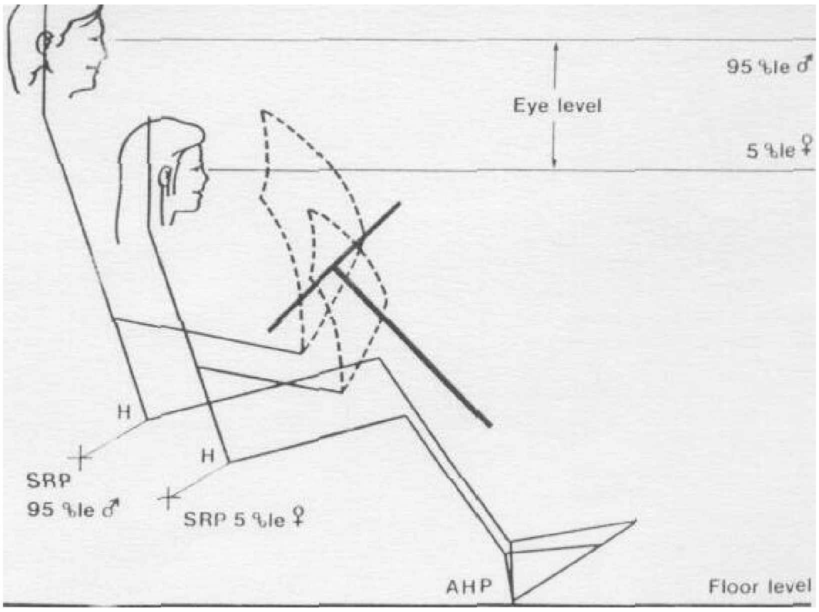


Figure 5.2. Layout of the driver’s workstation using linkage anthropometry.
(Source: McCormick 1970)

If extreme members of the population are to adopt the same 'ideal' posture of the lower limb, the seat must have vertical adjustment as well as horizontal (or else adjust along an oblique track). However, if vertical adjustment is used in the manner shown, it will have the effect of increasing the disparity of eye levels. The eyes should ideally the around halfway up tlie windscreen—giving approximately equal views of road and sky. Alternatively, vertical adjustment may be used to equalise eye levels at the cost of deviating from the 'ideal lower limb posture' (McCormick 1970).

- 160 mm on either side of the longitudinal centerline of each seating position (Figure 5.3); and

- excludes any C-Zone areas which overlap the A-Zone (Figure 5.3).

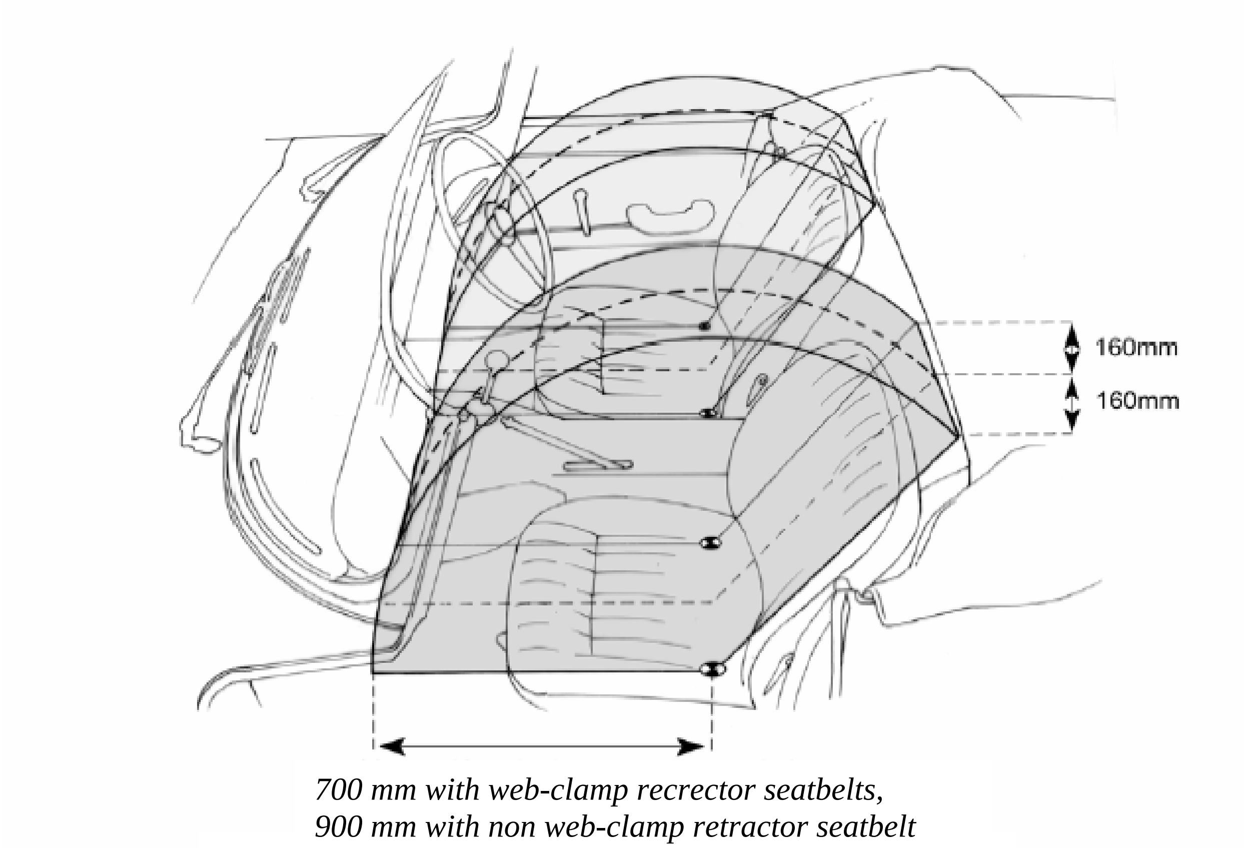


Figure 5.3. Occupant cell A-Zone area.

(Source: WEB 15 2005)

The driver's seat is in the A-Zone. Driver' s seat should have the following minimum seat adjustments and ranges;

- ✓ Seat Height Adjustment: The seat should be adjustable; flat seat cushion at the front edge. Air or an air driven motor should drive the height adjustment.
- ✓ Suspension Dampening: The seat should be equipped with a variable dampening shock absorber to allow the driver to adjust the ride from soft to very hard (lockout).
- ✓ Fore/Aft Adjustment: The use of an air slide release or similar system facilitates the movement of the seat, providing an infinite number of adjustments.

- ✓ Seat Pan Angle/Ranke: The seat should mechanically adjust 17º, ideally from –5º to + 12º. The adjustment mechanism must engage on both sides to prevent unwanted movement of the seat pan.
- ✓ Seat Pan Length: As measured from the front of the seat cushion to the backrest at the intersection of the seat cushion, the seat pan should adjust as one unit, leaving no gaps between sections of the seat pan, in order to fully support the thigth.
- ✓ Backrest Recline: The backrest should adjust backward to 35º from vertical to permit the user to lean against the backrest. The backrest adjustment should be independent from the seat pan adjustment.
- ✓ Lumbar Support: The seat should be equipped with air chamber lumbar support system to permit varying degrees of firmness and adjustment. The lumbar support should be large enough to accommodate a wide range of users.
- ✓ Headrest Up/Down Adjustment: The headrest should adjust a minimum of 2 inches to up and down from the top of the seat backrest in order to full support the head of the user.
- ✓ Headrest Forward/Backward Adjustment: The headrest should adjust a minimum of 40º forwards from the vertical. An additional consideration is the covering of the driver' s seat. To maximize driver comfort, a woven fabric covering should be used.
- ✓ Although more durable, vinyl coverings should be avoided.

