FITTING PASSENGER SEATS ON INTERCITY COACHES TO TURKISH POPULATION: AN ERGONOMIC STUDY

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ABSTRACT

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The physical dimensions of a population change in the course of time. On the other hand, the physical dissimilarities among different population are much more significant and remarkable than time-dependent natural evolution process that affects all populations in the world.

In this study, passenger seats of intercity coaches that are important industrial products for Turkey in terms of usage frequency and their prevalence were investigated from an ergonomic viewpoint. To achieve this aim, eight seat parts and their equivalent anthropometric variables were specified to gather their measures from four different intercity coaches: These coaches represent the normal and top segment in Turkish intercity coaches market in addition to being imported or not. After that, these seat measures are compared with two anthropometric studies in terms of the sufficient sample size to reflect the anthropometric data related to Turkish population and the inclusion of the specified variables that correspond to these parts. Finally, alternative dimensions were recommended for each seat part to be used in the design process of passenger seats.

In conclusion, it was found that dimensions of all seats demonstrated no significant differences among each other in terms of belonging to middle or luxury segment coaches. Only for seat pan widths, all seats had higher values than the hip breadths of both anthropometric studies. Conversely, for other seat parts, the dimensions of almost all seats had lower values. All backrest heights were the lowest among the other parts based on the studies of Hertzberg et al and Kayış. It was observed that although all seats showed approximate values with specified seat parts of the directive of European Commission- 2001/85/EC- generally, all seat brands except Grammer had a lower value than the seat pan width mentioned in this regulation. It was also found important differences between the outcomes of two Turkish studies and the regulation of EC.

Keywords: Intercity coaches, seating, passenger seat design, anthropometry.

ÖZ

ŞEHİRLERARASI OTOBÜSLERDE YOLCU KOLTUKLARININ TÜRK TOPLUMUNA UYGUNLUĞU KONUSUNDA ERGONOMİK BİR ÇALIŞMA

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İnsanın fiziksel özellikleri, zamanla bir değişime uğramaktadır. Ancak farklı toplumlara ait insanların fiziksel boyutları arasındaki farklılıklar, bütün toplumları etkileyen ve zamana bağlı olan doğal değişimden çok daha belirgin ve dikkate değerdir.

Bu çalışmada, kullanıcının fiziksel boyutlarına oldukça ihtiyaç duyulan ve aynı zamanda Türkiye için kullanım sıklığı ve yaygınlığı açısından önemli bir yere sahip bir endüstriyel ürün olan şehirlerarası yolcu otobüslerinin yolcu koltukları, ergonomik bir bakış açısıyla incelenmiştir. Bu amaçla, Türkiye'deki pazar paylarına göre normal ve üst sınıfı temsil eden, aynı zamanda yurtiçinde üretilme ya da ithal edilmelerine göre yolcu otobüslerinin dört farklı firmaya ait olan koltukları üzerinden sekiz adet nokta ve onlara eşdeğer olan antropometrik değişkenler belirlenmiştir. Sözü edilen bu koltuk boyutları, Türk toplumunun antropometrik verilerini temsil edebilecek örneklem yeterliliği ve tespit edilen değişkenleri kapsamaları bakımından Hertzberg ve ark. ile Kayış' ın gerçekleştirdikleri iki araştırmanın sonuçlarıyla karşılaştırılmış ve son olarak tasarım aşamasında kullanılmak üzere her bir koltuk bölümü için alternatif boyutlar önerilmiştir.

Buna göre, incelenen orta ve üst sınıf otobüslerin koltuk boyutlarının kendi aralarında önemli değer farklılıkları göstermedikleri, yalnızca oturma paneli genişliklerinin, her iki antropometrik çalışmaya ait kalça genişliği değerlerinden daha yüksek oldukları tespit edilmiştir. Diğer koltuk bölümlerinin değerleriyse, söz konusu araştırmaların antropometrik değişkenlerine göre düşük değerler göstermektedir. Bir başka sonuç da, incelenen dört farklı koltuğa ait sırtlık yüksekliği değerlerinin diğer koltuk bölümleri içerisinde her iki antropometrik araştırmanın ilgili verilerine yakınlığı açısından en düşük değerde olduklarıdır. Her ne kadar Avrupa komisyonuna ait 2001/85/EC direktifi ile genel olarak bütün koltuk markalarının bölümleri uyumlu olsalar da, bu yönetmelikçe belirtilen oturma paneli genişliği değerine göre, Grammer marka koltuk haricinde, diğer markaların oturma paneli genişliklerinin daha düşük değerlerde oldukları gözlenmiştir. Aynı zamanda söz konusu Avrupa komisyonu direktifi ile bu çalışmada sonuçlarından faydalanılan iki yerli antropometrik araştırmanın karşılıklı değerlerinin de önemli farklılıklar gösterdikleri tespit edilmiştir.

Anahtar kelimeler: Şehirlerarası otobüsler, oturma, yolcu koltuğu tasarımı, antropometri.

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CHAPTER 1

INTRODUCTION

1.1 Problem definition

Today, in the design process of every kind of product, the collaboration among specialists from various disciplines seems to be a requirement. This fact is not only due to increasingly sophisticated products in markets but also determining the aim and the user, that is to say the “human” element, of the product. Therefore, the broad minded producers adopt the mentality of a user-centered design. Actually, the appropriation of such a mentality is almost of vital importance for everyone. These being vast product alternatives in front of consumers and with the help of studies performed on this subject, they prefer human-centered products much more.

Ergonomics collects all human based approaches in its body. As a sub field, physical ergonomics is concerned with anatomical, anthropometric, physiological and biomechanical characteristic of the user. Anthropometric properties provide primary data for physical ergonomists and designers about the potential user of any product. Especially in a global world where every manufacturer may sell the same product to different countries, anthropometric factors play a more important role. The body dimensions of a user in any population differ from another population. Consequently, when a product that is designed according to anthropometric data of a population is used by people that belong to different countries, this may lead to various complaints or sometimes even serious injuries. Perhaps seat design needs anthropometric knowledge much more than any other product thanks to its structure. On the other hand, in the design of public seats like passenger ones, using this information become meaningful completely due to their usage profiles and frequencies.

1.2 The scope of the study

This study aims to analyze current passenger seats on Turkish intercity coaches from an anthropometric viewpoint so as to assist the designers that will work on design of seats. It also aims to compare the dimensions of these seats, with the help of studies that contain anthropometric dimensions of Turkish people. In this way, to define what the dimensions of the seats should become and then to provide insights for future to designers so as to what should be paid attention in the design process of passenger seats.

In this context, the following research questions were prepared for the field study:

1. What are the dimensions of passenger seats in intercity coaches in Turkey?

2. What are the anthropometric dimensions of Turkish people that are related with seats?

3. Are anthropometric factors in the passenger seat design for Turkish market considered adequate?

4. Which dimensions can be taken into consideration in the design of passenger seats ergonomically for Turkish population?

In this study, it will be benefited from literature surveys especially in the second and the third chapters. It should also be noted that the problems that are caused by the aforementioned phenomenon will be evaluated. In the final phase of the thesis, a field study will be presented to draw a projection about the condition in Turkey.