II. B-Zone Areas: The B-Zone of a vechile occupant cell is the remaining area within the occupant cell surrounding the A-Zone specified in Figure 5.3, but does not include the C-Zone of a vechie occupant cell specified in (Figure 5.4, 5.5, 5.6)

III. C-Zone Areas: The C-Zone of a vechile occupant cell is:

- the area:
    - below the horizontal plane measured at the lowest point of the front seat cushion (Figure 5.4); and

- behind, and back of the backrest on the rearmost seat (Figure 5.4);

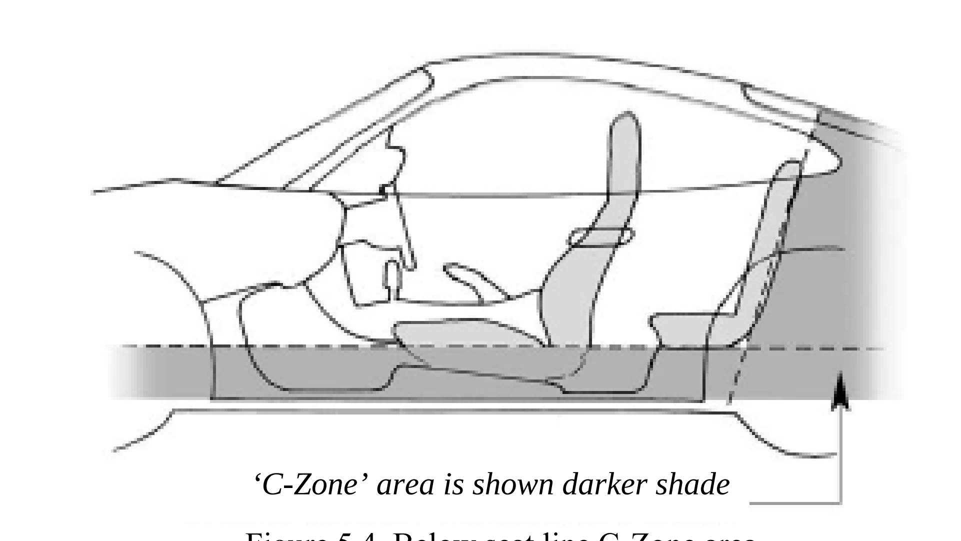
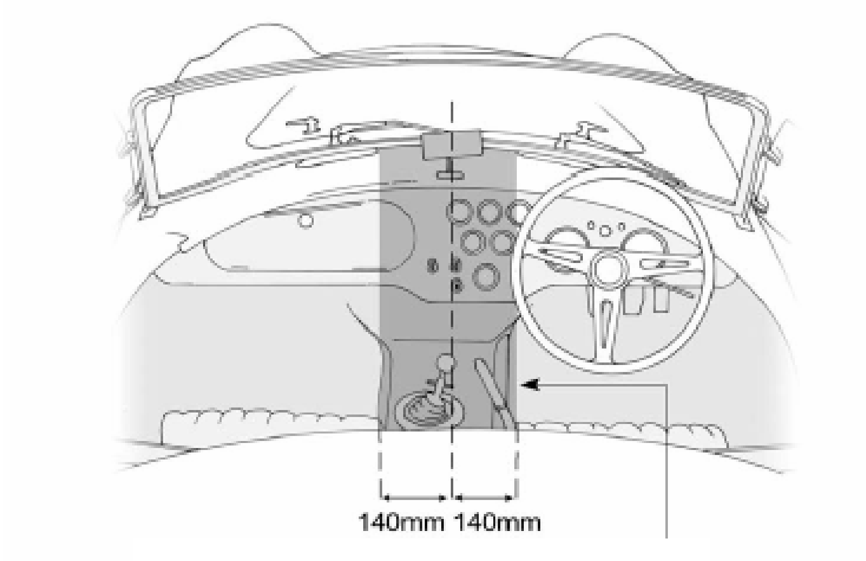


Figure 5.4. Below seat line C-Zone area.

(Source: WEB 15 2005)

- provided that no front center seating position exist, the width of the dashboard and center console surface area, which may not exceed 140 mm on either side of the longitudinal centerline of the vechile (Figure 5.5)

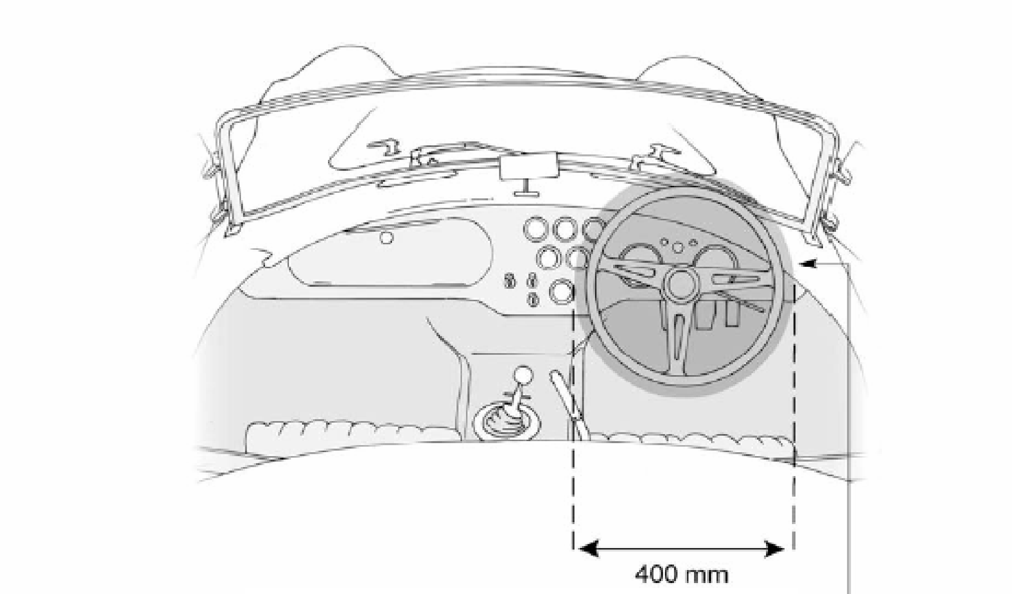


‘C-Zone’ area is shown darker shading

Figure 5.5. Dashboard and center console C-Zone area.

(Source: WEB 15 2005)

- the area forward of the steering wheel or control, defined as a forward horizontal projection of an area 400 mm across, circumscribing the upper-most end of the steering column, provided that no fittings, controls, or surfaces are positioned closer than 100 mm from the dashboard surface to the steering wheel (Figure 4.6)



'C-Zone' area is shown darker shading

Figure 5.6. Steering control C-Zone area.
(Source: WEB_15 2005)

There is a degree of overlap between the hand zones of the 95th %ile man and the 5th %ile woman. A 360 mm steering wheel set at 45° has been drawn centred on this region. In this position it only just provides abdominal and knee clearance as described above. Hence, there is a strong argument for the adjustable steering columns which some manufacturers provide. Furthermore, a 360 mm diameter is at the lower limits ot acceptability and 400-450 mill would probably he better, giving additional torque to the weaker driver. A more vertical wheel might be more easily accommodated. The maximum force (torque) was exerted on a horizontal wheel, although paradoxically the speed ot rotation was maximal when the wheel was vertical. Recommended that the axis of the wheel (i.e., the steering column) should be 50—60° to the horizontal, in which position 70% of the maximum force can be exerted. At present there is a trend towards smaller and more vertical steering wheels, which are associated with a more 'sporty' image (McCormick 1970).

- any part of the dashboard and instrument panel between the edge of the steering column and wheel, and the nearest inner pillar or sidewall area (Figure 5.7)

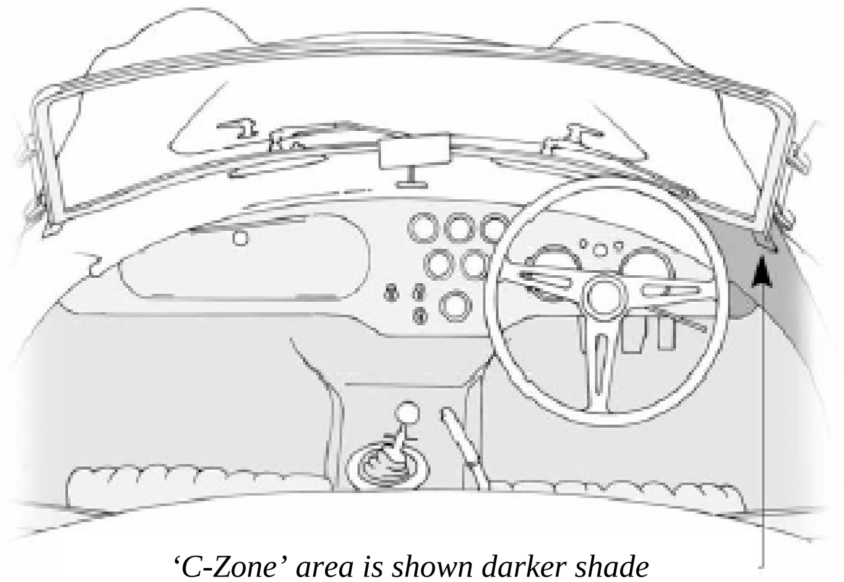


Figure 5.7. Steering control nearest to pillar or sidewall C-Zone area.
(Source: WEB_15 2005)

Steering whell is in the C-Zone.The steering wheel control was designed regarding its orientation, size, and adjustment mechanism. In order for the steering wheel to accomodate all of the positions and orientations required to provide sufficient visibility and comfortable reach for the small or large drivers, the wheel must have three degrees of freedom: a hub orientation adjustment, a column telescope adjustment, and a column tilt adjustment at the base of the steering column. Since existing steering wheel system provides two degrees of freedom such as the hub tilt and the telescope, only a column tilt adjustment was added to the wheel assembly. Finger grips should be provided where heavy loads are involved. For vehicles, prefer of 178-533 mm, with three spokes providing an open view of displays or traffic.

5.3. Design Criteria

The instrument panels containing displays and controls were investigated designing the adjustment range, panel layout, size, and locations. All instruments panels are adjustable to accomodate the population extremes in visibility and comfortable reach. The displays and controls are grouped according to their functional characteristics and systematically arranged into three areas; the left, central and right instrument panels.

The functional purpose of the left instrument panel is to provide easy acces for all driver to the secondary controls or controls that are used during the predriving tasks. These controls are the parking brake, the exterior mirror remote adjustment knobs, the exterior mirror defrost control, the radio controls, the run selector knob, the transmision and the ignition swich. The size of the left instrument panel is determined by the space required for the controls and the instrument panel is located in the side and plan views based upon comfortable reach of the left arms.

The central instrument panel is intended to provide the driver with operating status of the car. Any information that does not require continuous monitoring by a particular gauge is replaced with an indicator light. The right instrument panel will contain a keypad with a small display called an driver digital assistant. The functions that can be accomplished through the digital assistance include: present the road routeschedule, monitor the gas mileage, possibly link with a global positioning system (GPS) for real time location of the car, audio and climate monitor. The dimentions of the right instrument panel are based on the controls tha it will contain. Also, comfortable reach of the right arms are considered in the determination of the right instrument panel location.

5.3.1. Dashboard Surfaces

Upper and lower surfaces of dashboard fascias, shelves, and trays fitted within the B-Zone of a vehicle occupant cell, must be designed and constructed so that any surfaces that face the occupants (WEB_15 2005):

- have all comes and edges with a radius of no less 5 mm,
- either; absorb impact energy by collapsing, deforming, or displacing in the event of an impact, leaving no sharp projections in doing so; or are covered in an energy-absorbing material of no less than 10 mm thicness, protected by a rigid surface positioned beneath of the energy-absorbing material to prevent the penetration of sharp objects through the energy-absorbing material in to the occupant cell.

Any solid structure (dashboard supporting structure) supporting any deformable upper or lower surfaces of dashboard fascias, shelves, and trays within the A-Zone of a vheicle occupant cell, must

- if directly exposed to the occupant cell, have any sections of the structure that face the occupants:
  - provided with a radius on all corners and edges of no less than 10 mm;
  - be covered in an energy-absorbing material of no less than 10 mm thicness, protected by a rigid surface positioned forward of the energy-absorbing material to prevent the penetration of sharp objects through the energy-absorbing material into the occupant cell;
- if not directly exposed to the occupant cell, but positioned within 50 mm beneath any surface that is exposed to the occupant cell and faces the occupants, either:
  - the structure must have all corners and edges facing the occupant cell with a radius of no less than 10 mm, or
  - the surface of the structure facing the occupant cell must be covered by an energy-absorbing material of no less than 10 mm thickness; or
  - the surface above the structure must be covered in an energy-absorbing material of no less than 10 mm tickness, protected by a rigid surface positioned forward of the energy-absorbing material to prevent the penetration of sharp objects through the energy-absorbing material into the occupant cell;

5.3.2. Switches, Knobs, and Instruments

Dashboard and steering column switches, knobs, instruments, accessory equipment, and other fittings and controls fitted to vehicle which protrude from the dashboard surface by (WEB_15 2005):

- between 5 mm and 10 mm from the panel surface, must have a face area of no less than approximately 2 cm^2; or

- 10 mm or further from the panel surface, must have a face area of no less than approximately 6 cm^2.

All dashboard and steering column switches, knobs, instruments, accessory equipment, and other fittings and controls fitted to vehicle must be attrached in such a way as to remain secure during normal vehicle operation, and either:

- have all contactable edges and corners with a radius of no less than 3 mm; or
- be designed so that in the event of an impact the items will collapse through the panel surface, or break off or bend leaving no sharp edges or protrusions facing towards the occupant cell in doing so.

5.3.2.1. Manuel Controls

- Grip Designs: Hand grips should conform to use and hand motion, and all handles should feel comfortable; use rounded shapes and cylindrical grips. Thin handles cut under heavy loading. Gripping handles that are too large feels insecure. A diameter of 22-32 mm is the optimal range (Tilley 2001). The ball or smilar frips are used for heavy and light loading.
- Push Buttons: Push buttons are avaible in great variety of types. Buttons should give the operator positive feedback to show activation of the control. This can be provided by incorporating a sensory or audible click when the motion is carried out. Push-on-push-off types are not as good, because they cancel out the excepted movements for “on”.
- Rocker, Toggle, and Slide Switches: Rocker switches carry important messages on the front face, in addition to titles that must appear on the panel face. Rocker switches must be oriented the same way as the toggle switch: “off” is always down or to the left. The simplest toggle switches are accurate if they follow this rule. If tripple-possition switches are used, their position may not be immediately apperent. Toggles today take many forms; some have a flip cover, and so on. Slide switches must have the “off” down or to the left. Their position is difficult to determine if the slot is long.

- Thumbwheels: Thumbwheels, which are difficult to read, must also be “off” when down or to the left. they are convenient and widely used on small audio receivers and players.

5.3.2.2. Displays

The preferable reach is that of the small woman sitting, with a radius about the shoulder pivot of 67.2 mm and dropping until it touches the deck of console. This includes a 76 mm shuolder movement. With an additional 152 mm bend to trunk, she can reach the 610 mm panel (Tilley 2001). The best location for a display is an a 30^{o} cone 15^{o} up and down from the relaxed sight line. This allows a perfect visual circle with a diamater of 280 mm on any of the four consoles. This is the area for the most important displays, with or without manual corrections, and for a monitor.

- Circular Analog and Digital Displays: Prefer circular dials, semi-circular dials, check dials, and zone-coded dials. Counter, mechanical, and digital dials are useful, as are dot-matrix and segment-matrix readouts and graphic displays. Avoid ornate pionters. Make the pionter width as required and taper the end of it to match the minor index width. The colors of the pionter and the indices should match, especially if the pionter is to be flush with the indices.

- Circular Analog and Graphic Displays: Prefer a dial diameter of 57-102 mm, or for high accuracy, prefer 102-152 mm. Start 0 to the left of the bottom of the dial and always count clockwise; putting 0 at 12 o’clock is also acceptable. Numbers are usually outside the indices; very small dials, check dials, and zone-coded dials required the numbers inside.

  Graphic displays using LEDs and LCDs are easy to read and can convery much information in small space.

  - Markings: All numbers should read vertically. Use simple sans-serif numbers and letters. Avoid fancy pionters, trade names, and logos. Keep pionters simple. Note the optimum proportions for a clearly recognizable directinonal arrow.

- Pionters: Pionter width are specified for different dials as follows:

  0,8 – 2 mm dials.

  1,6 – 76 mm dials.

  2,4 – 101,6 mm dials.

- Pictorial Indicators: Pictures can greatly assist in the interpretation of special relationships and also for components. Symbols must conform directionally with tha object or components they represent.

- Signal and Warning Lights: Lighted displays can be omni directional. They can be simple indicators on a panel, with flashing indicators to signal an abnormal condition. Meters can have signal lights to emphasize that safe limits are being exceeded, and so on. Multi-projection indicators can show pictures, flow charts, numerical readouts, or verbal data. Master warning lights should be used if signals are extensive or beyond normal viewing.

  Annunciator panels give visual commands. An annunciator panel displaying a matrix of simple indicators in the optimum viewing area can replace signals on many scattered devices. Back-lighted panels with color coding are the best way of presenting pictorial displays.

  Do not overuse lighted displays, and if possible, keep them within the 30^{o} cone, preferably in the15^{o} downward view. Keep colors to a minimum. The following guide to signal light colors has been developed for color-deficient observers:

  White is a general status indicator.

  Red denotes situation critical; malfunctioning.

  Green denotes safe, nominal, or go-ahead conditions.

  Amber or Yellow denotes a need for caution.

  Consider providing two brightness, one for daylight and one for nighttime use. A matte black panel can improve the effectiveness of signals. Isolate the most critical signals from the others. Indicator lihgts need not be large to be effective; proper choice of color and intensity are the important factors.

Flashing lights are more effective in attracting attention but are more disturbing to the observer. The reccomended flash rate is 4 flashes per second with approximately equal timi for light and dark durations.

- Electronic Displays: In general, the viewing distance should be 305-460 mm. For more individual use, 180-360 mm is a suitable distance. For two or more observers, prefer 610-760 mm. The display screen should be perpendicular to the normal sight line, or no greater than 30^o off axis.

  The minimum signal size is 1 minute of visual angle. The minimum duration is 0,2 seconds. Signal brightness and contrast with the backround should be as great as possible. Contrast usually exceeds 1 mL. Ambient illumination should not reflect from the face of the panel or dizplay screen. Use hood or filters, if necessary.

5.3.2.3. Handbrake Levers and Gear Levers

A gear lever or handbrake lever fitted to a vehicle, whilst in the fully released position, must (WEB_15 2005):

- be designed and constructed so as to minimize the risk of injury tooccupants in the event of contract; and
- not have associated linkages, flanges, mounting brackets, or shafts, protruding in such a way as to increase the risk of injury to occupants in the event of contact.