1.3 Structure of the thesis

This study can be divided into three main parts. In the first part, information will be given about the ergonomics and anthropometry with its sub fields and by evaluating the effects on the problem. Then, the study will continue by the importance and statistical explanations of the problem. Finally, the conditions of problem in Turkey with the help of a case study will be investigated.

In the following chapter, the effect of ergonomics on design process of the products will be discussed. In this context, use of anthropometry as a tool, factors that affect on anthropometric data and the ways of benefiting from these data will also be discussed.

In the third chapter, it will be focused more on the concept of “seating”, the main point of the problem, with anatomical, physiological and psychological aspects. In addition, anthropometric dynamics of seating will be analyzed according to standards. On the other hand, within the subject of seats in transportation, the differences between inner city and long-time travel vehicles will be examined based on the related directive to understand more the roots of the problem.

Fourth chapter will be mainly on intercity coaches and Turkish transportation system. In this chapter, statistical information about general and Turkish transportation will be presented. Afterwards, it will be glanced to Turkish intercity coach market to define coaches that their seats will be analyzed. Furthermore, the dimensions of seats that belong to selected coaches will be submitted.

Fifth chapter will start by presenting the anthropometry studies that had been performed in Turkey chronologically. Then, the headings discussed throughout the study will be shown with a comparison between the conclusions of the related literature and the dimensions of seats. The consequences of this comparison will be evaluated within the context defined the previous parts of the study.

Finally, results that are acquired from beginning to end the study will be evaluated and potentials for the further studies will be investigated.

CHAPTER 2

THE EFFECTS OF ERGONOMICS IN PRODUCT DESIGN

2.1 Ergonomics and its role

One of the most important characteristics of *Homo sapiens* that differentiate him from many other primates is being *Homo faber*, that is, using and making tools. Using bone, wood and stone as pounders, scrapers and missiles but selecting these materials to fit to the human hand shows as “early ergonomic activities of human” (Kroemer, Kroemer and Elbert, 1994). The word ‘ergonomics’ is derived from the Greek words ‘ergos’ (work) and ‘nomos’ (law). In the United States, generally the term ‘Human Factors’ is used. For the first time, as a discipline, ergonomics came into existence during the Second World War. To meet the need of developed military equipment, anthropologists, physiologists, psychologists, medical doctors, work scientists and engineers joined together. However, after the Second World War, the cooperation among scientists continued especially in industry. Ergonomics, in England and the United States, became an important discipline. Therefore, the first national ergonomics society was founded in 1949 in England. Moreover, the term ‘ergonomics’ was adopted firstly by these society members. This was followed in 1961 by the creation of the International Ergonomics Society (IEA), which at present represents ergonomics societies which are active in 40 countries or regions, with a total membership of some 15000 people (Dul and Weerdmeester, 2001).

The last official definition of ergonomics and ergonomist approved in August 2000 by International Ergonomics Association (IEA) with the following words:

> “Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles data and methods to design in order to optimize human well-being and overall system performance.

> Ergonomists contribute to the design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people (International Ergonomics Association, [IEA], 2000)."

IEA also defines the main domains within the discipline of ergonomics with the following words:

> "Physical ergonomics is concerned with human anatomical, anthropometric, physiological and biomechanical characteristics as they relate to physical activity. (Relevant topics include working postures, materials handling, repetitive movements, work related musculoskeletal disorders, workplace layout, safety and health).
>
> Cognitive ergonomics is concerned with mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system. (Relevant topics include mental workload, decision-making, skilled performance, human-computer interaction, human reliability, work stress and training as these may relate to human-system design).
>
> Organizational ergonomics is concerned with the optimization of socio-technical systems, including their organizational structures, policies, and processes" (IEA, 2000).

As it is shown in the definition, ergonomics is a multidisciplinary field. Dul and Weerdmeester (2001) mention that:

"Ergonomics differs from other fields by its interdisciplinary approach and applied nature. The interdisciplinary character of the ergonomic approach means that it relates to many different human facets. As a consequence of its applied nature, the ergonomic approach results in the adaptation of the workplace or environment to fit people, rather than the other way around" (Dul and Weerdmeester, 2001).

The root of ergonomics is based on basic sciences such as anthropology, physiology, psychology, sociology, medicine. These contain primarily anthropometry, the measuring and description of the physical dimensions of the body; biomechanics, describing the physical behavior of the body in mechanical terms; industrial hygiene, concerned with the control of occupational health hazards that arise as a result of doing work; industrial psychology, discussing people's attitude and behavior at work; management, dealing with and coordinating the intentions of the employer and the employees; and work physiology, applying physiological knowledge and measuring techniques to the body at work (Kroemer et al, 1994).

In addition, there are many application areas that make use of ergonomic data as components of their knowledge base, or of their work procedures. Some of them are industrial engineering, by definition concerned with the interactions among people, machinery and energies; bio-engineering, working to replace worn or damaged body parts; systems engineering, in which the human is an important component of the overall work unit; safety engineering and industrial hygiene, which focus on the well-being of the human; and military engineering, which relies on the human as soldier or operator. Some other new application areas such as computer-aided design, in which information about the human must be provided in computerized form; oceanographic, aeronautical, and astronautical engineering, also depend profoundly on ergonomic knowledge (Kroemer et al, 1994).

Design is the unique field for ergonomics to use and prove its approaches and methods. An ergonomic approach to design is summarized by Pheasant (1996) with the following words:

> "The principle of user-centered design is if an object, a system or an environment is intended for human use, then its design should be based upon the physical and mental characteristics of its human users (insomuch as these may be determined by the investigative methods of the empirical sciences). The object is to achieve the best possible match between the *product* and its *users,* in the context of the (working) *task*. In other words, ergonomics is the science of fitting the job to the worker and the product to the user" (p. 5).

Pheasant (1996) also states from a pamphlet published by Ergonomics Society in his book to explain the way to recognize an ergonomically designed product with the following words:

> "Try using it. Think forward to all of the ways and circumstances in which you might use it. Does it fit your body size or could it be better? Can you see and hear all you need to see and hear? Is it hard to make it go wrong? Is it comfortable to use all the time (or only to start with)? Is it easy and convenient to use (or could it be improved)? Is it easy to learn to use? Are the instructions clear? Is it easy to clean and maintain? Do you feel relaxed after a period of use? If the answer to all of these is 'yes' then the product has probably been thought about with the user in mind" (as cited in Pheasant, 1996).

2.1.1 The importance of ergonomics in product design processes

It was mentioned about disciplines concerned with ergonomics and their application areas. For all these disciplines, design also plays a common role as the main aim is starting to design a product that will be finalized with mass production. Design is also a touchstone for ergonomics since the thing that differentiates it from academic disciplines is that information is used about people to design products that are needed or requested. In this point, two key questions come to mind are the contributions of ergonomics to the design process and how it will realize them in each phase of this process (Chapanis, 1995).

From time to time throughout the history, it may be observed that there is a communication problem between ergonomists and designers. The basic reason of this is the level of generality of the recommendations defined from studies made by ergonomists. For this issue, Meister and Sullivan (1968) stress that

> “Despite the evidence that human engineering can prevent system failure, equipment designers continue to reject the remedies offered by human factor specialists. The specialists share the blame often the engineer cannot read the prescription” (as cited in Simpson and Mason, 1983).