5.4. Understanding Consumers

To understand the consumers, we should answer the following questions:

- How do consumers assess product appeal?

- Different consumer groups, same vehicle platform?

For the product appeal; through buying decisions once emphasized quality (defined as minimizing the number of defects in car), consumers are now focusing more on maxzimizing the appeal...wheather the car fun to drive, well design or stylish. Consumers often discount or disbelieve factual information... they cope by using (sensory) signals.

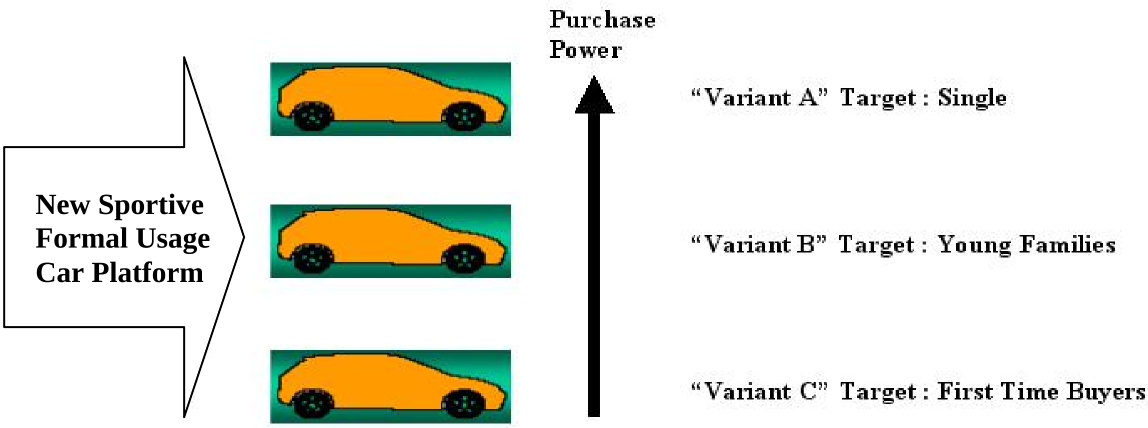


Figure 5.8. Target a sportive formal usage car platform.
(Source: WEB_16 2005)

For the consumer groups; leasing allows a young people to access new cars. They generally choise sport or sportive formal usage car. Nowadays, there is gernarally at least a sport version of the cars in the bazaar. Some example can be seen in (Figure 5.9, 5.10);

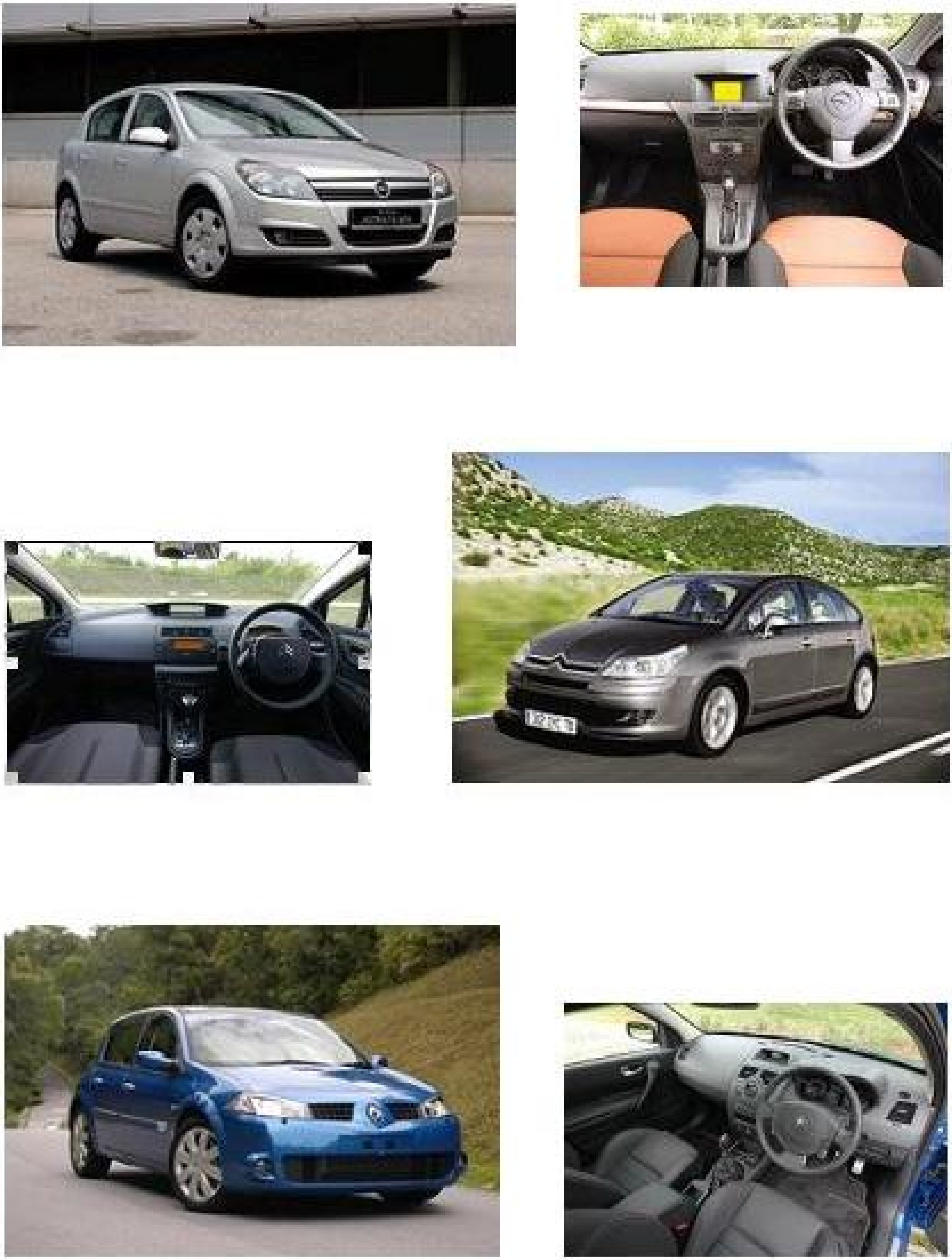


Figure 5.9. Some example of sportive formal usage car.
(Source: WEB_17 2005)