A similar statement is maintained by Chapanis (1995). According to him, generally, the goal or conclusions of any ergonomic study is describing, analyzing or trying to explain what happened. In other words, some studies start acquiring data after a product or a system designed. Whereas, in designing or improving a product, the main goal is prediction and therefore to determine to the precise design requirements before it is made. Many ergonomists appear to believe that their mission is ended when they have provided general guidelines and turned them over to engineers to deduce and execute. That is the reason of speaking sometimes the different language between designers and/or engineers and ergonomists since the designers need more specific or precise information rather than general guidelines during the product development process.

The thing that differentiate ergonomics from other disciplines rests on the ability to apply successfully what is known about people to the design of products that are safer, easier to use and generally better than they would have been without its contributions. However, how ergonomics do that is a vital question. There are many steps in the product improvement process. Chapanis (1995) classifies respectively these as:

- Recognition of a need
- Need statements
- Utilization concept
- Concept exploration
- Concept validation
- Engineering development
- Production and distribution
- Operation and maintenance
- Life cycle variations (p. 1628-1630).

According to him, the mission of an ergonomist starts with the recognition of a need to produce a new product. In this step, he/she can analyze existing products with the help of special techniques such as interviews, questionnaires, fault tree analysis, etc. That is, he/she can contribute to the process from customer viewpoint. The step of utilization concept gives basic information as what will the product look like or how will the product is used by customer to the ergonomist. This may be useful for training customers or preparation of an adequate user's guide. In concept exploration, various design solutions are attempted. For this aim, some are modeled or tested. However, this stage is also an important opportunity for the ergonomist to apply many ergonomics activities. Some of them are assisting in the allocation of functions to people, hardware, software or some combination of them and conducting trade studies to evaluate the costs and benefits of various alternatives involving human users or operators, developing user-product interfaces and prototyping and evaluating user interfaces and finally, concept validation is a stage simulated and tested to control requirements recognized in previous stages. Some questions are asked about meeting user requirements by ergonomist such as does the design concept meet requirements related to staffing, operating, maintaining and supporting the product? Or does it meet dimensional requirements for workspaces, ingresses, egresses, and accesses for maintenance? When the engineering development starts, builds or materials such as hardwares or softwares that are needed for the product is identified by engineers. In this phase, ergonomist conduct operational tests with representative users performing tasks to determine whether the product meets performance requirements established earlier. After that, the production and the distribution stages start. At this point, the product goes into production and multiple copies of it are manufactured limitedly because to establish its acceptability in the market. Here, the ergonomist may be involved in training users in the operation of the product, in evaluating the usability or operability of the product. After the product is marketed, the ergonomist may pursue the customer satisfaction with the use and maintenance of the product. Finally, although a product can be developed by the maximum contributions of ergonomist, in accordance with the product’s natural life cycle, it will be eventually get unusable.

2.2 Anthropometry as a tool for meeting ergonomic requirements

Physical ergonomics, as it is mentioned in the definition by IEA is directly related to and determined by product design processes. Nevertheless, anthropometry is the most important assistant and knowledge bank to physical ergonomics. Anthropometry is the study and measurement of body dimensions of human beings. The word ‘anthropometry’ is derived from two Greek words: ‘anthropos’ (man) and ‘metron’ (measure). “Currently, anthropometric data are extensively used by design engineers and human factors professionals to specify the physical dimensions of products, tools, and workplaces to maximize the match between the physical dimensions of the designed products and workplaces and the body dimensions of the users” (Wickens, Gordon, Liu, 1998).

Anthropometric data are used to meet many general and specific objectives in ergonomics such as developing design guidelines for heights, clearances, grips, and reaches of workplaces and equipments for accommodating the body dimensions of the potential work force, applying in the design of consumer products such as clothes, automobiles, furniture, hand tools, elevators and so on. Moreover, using of anthropometric information in occupational biomechanics with the help of data are used in biomechanical models together with information about external loads to evaluate the stress imposed on worker’s joints and muscles during the performance of work (Wickens et al, 1998).

The vital point of being related with using and identity of anthropometric data is, except for a small number of handicapped people or required special equipments such as pilots, the necessity of reflecting a population values. Pheasant (1996) says that:

> "What is rather less obvious is how we should choose the best compromise dimensions for equipment to be employed by a range of users, and at what point we should conclude that adjustability is essential. In order to optimize such decisions we require three types of information:
>
> "i) The anthropometric characteristics of the user population;
>
> "ii) The ways in which these characteristics might impose constraints upon the design;
>
> "iii) The criteria that define an effective match between the product and the user" (p. 15).

2.2.1 Natural variations and their effects on anthropometric dimensions

Natural variation of human physical characteristics is the main factor that directly affects anthropometric data. For this reason, these variations also directly affect design guidelines of products, workplaces or devices. There are many sources of variations among people in populations. Some small genetic differences may lead to wide distribution of body dimensions and shapes which may be encountered in a population. However, other more readily observable variables that are age, sex, culture, occupation, and even historical (secular) trends can also affect body dimensions and their variability. Wickens et al (1998) define and list the major sources of variability as:

- Age Variability
- Sex Variability
- Racial and Ethnic Group Variability
- Occupational Variability
- Generational or Secular Variability
- Transient Diurnal Variability (p. 291-292).

Age variability: Dimensions of the body show increases or decreases based on the age of a person. For instance, Roche and Davila, and, Vancott and Kinkade indicate that stature increase to about age 20 to 25 and starts to decrease after about age 35 to 40 (as cited in Wickens et al, 1998).

Sex variability: Many body dimensions vary between males and females. This fact is vital in designing workplaces or products. An example to sex differences may be seen in the various hand dimensions. “Garret surveyed on 34 different hand dimensions for both sexes. According to his study, male sizes were larger than female sizes with the greatest differences occurring in the thickness dimensions (male dimensions being approximately 20 per cent larger than those of the females). For the length dimensions (hand, finger) males were approximately 10 per cent larger than females” (as cited in Oborne, 1995).

Racial and ethnic group variability: Differences between populations also become important for designing issues. The study of Roberts is an example to this fact. In his study, he defines that the average male stature of African Pygmy tribes is 144 cm. Nevertheless, the stature of the Northern Nitoles of Southern Sudan is 183 cm. In same population, being different dimension values is another reality. The surveys realized by Long and Churchill and NASA show that the average height of black and white males in the U.S. Air Force is identical. On the other hand, blacks tend to have longer arms and legs and shorter torsos than whites (as cited in Wickens et al, 1998 and Oborne, 1995).

Occupational variability: People working in different occupational groups can have different dimensions. The reason for this depends on a few factors. Wickens et al (1998) define these factors as “the type and amount of physical activity involved in the job, the special physical requirements of certain occupations, and the self-evaluation and self selection of individuals in making career choices. A study realized by Sanders and Shaw (1985) on truck drivers in the United States reveals that truck drivers tend to be taller and heavier than average. In Turkey, however, Duyar and Özener (2005) studied 13 and 18 years old working children. Özarslan (1981), and Polat and Köseli (2002) took measurements from apprentice children that work in small industry. All these studies show that mean anthropometric dimensions of working children have lower values than nonworking ones.