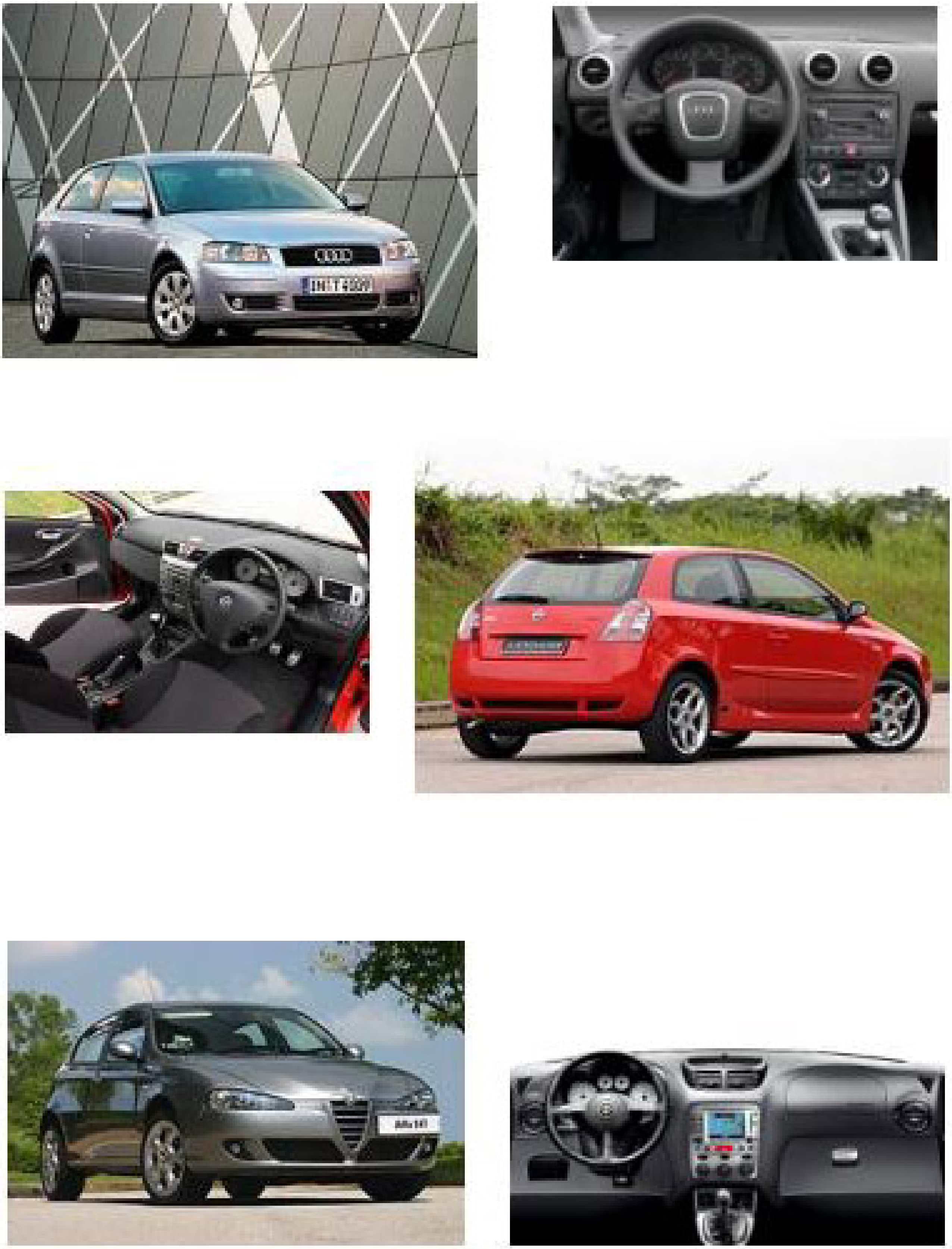


Figure 5.10. Some example of sportive formal usage car.
(Source: WEB_17 2005)

5.5. Trends

Design must provide 'value' if customers are to want them;

- Value makes you turn the system on or 'press the button'
- You want to use it again and again
- It becomes an integral part of your life
- It helps create a willingness to pay

A system that adds value to a driver makes a difference to them in the real world.

5.5.1. Today's Trends

- Control of functions by driver/passenger
- Display information or entertainment (Displays / LCD screens)
- Air flow to driver/passengers and windows (Automatic Air Conditioning)
- Reduction of interior noise
- Thermal and dimension stability
- Ageing, warranty more than 10 years
- Additional Switches for more and more functions (e.g. audio controls from steering wheel)
- Storage
- Cup holder
- Service interval indicator
- Safety (e.g. airbags)
- Smart Card/Key
- Immobiliser

- Navigaiton / GPS System
- Luxury Trim / Alloy Look
- Fixed Hub Steering
- Adjustable steering column
- Park distance Control
- Easytronic auto transmission
- Multi-function steering Wheel with cruise control
- Interior and exterior mirrors with automatic anti-dazzle function

5.5.2. Future Ternds

- Head up Display: An optional feature of exceptional intelligence, the Head-Up Display enables drivers to read information about their current driving situation without even taking their eyes from the road. A projection unit in the dashboard creates an image containing this data and projects it onto the windscreen: drivers see this image at a point that appears to be just above the bonnet some two metres in front of the them. This means that information can be read faster, and drivers' attention is never distracted from the road ahead of them.
- Idrive: The revolutionary concept embodied by iDrive enables drivers to access the extensive driving and comfort functions of the automobile intuitively and quickly. Menu information is displayed on the high-resolution Control Display, ideally located directly in the driver's line of sight (Head up Diplay). Frequently used functions such as the indicators, wipers or temperature settings can be accessed using the familiar levers and buttons ergonomically located in the cockpit.

- Active Steering Wheel: The active steering wheel, for example, provides information for the comfort and safety-oriented Heading Control, seeking to support the driver in remaining on track. An electric motor in the steering wheel builds up steering forces in the direction the driver is supposed to follow. These forces are however intentionally not strong enough to automatically turn the steering, nor will the steering wheel build up excessive resistance to the driver's commands. Accordingly, the driver can easily override the system in order to avoid an obstacle on the road or safely overtake another vehicle, meaning that the driver always remains in control. A further point is that the system is only active when the driver has his hands on the steering wheel, thus being able to intervene immediately should he briefly "doze off".
- Active Gas Pedal: The active or "feel-oriented" gas pedal follows the same principle as the active steering wheel, applying a force against the driver's foot whenever the car is moving too fast in a given situation. Such advice to reduce speed may be provided, say, by the navigation system when entering a bend or a built-up area. Critical road conditions such as wet and snowbound surfaces detected by sensors or vehicles ahead moving at a lower speed may also trigger this assistance function. And like the active steering wheel, the active gas pedal will naturally "give in" to the driver's commands whenever necessary, allowing the driver to override the function for example when overtaking another vehicle.
- Dynamic Speedometer: The dynamic speedometer is created by using a visualization similar to that of the tachometer – visually distinguishing the regions of the speedometer which are higher than the current speed limit. As the speed limit changes, the visualization on the display updates accordingly. This relieves the driver of the task of waiting/searching for a speed limit sign on the

road to determine the current speed limit in effect. The dynamic speedometer can be instrumented to provide visual cues such as making the speedometer needle glow, changing the color / luminosity of the over-the-speed limit region of the speedometer, or changing the background of the dial itself when the driver exceeds a certain threshold over the speed limit (WEB_18 2005).

CHAPTER 6

CONCLUSION

This study describes the role of user-centered design criteria for design phase and the role of ergonomic and human factors for automobile dashboard design; and also describes and discusses the approach, development aspects, and evaluation phases of a new generation dashboard and interior design.

The primary interest in the driver's environment is the relationship between the driver's seat, steering column and wheel, dashboard-instrument panel design and location. Drivers are required to interact and maintain constant contact with each of these components. It is the use and combination of these components that influence the driver's posture. There are different relationships between driver and automobile's interior:

- Hand and foot interactions: gas, break, turn signals and steering wheel,
- Real time interactions: obviously the car is moving everything needs to happen real time,
- Multiple system integration: mechanical systems, climate control, entertainment system, navigation systems, safety systems and communication systems, multiple displays, gauges and outputs all competing for visual attention,
- Alerts, notifications and distractions both on the screen and on the road.

Some manufacturers make these relationships and the interface more complicated than they need to be. In this interface, complexity introduces danger. But with a well experimented, thought out, and fine-tuned interface, pretty much anyone from the general public can control a contraption far more complicated than they will ever understand. While designing the dashboard, simplicity was being taken into consideration.

The major finding of this paper is that, there is an increasing importance of 'user' in the source of design activity and innovation; there is an obvious increase in the importance given to ‘user needs’ as an essential base for demand factors. The emphasis on ‘need’ or ‘user need’ has started with using market data such as sales figures, marketing feedback, etc. Recently, design methods are also challenged by new methodological approaches those require users to be a part of the creative product design and development process, such as collaborative methods, etc. Consequently, as one of the major findings of this research, user needs and expectations can be highlighted as the most significant source for design innovation. Along with the importance given to technological development, there has been a growing emphasis on new ways, methods, and approaches to understand user needs and expectations as an output for the innovation process. On the other hand, in the case for design innovation, user needs and expectations is the main source of innovation.

In conclusion, the emerging changes in the design discipline bring about a convergence between the practice of design and human-centered practices, therefore lead to the emergence of a new design mindset, which focuses on understanding user experience, collaborating with users and fostering innovation by user creativity. The central premise of user-centred design is that the best-designed products and services result from understanding the needs of the people who will use them. New methods challenge not only the tools and techniques used by design discipline, but also the role of both users and design and design research practitioners. They also revolutionize the organizational aspects of the innovative activity to proceed relying more on research and collaboration. A user-centred approach can generate new insights in all design projects but it is particularly useful when a new product or service is to be introduced or where a step-change in an existing product or service is required. Awareness of the experience of end-users can lead designers to question established practices and assumptions - and it can yield innovation that delivers real user benefit. User focus in design increases competitiveness, leading to the development of products and services that people:

- genuinely need and value
- find intuitive and easy to use.

Further study is necessary to determine the effectiveness of the redesigned dashboard in controlling the frequency and severity of musculoskeletal disorders due to the design of the occupant’s cell. This project used an alternate approach to the way an automobile’s dashboard is designed. The dashboard was designed for a sportive formal usage car taking into consideration simplicity, ergonomic, trends (user needs), interactive functions, functional and general safety requirements and specific design criteria. The above (Figure 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7) represent a outlook of the design.