Generational or secular variability: For last hundred years, thanks to better conditions of nutrition and hygiene, it is seen that today people have more robust body. “Especially, in last five decades, stature has increased in North America and in Europe by about 1 cm per decade, on the average, while body weight has increased about 2 kg per decade” (Kroemer et al. 1994). In addition, studies show that “data from Japan indicated initially a much faster average growth than found among Caucasians, but the rate seems to be slowing down now” (Kroemer et al. 1994). In Turkey, anthropometric studies also indicate that a positive secular trend observed in human physical dimensions, especially in terms of standing height. However, this positive secular trend is almost because of increase in lower segment of the body (Duyar, 1995).

Transient diurnal variability: Various factors can be effective on body measures. For instance, clothes can change measurements of the body; taking measure in different postures also might lead to incorrect results. Due to the effects of gravitational force on a posture and the thickness of spinal disks, the stature of a person might be reduced by up to 5 mm at the end of the day (Wickens et al, 1998).

2.2.2 The types and the statistical explanations of anthropometric data

Designers select and use anthropometric data based on their types and statistical conditions when designing for different purposes. Generally, two types of anthropometric data can be collected from the human body are available. These are structural (static) and functional (dynamic) anthropometric data (Croney, 1981).

Structural (static) anthropometric data can be obtained by measuring body dimensions in standard or static positions. Measurements are taken from one clearly identifiable anatomical point to another or to a fixed point in space. Stature, elbow height, foot length can be given as examples to static anthropometric data. The usage of structural anthropometric data wherein design process may be exemplified as to specify furniture dimensions and ranges of adjustment and to determine ranges of clothing sizes (Bridger,1995).

In functional (dynamic) anthropometric data, however, data is acquired when the body adopts various working postures (i.e. when the body segments move with respect to standard reference points in space). For example the horizontal distance from the back of the upper arm i.e. at the elbow to the fingertips, with the elbow bent at right angles of a sitting person defines as ‘ forearm-fingertip length’ which provides critical information for work-space design or visual display terminals (VDT) (ISO 7250:1996).

In addition to these two types of data, Bridger (1995) mention another anthropometric data whose name is Newtonian.

Newtonian anthropometric data is used in mechanical analysis of the loads on the human body. According to Bridger (1995) “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. Newtonian data may be used to compare the loads on the spine from different lifting techniques” (p. 75).

Anthropometric studies help designers to recognize the formal structure of the target population. Nonetheless, data of these studies are represented with statistical explanations. In anthropometric studies, firstly, are specified a portion from the population that can be measured. The statistical synonym of this portion is called a “sample”. In addition, whether or not the sample selected is statistically representative is fundamental concern. For instance, if the anthropometric data are to be applied to the design of sportsman shoes that are intended to accommodate an entire population of related branch of sportsman, selected foot sizes used for the design data have to be entirely representative. Otherwise, the design will basically not accommodate everyone. Gathered anthropometric data may be shown statistically with the help of normal (or Gaussian) distribution. Normal distribution has two components that are the mean and the standard deviation. The mean is a measure of central tendency that tells us about concentration of a group of scores on a scale of measurement. It is a measure of the degree of dispersion in the normal distribution along the x or horizontal axis and it can be obtained with the sum of the all measurements divided by the number of measurements. However the standard deviation is a measure of the degree of dispersion or scatter in a group of measured scores. The value of the standard deviation controls the shape of the normal distribution and it can be obtained with the square root of the mean squared difference between each score and the mean. If the standard deviation has a small value, then the many measurements will be approximate to the mean value. In contrast, if the standard deviation has a large value that means the measurements are scattered more distantly from the mean, the distribution will have a flatter shape (Burgess, 1989, Bridger 1995).

An example to the normal distribution is shown in figure 2.1:

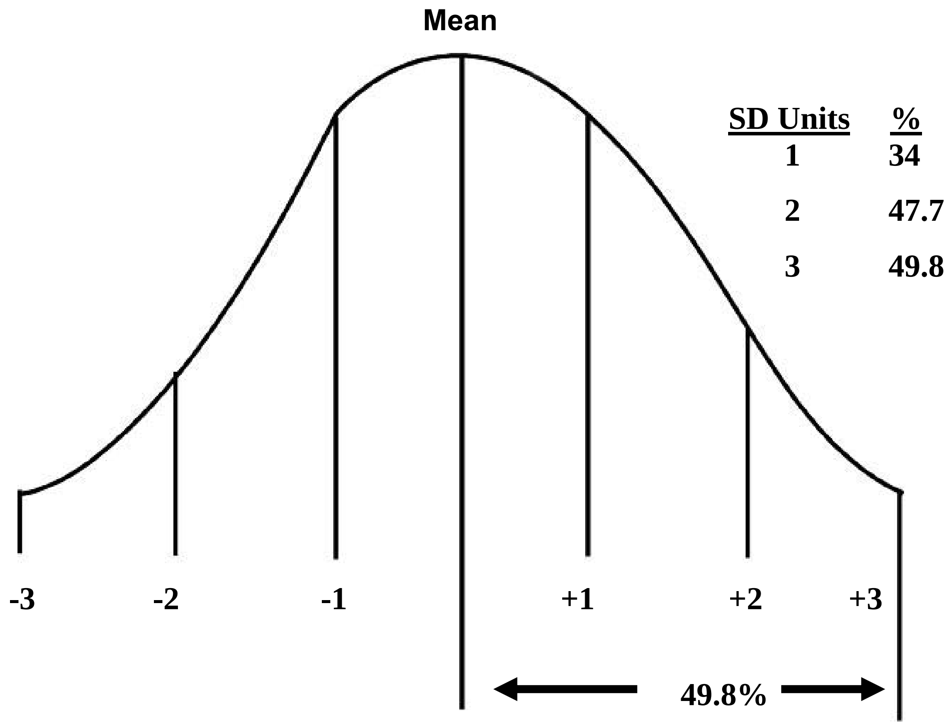


Figure 2.1: A normal distribution percentage breakdown of SD units (From Burgess, 1989)

The interpretation and using of anthropometric data in ergonomics and design issues might be described properly via *percentiles.* A percentile value of an anthropometric data represents the percentage of the population with a body dimension of a certain size or smaller. This information is particularly important in design because it helps designers estimate the percentage of a user population that will be accommodated by a specific design. In figure 2.1, an example of normal distribution curve from Burgess (1989) can be seen. This curve shows the distribution of the stature of a specified population, here the mean value can be defined as 69 inches (=175.26 cm) and an individual measure can be defined as 72 inches (=182.88 cm), according to these variables standard deviation is calculated as 1,6. In the figure, 49.8 means percent of all cases fall within 3 SD's (standard deviation) above or below the mean, and 99,6 percent of all cases fall within ±3SDs. According to the height given in the example, 1.6 SDs greater than the mean is where about 87 percent of all the cases occur, i.e., less than 72 inch (=182.88 cm) tall. This is called the 87th percentile. Similarly, 66 inches (=167.64 cm) in height, or 1,6 SDs below the mean, is where about 13 percent of all cases are shorter. This called the 13th percentile. (Burgess, 1989, Wickens et al, 1998).