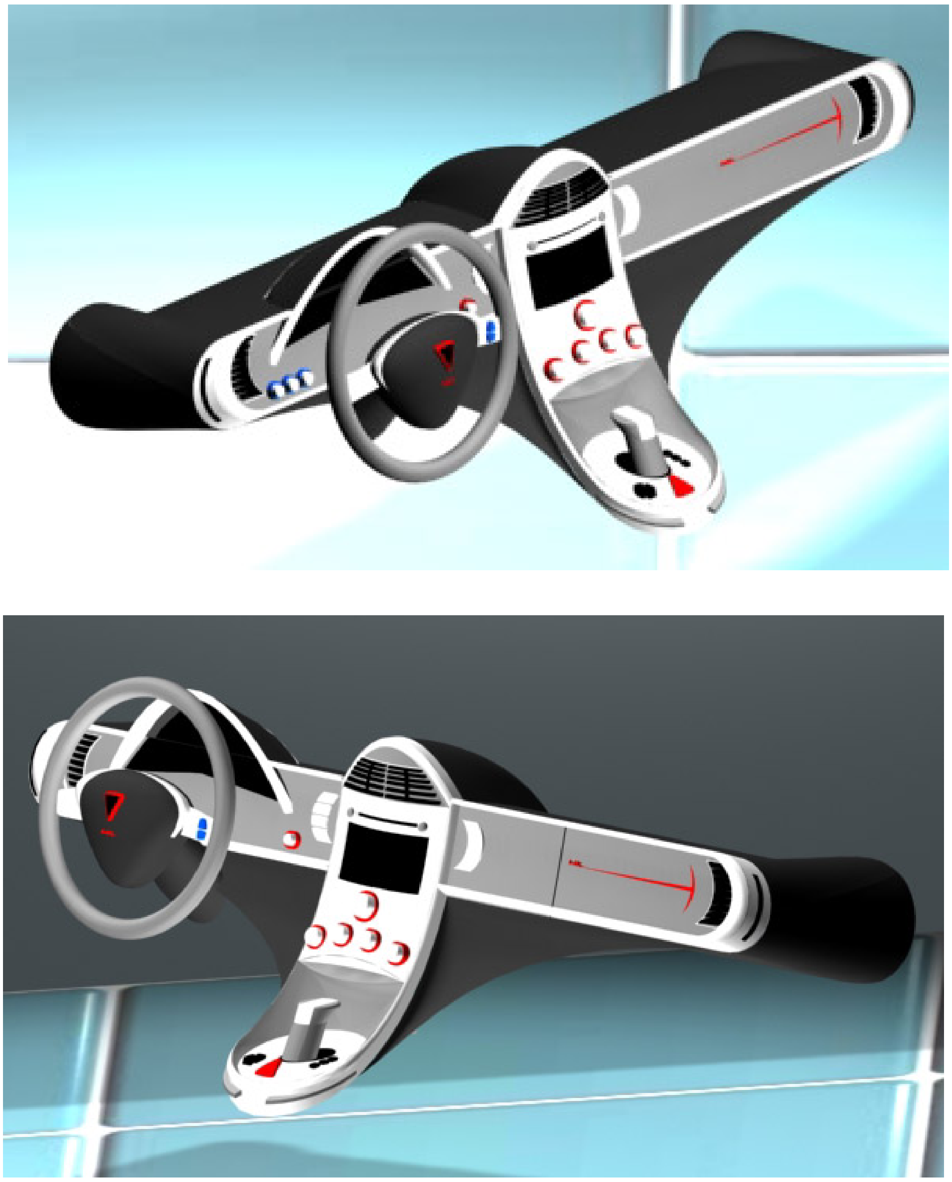


Figure 6.1. Perspective views of the dashboard design.

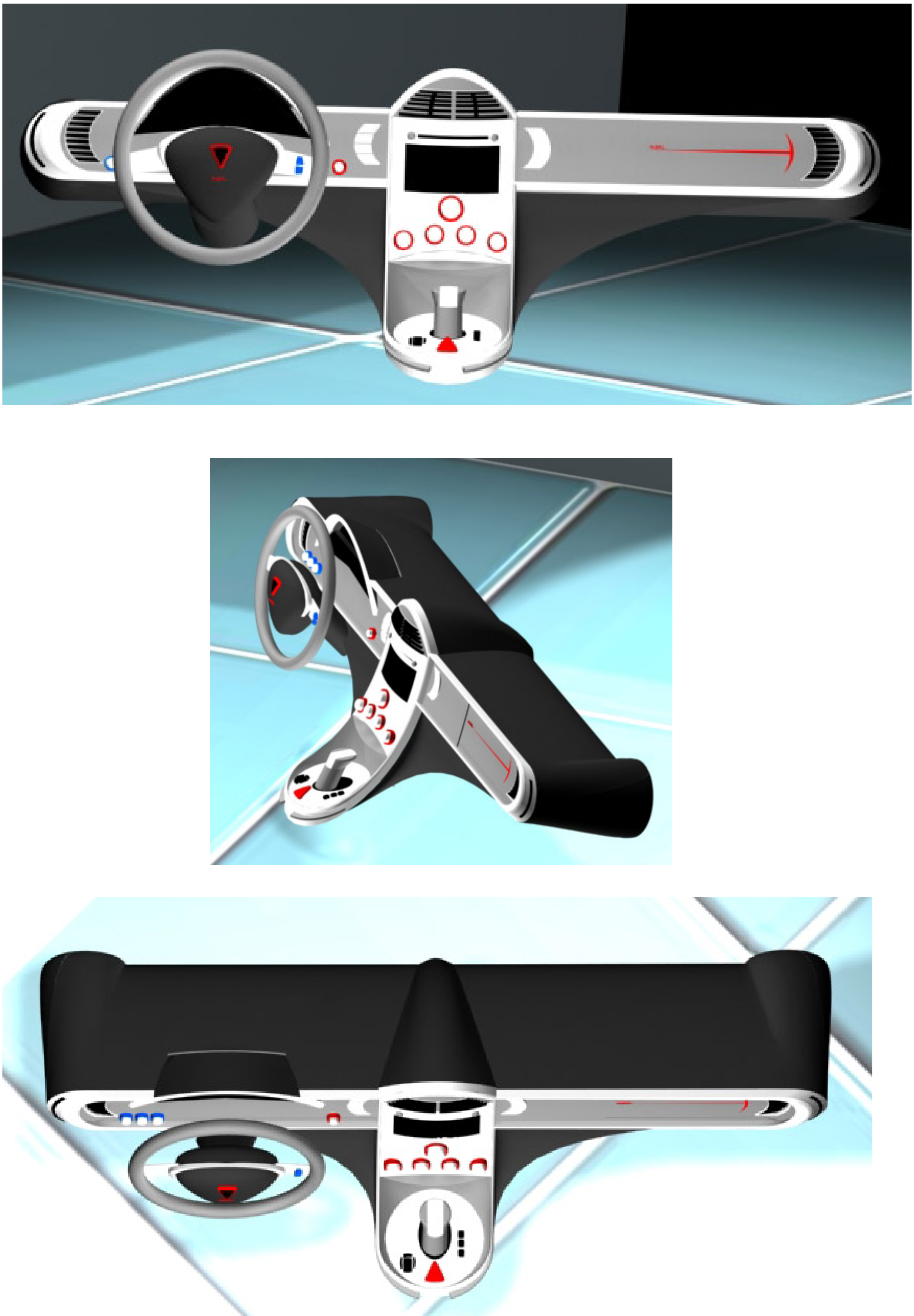


Figure 6.2. Front, side and top view of the dashboard design.

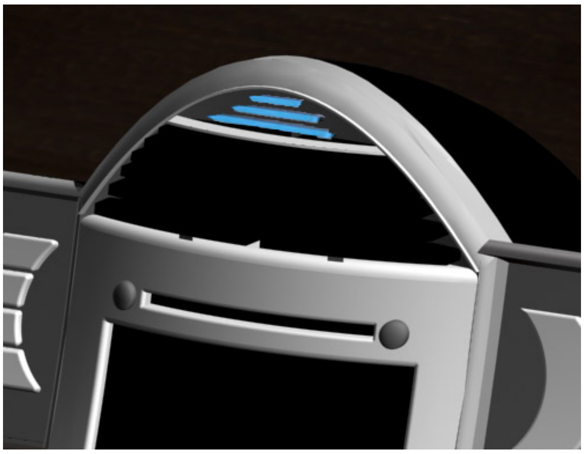


Figure 6.3. The park sensor's led is top of the right instrument panel.

Figure 6.4. The GPS/navigation screen is suited middle of the right instrument panel.

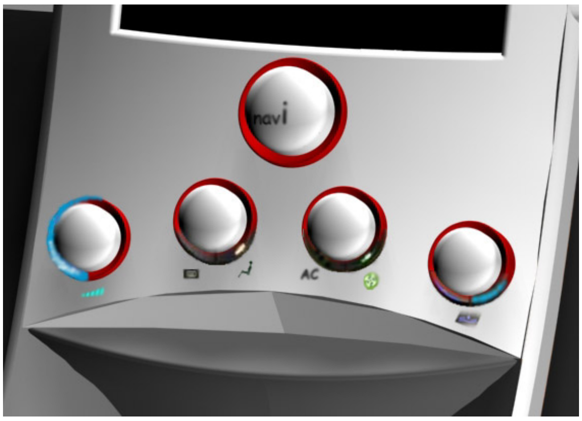


Figure 6.5. Air condition/heating and navigator controls are under the GPS screen.

Figure 6.6. Easytronic gearbox and side mirrors controller are underside of the right instrument panel. Cup holders are on the both side of the gearbox.