Kroemer et al. (1994) represent percentiles and their meaning for designers with the following words:

> "Percentiles serve designer in several ways. First, they help to establish the portion of a user population that will be included in (or excluded from) a specific design solution. For example: a certain product may need to fit everybody who is taller than 5th percentile or smaller than 95th percentile in a specified dimension, such as grip size or arm reach. Thus, only the 5 percent having values smaller than 5th percentile, and the 5 percent having values larger than 5th percentile, will not be fitted. The central 90 percent of all users will be accommodated. Second, percentiles are easily used to select subjects for fit tests. For example: if the product needs to be tested, persons having 5th or 95th percentile values in the critical dimensions can be employed for use tests. Third, any body dimension, design value, or score of a subject can be exactly located. For example…a certain seat height can be described as fitting a certain percentile value of popliteal height (a measure of lower leg length). Finally, the use of percentiles helps in the selection of persons to use a given product. For example: if a cockpit of an airplane is designed to fit 5th to 95th percentiles, one can select cockpit crews whose body measures are between the 5th and 95th percentile in the critical dimensions" (p. 35).

In this point, a critical reality that needs attention by designers is that there is no "average person" anywhere in the world, in other words, it cannot be found a person whose body dimensions have 50th percent value. For example, a person that has average stature might have long or short arms or wide or narrow feet (Wickens et al, 1998).

Although many factors affect anthropometric data that are concerned with a population, they procure vital information to designers that can design products or workstations. Nonetheless, designers should consider some precautions to use data effectively. Bridger (1995) explains these precautions as:

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 (p.76).

Similarly, Wickens et al (1998) summarize the necessities that should be followed in six procedures to help designers:

1) Determine the user population (intended users): Who will use the product or workplace?

2) Determine the relevant body dimensions: Which body dimensions are most important for the design problem?

3) Determine the percentage of the population to be accommodated:

4) Determine the percentile value of the selected anthropometric dimension.

5) Make necessary design modifications to the data from the anthropometric tables.

6) Use mock-ups or simulators to test the design (p. 302-304).

CHAPTER 3

SEATING CONCEPT AND SEAT DESIGN

3.1 The anatomical, physiological, and psychological aspects of seating

Seating is a posture where the weight is sent to hip area and dispersed by mainly ischial tuberosities and surrounding soft tissues. However, according to the place in which seating like a seat and the position of the body, some weight is also transferred to ground by, if exists, armrest and/or backrest of the seat. Gunnar (1987) defines the advantages of sitting compared with standing postures as:

a) Sitting provides stability required on tasks with high visual and motor control components.

b) It is less energy consuming.

c) It places less stress on the joints of the lower extremities

d) It lowers the hydrostatic pressure on the lower extremity circulation (p. 309).

3.1.1 The anatomical and physiological aspects of seating

In order to understand the advantages of sitting better, anatomical and physiological structures of the human body and their effects on sitting behavior have to be known. There are two bone systems and their muscles play key role in constituting sitting environment that are spinal column, and pelvis. As can be seen in Figure 3.1, the spinal column comprises twenty-four flexible bony vertebrae which are grouped based on regions on trunk from up to down. First seven vertebrae are named as cervical (in the neck region), twelve are thoracic (in the chest region) and five are lumbar (in the waist region).

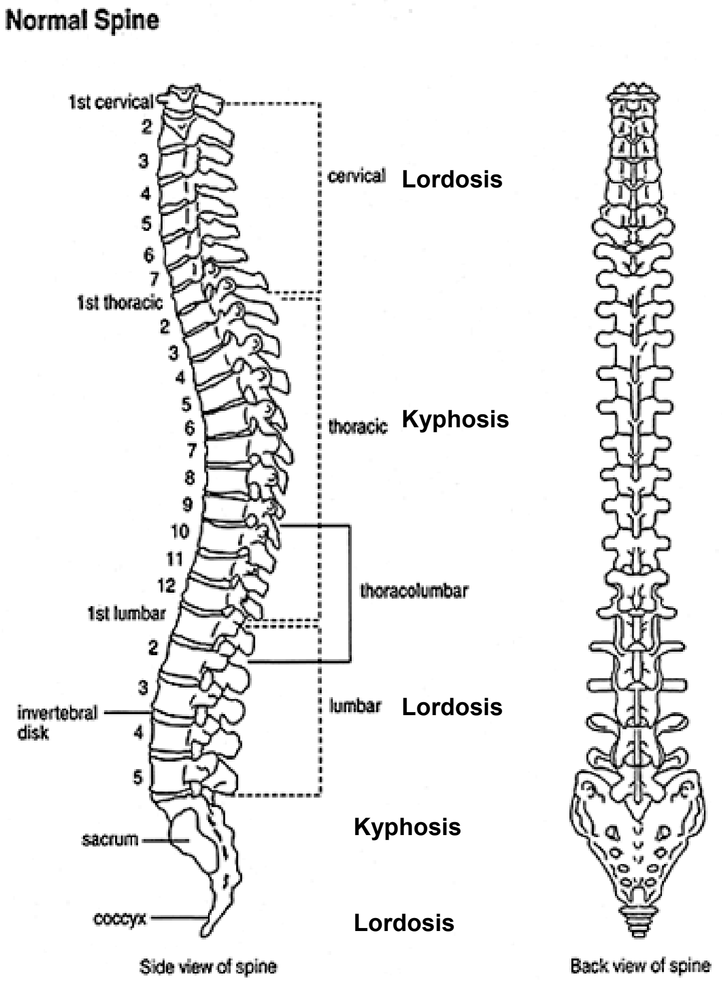


Figure 3.1: Side and back views of vertebral column (From National Institute of Arthritis and Musculoskeletal and Skin Diseases, 2001 [online])

Nonetheless, Pelvis comprises of three bones named as *os coxa*, *os sacrum* and *os coccyges* (Kroemer et al. 1994). Sacrum and coccyx are also fixed parts of spinal column. In other words, with these fixed vertebral bones, spinal column comprises totally from thirty-three vertebrae. *Os coxa* also comprise of three bones that names are ilium, ischium and pubis. Thanks to the sacrum and coxae located in right and left, pelvis appears a deep bucket.

In addition to these bones, many muscles and ligaments support and control the spine to continue its flexibility. The tissue connections between pelvis and thigh define primarily trunk posture. Hence, they are actually sources of pressure in the intervertebral discs (Woerdeman, 1950; Pheasant, 1996; Kroemer et al. 1994).

In standing position spinal column is not straight; however it has two forward bends (lordoses) in the cervical and lumbar regions and one backward bend (kyphosis) in the chest area. Pheasant (1996) describes the position of these bends as “With the convexities of the occiput (back of the head) above and the sacro-iliac region and buttocks below, existing five curves totally in the upper segment of the body” (p.52).

Moreover he adds that “Nucleus pulposus, the soft fibro-cartilage central portion of the intervertebral disc exists between two vertebrae; it is kept in place by layers called annulus fibrosus i.e. a ring of fiber which forms the circumference of an intervertebral disc (See Figure 3.2)” (p. 53). The major role of the disc and elastic layers is being a physiological shock absorber. If it is not functioning properly because of an accident or any kinds of injury, transmission will be unsuitable.

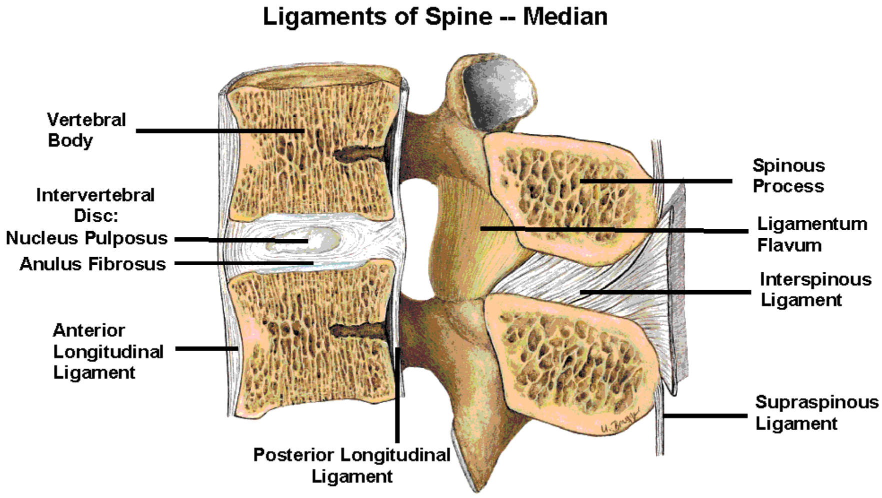


Figure 3.2 The section of spine and the structure of intervertebral discs (From MEDIC, 2005 [online])

Since intervertebral discs have visco-elastic structure, when the force applied, deformation of the disc starts and then returns rapidly to normal appearance. Nevertheless, if the force applied continuously below or above a threshold level, the disc shows a kind of deformation known as creep. Eklund and Corlett (1984) observe that “under compressive loading, the disk narrows as fluid is expelled and the superior and inferior vertebral bodies move closer together”. In addition, Bridger et al (1990) explain that “under traction (stretching or pulling forces), fluid moves into the disc and disc space becomes wider” (as cited in Bridger, 1995).

The pelvis, however, is another important component of the human skeleton system and contributor to sitting behavior. It transfers the weight of the upper segment of body to the proximal heads of the femurs in standing position. On the contrary, in sitting position, it transfers same weight to the ischial tuberosities i.e. the part of an ischia. When pelvis seen from above, the sacrum tends to slide forward. Nevertheless, under the weight of trunk, the tendency for the sacrum to slide forward anteriorly increases and the strong ligaments between the sacrum and the ilia, i.e. posterior sacroiliac ligaments that stabilize the joint, withstand this tendency. Because of this fact, a kind of pain that is different from low back pain is felt (Bridger, 1995).

Low back pain is a common complaint especially for people either standing or sitting long hours on any kind of seats and it is mainly resulted from incorrect postures. Degeneration of fourth and fifth lumbar intervertebral discs based on age and stooping strain creates a stress on lower lumbar spine. Keegan (1953) who is one of the first researchers on correct sitting positions discusses this fact with the following words:

> "Man's assumption of the erect posture has resulted in a lumbosacral region poorly constructed to support the strain of active physical life. It is a rare person who reaches middle age without experiencing some postural low-back pain when sitting or stooping. In middle-aged people some loss of elasticity has occurred in intervertebral discs and ligaments, and obliteration of the lumbar curve tends to force the degenerated and somewhat separated central portion of the lower lumbar discs posteriorly by hydraulic pressure from anterior wedging. This occurs in variable degree in sitting and causes painful stretching of the sensitive posterior longitudinal ligament of the disc, with pain in the mid-line of the lower back" (p.42).

Keegan (1953) concludes the source of low-back pain related to seating mainly from flexion or extension of lower intervertebral discs. He also adds, in an adult man/woman, the normal curve of the lumbar spine is determined by the trunk-thigh and the knee angles at approximately 135 degrees. The two factors; decrease of the trunk-thigh angle and consequent flattening of the lumbar curve and lack of primary back support over the vulnerable lower lumbar vertebral discs, are the main postural factors of low-back pain.

Schoberth (1962) has also studied on sitting posture and its problems. According to him, in a standing person, there is a vertical axis through the thigh and the pelvis approximately. In addition, a concavity i.e. lordosis occurs in the lower back. In contrast, when seated, the thigh is horizontal, the hip joint is flexed by about 60^o and the pelvis stretches along a sloping axis. The lumbar region then exhibits a convexity, or kyphosis. In his study, he examined 25 people seated upright; found that an average flexion of 60^o in the hip joint and a 30^o flexion in the lumbar region and even in the ordinary relaxed position there is considerable loading. If the body is bent forward when sitting to do some actions such as reading, writing or working, it will be loaded more on 4^{th} and 5^{th} lumbar discs because of the front edges of the lumbar vertebrae are pressed towards each other with considerable force (50-150 kgf), thus the lumbar vertebrae press the discs back towards the spine but the rear edges of the vertebrae are pulled apart with a corresponding force (as cited in Mandal, 1981).

In conclusion, the central gravity of body passes through the trunk and the feet when standing and muscular activity of those postural muscles holding the trunk erect will occur when there are no continuous counteracting moments to support the trunk. Lumbar lordosis of the spine plays a major role in reduction of this muscle activity. It provides the lumbar vertebrae close to or below the central gravity of trunk, arms and head. Thus, the central gravity of the trunk can be kept as balanced over the lumbar vertebrae with the help of small muscular activity on anterior and posterior. For sitting posture, on the other hand, the lumbar lordosis has same role, however, about 90^o angle between trunk and thighs in sitting leads to a reduction in lumbar lordosis because of the backward rotation of the pelvis and this reduction also lead to an increased tension in the erector spinae of the lumbar area and from passive structures such as ligaments (See Figure 3.3).

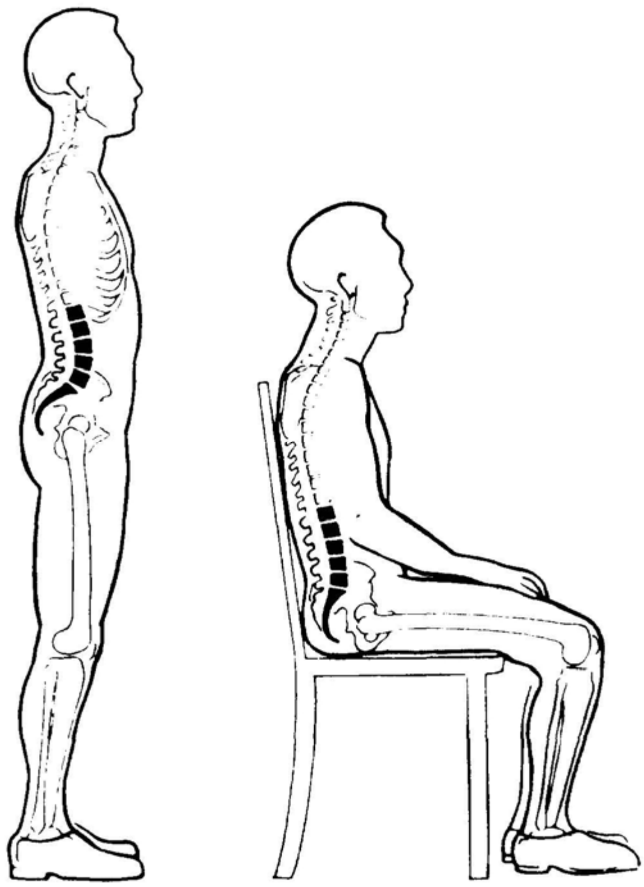


Figure 3.3 The appearance of spinal column while standing and sitting (From Mandal, 1981)