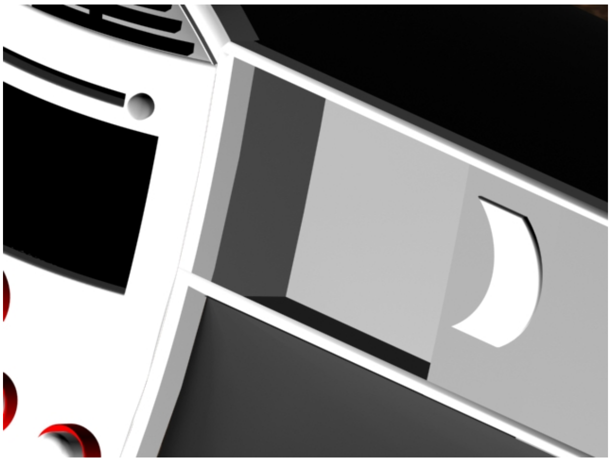


Figure 6.7. There is a storage box on the passenger side.

Every dashboard will contain a speedometer, rev counter, fuel, oil and temperature gauges. Each one of these is easy to find, read and comprehend. A car dashboard gives up to the minute and accurate information on the status of your car. The user questionnaire was made for the display unit placement in central instrument panel. Fourty questionnairie informed their opinion and asked them marked for how important these displays for their driving. While marking, they used 7 for very important, 5 for important, 3 for normal and 1 for less important meaning. The questionnaire can be seen in (Table 6.1).

Table 6.1. User questionnaire for the display unit.

USER	SPEEDOMETER	REV COUNTER	FUEL INDICATOR	TEMPERATURE GAUGE	CLOCK	OIL INDICATOR
1	7	5		1		3
2	3	7	5		1	
3	3	7	5			1
4	7	5	1		3	
5	5	7	3	1		
6	7	3		5		1
7	7	1	5		3	
8	7		3	5		1
9	5	7	3	1		
10	7	3		5	1	
11	7	5		3		1
12	5	1	7	3		
13	5	7	3	1		
14	7	5		3		1
15	5	7		3	1	
16	7	5		3		1
17	5	7	3	1		
18	7	3		5		1
19	7	5	3	1		
20	5	7		1	3	
21	5	7	3	1		
22	3	5	7	1		
23	7	5		3		1
24	7	3		5	1	
25	7	5	3			1
26	5	3	1	7		
27	7	3		5	1	
28	7	5	1	3		
29	5	7	3		1	
30	7	1	5	3		
31	7	5	3	1		
32	5	7		3		1
33	5	7	1			3
34	7	5	1	3		
35	3	7	5		1	
36	5	7	1	3		
37	5	7	3			1
38	7	5		1	3	
39	7	5	1	3		
40	3	7		3		1
COUNT	**232**	**203**	**79**	**87**	**19**	**18**

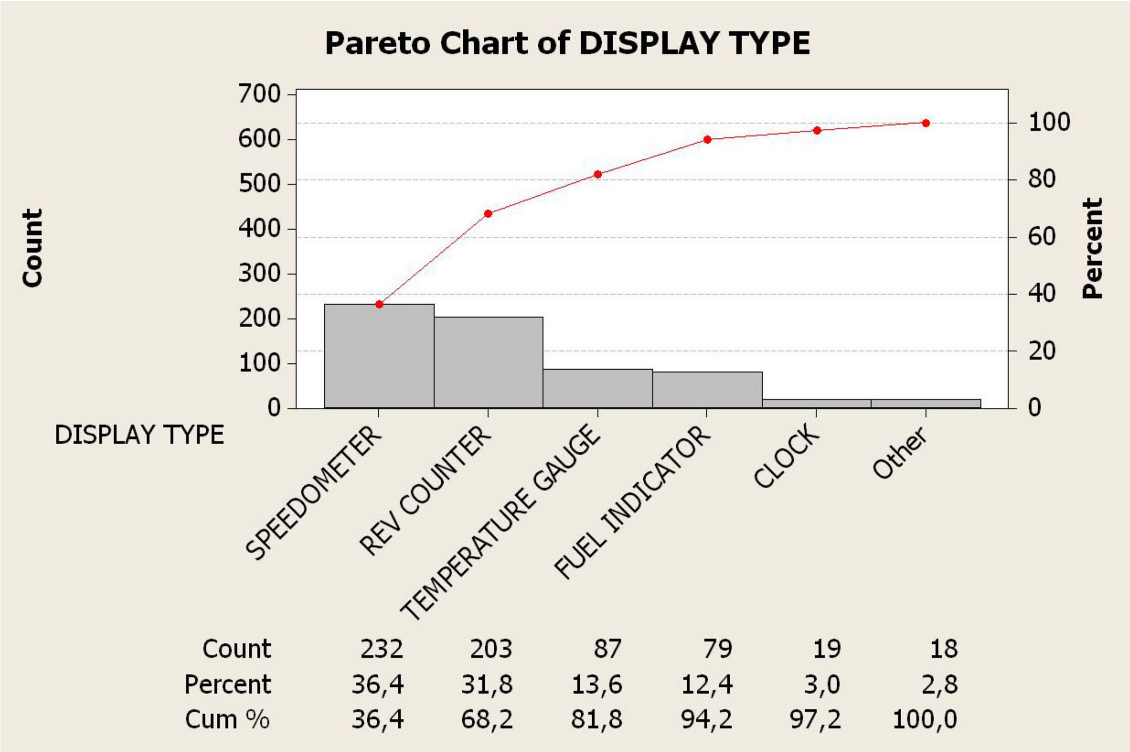


Figure 6.8. Pareto chart of display type.

Pareto chart (Figure6.8.) was prepaired from user questionnaire's data shows us the two most important display units are "speedometer" and "rev counter". Circular displays are chosen for the main display units. Accordance with pareto chart, main display unit is made up of two big circular displays. One of them is "speedometer" and the other is "rev counter"; "fuel indicator" and "temperature gauge" were also placed as a small circular displays under the big ones (Figure 6.9).

The parking brake, lighting on/off switch and the exterior mirror defrost controls are on the left instrument panel (Figure 6.9).

Steering wheel and central instrument panel were placed on concentric. There is a small data screen underside of display unit for driver. The control bars were designed upper side of the steering hub to control signals, windscreen wipers, lights and audio system. With sliding the switch; on the leftside bar, you can control signals; on the rightside bar, can control audio system. With push and pull, the left bar you can control the lights; the right bar, can control the windscreen wipers. Easytronic speed control buttons were placed on the right side of steering hub and start button on the dashboard surface. There are two airbag on the dashboard; one of them is in the steering hub and the other is on the passenger side. These can be seen in (Figure 6.9, 6.10).