Because of this fact, in the origin of many studies on seating and seat design, prevention of backward rotation of the pelvis becomes basic aim (Kroemer and Robinette, 1968). In addition, using backrest and armrests may decrease the tension on discs. Kroemer et al (1994) summarize the fact with the following words:

> "Experiments on sitting postures yield three important findings. The first is that sitting without use of backrest or of armrests may increase disc pressure over standing by one-third to one half. The second is that there are no dramatic disc- pressure differences between sitting straight, sitting relaxed, or sitting with supported arms, if there is no backrest or only a small lumbar board. The third finding is that leaning on a well-designed backrest can bring about disc pressures that are as low as experienced by a standing person, or even lower." (p. 438).

On the other hand, using a high and straight backrest affects lumbar support negatively. In this subject, Goossens et al (2003) have done a biomechanical study to determine the influence of scapular support on the effects of lumbar support (See

Figure 3.4). They have measured the forces on shoulder and seat separately, and calculated the force on the pelvis. They have found three important conclusions that are:

"1) Lumbar support force increases with increasing free shoulder space and backrest inclination.

2) Scapular support force decreases with increasing free shoulder space and increases with backrest inclination.

3) Back muscle activity decreases with increasing free shoulder space and backrest inclination." (p.529).

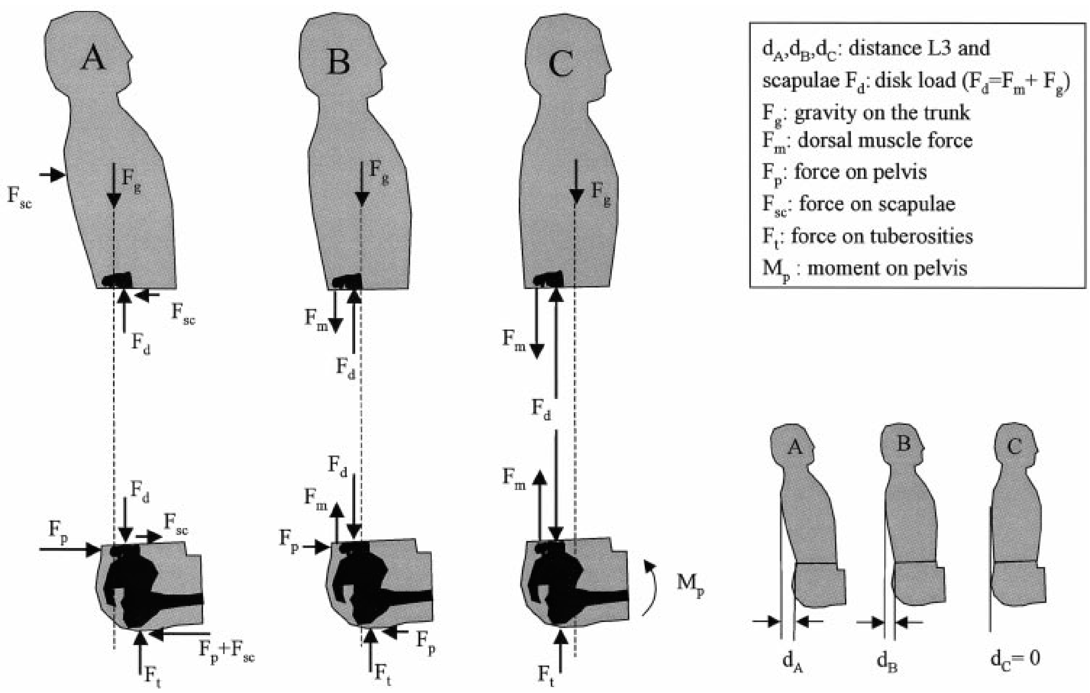


Figure 3.4 Three different situations in which the influences on back muscle forces and supporting forces were studied by Goossens et al as a function of the distance (d) between the tangent to the scapulae and the parallel tangent to the pelvis. (From Goossens et al, 2003).

They also recommend that a minimal free shoulder space of 6 cm should be available in chairs to permit better adaptation to the spinal contour and to provide lumbar support.

Another approach stressed more on seat pan is adopted by Corlett (1999) and Goonetilleke and Feizhou (2001). Corlett (1999) designed an office chair called

“Nottingham Seat”. It takes the form of a seat pan which is curved from front to back. He brings forward that this curve is chosen so that the sitter can have the ischial tuberosities on a horizontal part of the seat pan while the sloping –forward thighs can also rest on the anterior portion. Moreover, at whatever seat height is chosen by the sitter, the pan can be rotated so that the thighs have the necessary slope to allow the feet to reach the floor (See Figure 3.5).

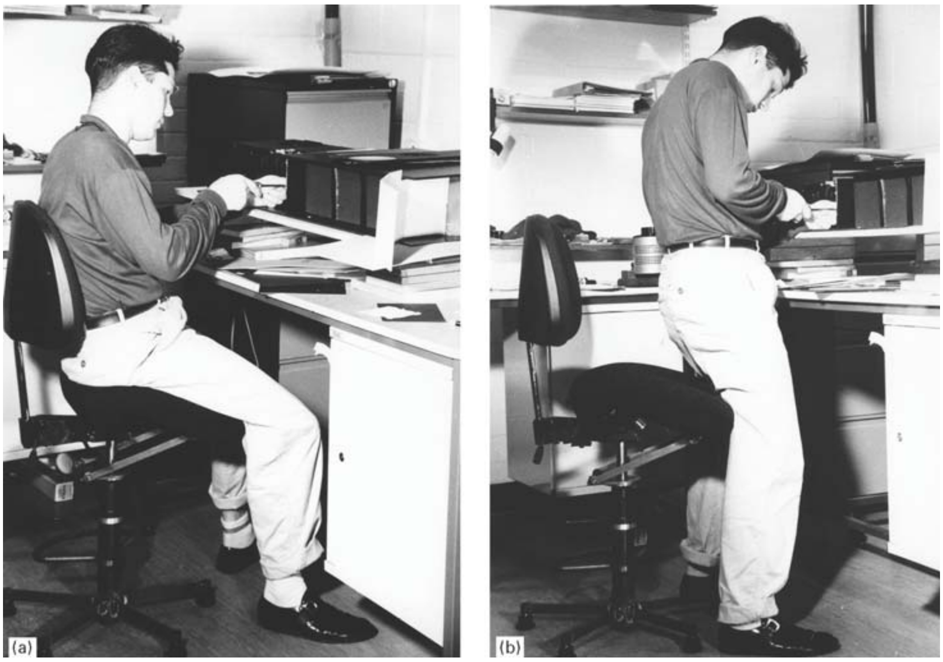


Figure 3.5 Corlett’s seat called “Nottingham Seat” (From Corlett, 1999)