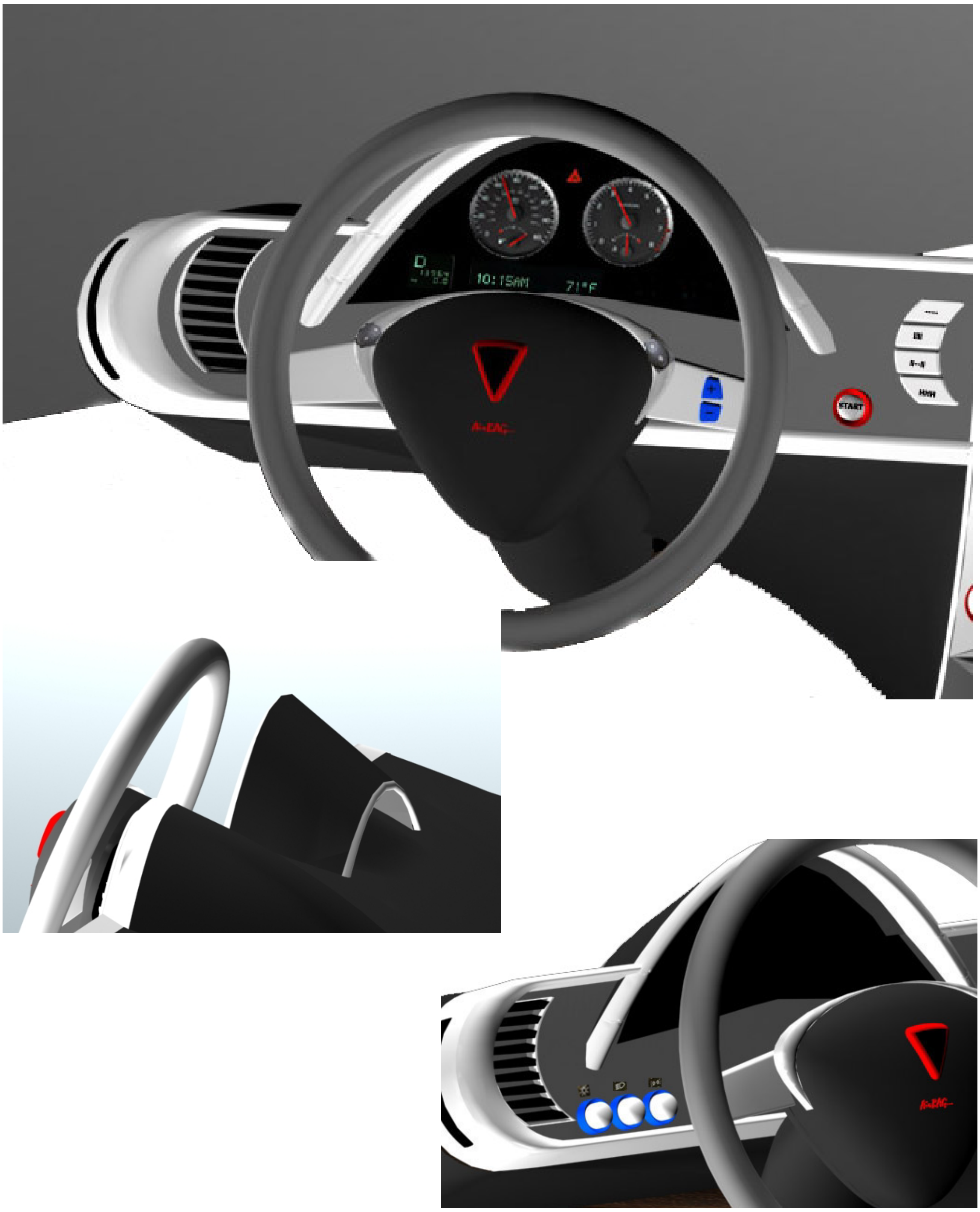


Figure 6.9. Central instrument panel.

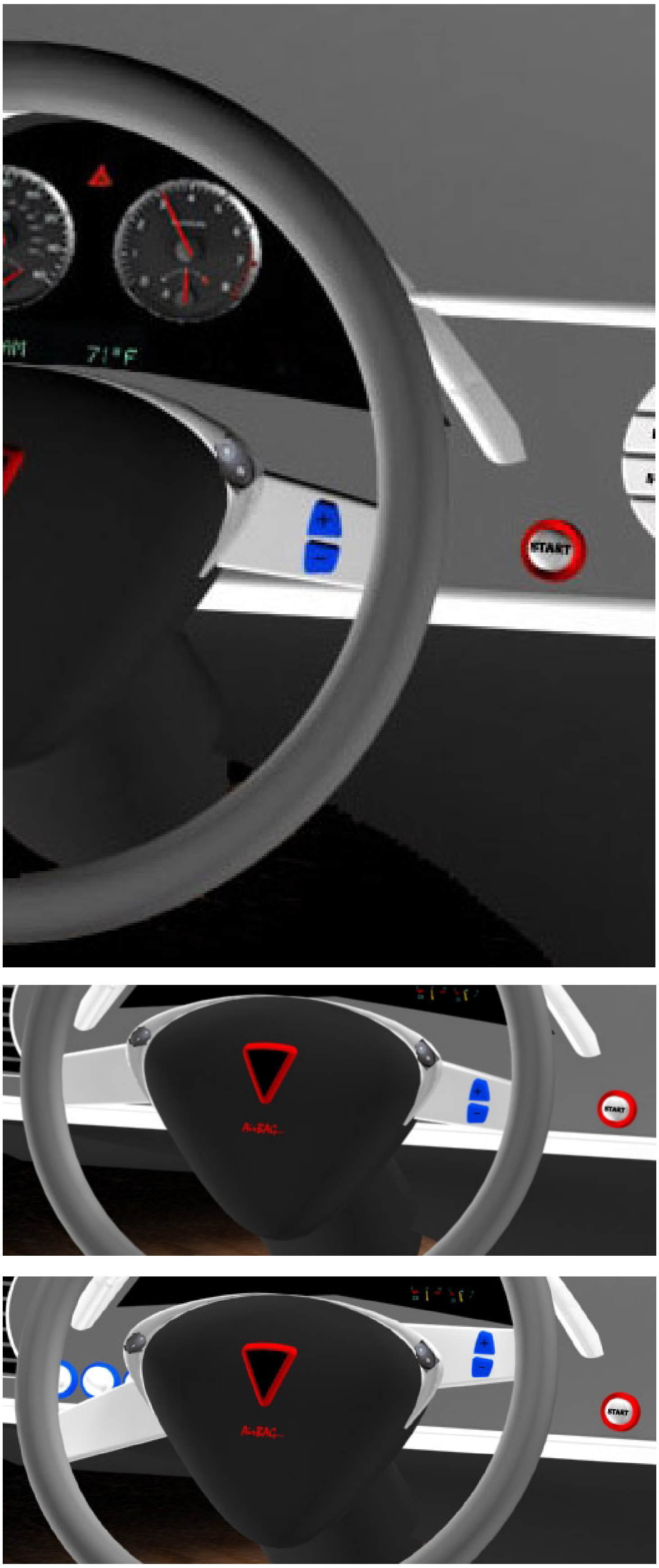


Figure 6.10. Fixed hub steering and controls.

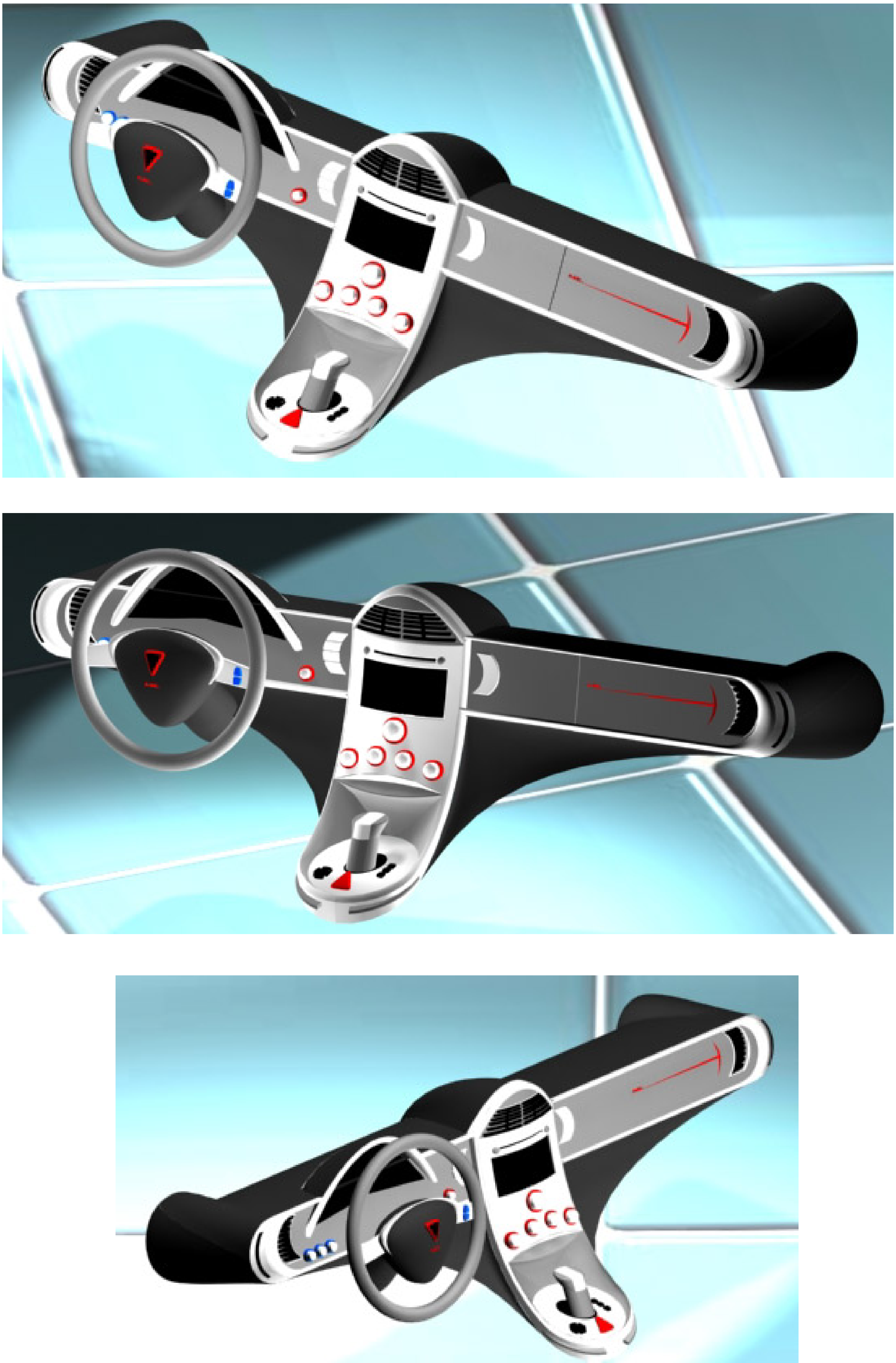


Figure 6.11. Different views of dashboard design.

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