Fundamentally, maintaining that trunk posture over long periods is rather uncomfortable. It is because of the tension of muscles to carry on keeping the body in any position. Consequently, the posture should be changed in sitting or standing often to minimize the negative effects on spinal and muscular structures of the human body. Blood circulation, however, affects the relation between the lower extremities and the trunk of the sitter as a consequence of increasing pressure in veins due to prolonged seating. Swellings start and they lead to numbness in the lower limbs (Asatekin, 1975). Seat pan height increases or decreases of such swellings. Asatekin (1975) states the causes of these with the following words:

> “Swellings are increased even more if the vein is constricted at some point, obstructing the venous return. Such a constriction usually happens to femoral and popliteal vein when sitting on a too high chair. When the seat is higher than it should be, the feet cannot touch the ground properly and the part of the body weight that should be transferred to the ground by the feet squeezes the

> hind muscles of the thigh and the popliteal artery and vein between the seat surface and the femur" (p. 67).

On the other hand, continuing the constriction of arteries bring about a fact called "ischemia". Two regions in which can be seen to this fact during the prolonged sitting is popliteal and femoral by the front edge of the seat pan and the buttocks by the rear end of the pan. Sliding forward leads the body weight to buttocks. Therefore, the numbness observed in the popliteal region is moved to the buttock region. If the height of seat pan has a lower value, then excessive hip and knee flexions will be happened (Asatekin, 1975). Lumbar support, however, can prevent this kind of excessive flexion taken place in the buttock region. This is because it averts the body from sliding forward. On the other hand, the height of the lumbar support has to be specified correctly due to keeping lumbar lordosis aforementioned from this fact above.

3.1.2 The psychological aspects of seating

With the help of his sophisticated senses, the human-being has an excellent analysis capacity against foreign factors. Nonetheless, the interpretations of these factors by human brain and its reactions to the conclusions of these interpretations change from one person to another. In the literature on the subject of psychological factors of seating, it is seen that psychology of seating is examined with two concepts that are comfort and discomfort. According to Oxford Word-power Dictionary (1995), *comfort* means "the stage of having everything your body needs or of having a pleasant life, the state of being relaxed or something that makes your life easier or more pleasant" (p. 121). In contrast, *discomfort* means "a slight feeling of pain, something that makes you feels uncomfortable or that causes a slight feeling of pain or a feeling of embarrassment" (p. 181). Slater (1985), however, defines *comfort* scientifically as "a pleasant state of physiological, psychological and physical harmony between a human-being and the environment" (p. 4). In addition, Richards (1980) underlines that "comfort is a state of a person involving a sense of subjective well-being, in reaction to an environment or situation" (as cited in Looze et al, 2003). These definitions stress that, especially for comfort, it depends on many factors and it is not only the opposite of discomfort.

Today, the concept of comfort is almost the unique key for the preference of consumers in any product especially in western countries wherein there are high competitive market conditions between manufacturers. Producers recognize the role of comfort in product-buying process and they are working to improve their products' comfort level. On the other hand, employers are also getting interested in comfortable environment and equipment for workers so as to increase their performance and make up a healthy atmosphere. As a product, the comfort or discomfort of seats however is probably much more important than the other products because they are used by all people one way or another in the world.

Study on sitting comfort is mainly concerned with office seats, passenger seats in public transports and driver seats in cars, buses and agricultural machines like tractors. Nevertheless, many understandings and techniques are in use to comment and to measure the level of comfort or discomfort. Actually, apart from this fact, there is no extensively established description of comfort or sitting comfort (Looze et al, 2003). Some researchers have argued the concept of comfort/discomfort from one dimension like Hertzberg (1972) and Branton (1969). Hertzberg (1972) referred to comfort as "absence of discomfort… a state of no awareness at all of a feeling" (p. 41). Branton (1969) concurred that comfort "does not necessarily entail a positive effect" (p. 205). Zhang et al (1996) interpret these two arguments with the following words:

> "… comfort is conceptualized as a neutral feeling and only two discrete stages are possible: comfort present or comfort absent. A logical conclusion is that there cannot be a graded scale to measure comfort, and the use of a Likert scale would hence rest on erroneous assumptions of the properties of comfort (p. 378)."

In contrast, several researches used graded Likert scales successfully to measure comfort levels of significant differences among chairs can be found in the literature such as Gross et al (1992), Habsburg and Middendorf (1977) and Kamijo et al (1982). And with words of Zhang et al (1996), this shows us "there is indirect evidence to favor a unidimensional scale for comfort/discomfort" (p. 378).

The differences and relations between the concept of comfort and discomfort can be realized from the conclusion of many scientific studies. However, there are some points accepted in all these studies collectively. Looze et al (2003) orders these points as:

“1) Comfort is a construct of a subjectively-defined personal nature

2) Comfort is affected by factors of a various nature (physical, physiological, psychological)

3) Comfort is a reaction to the environment” (p. 2).

Hertzberg (1958), Floyd and Roberts (1958) suggest comfort as two distinct stages that are comfort presence and absence. Additionally, they define former one as the lack of latter one. Conversely, Zhang et al (1996) put forward that comfort and discomfort are affected by different variables; Discomfort mainly deals with physiological and biomechanical factors, whereas comfort mainly deals with aesthetics. With their words:

> “From the literature it seems that comfort and discomfort may be associated with different factors. There is evidence to link discomfort with biomechanical factors and fatigue, but there is less information as to which factors are related to comfort. No theory or model has been published that can satisfactorily explain any differences between the two” (p. 378).

To be able to define these different variables and to pose a unified model, Zhang et al (1996) sent out a questionnaire. One hundred and four respondents provided descriptors of the feelings when they felt comfortable or discomfortable in a seated workspace. Then, to be able to confirm these descriptors, 34 participants that different from the first group of people was asked to rate these descriptors on a 5-points scale, from ‘very strongly related to comfort/discomfort’ to ‘not related at all’. After these steps, 43 descriptors remained: 21 for discomfort and 22 for comfort. Afterwards, a classification analysis was performed, involving multi-dimensional scaling, factor analysis and cluster analysis, to statistically identify the factors related to comfort and discomfort (Figure 3.6). It was concluded that comfort and discomfort are based on independent factors. Feelings associated with discomfort are generally connected with “pain, tiredness, soreness and numbness, fatigue, environment and anxiety”. These feelings are assumed to be imposed by physical constraints and mediated by physical factors like joint angles, tissue pressure and circulation blockage. In contrast, comfort is related with feelings of relaxation and well-being. In another study, realized by Halender and Zhang (1997) on 20 and 37 participants in that order, the deduction of the former study was established. In addition, it was found that aesthetic design matters with regard to comfort, but not to discomfort. Moreover, low values of discomfort scores were associated with a full range of values of overall comfort rating from 1, while comfort ratings decreased sharply to 9 with increasing discomfort scores. “This fact indicates that, when discomfort factors are present, comfort factors become secondary in the comfort /discomfort perception. Therefore discomfort has a dominant effect” (Looze et al, 2003).

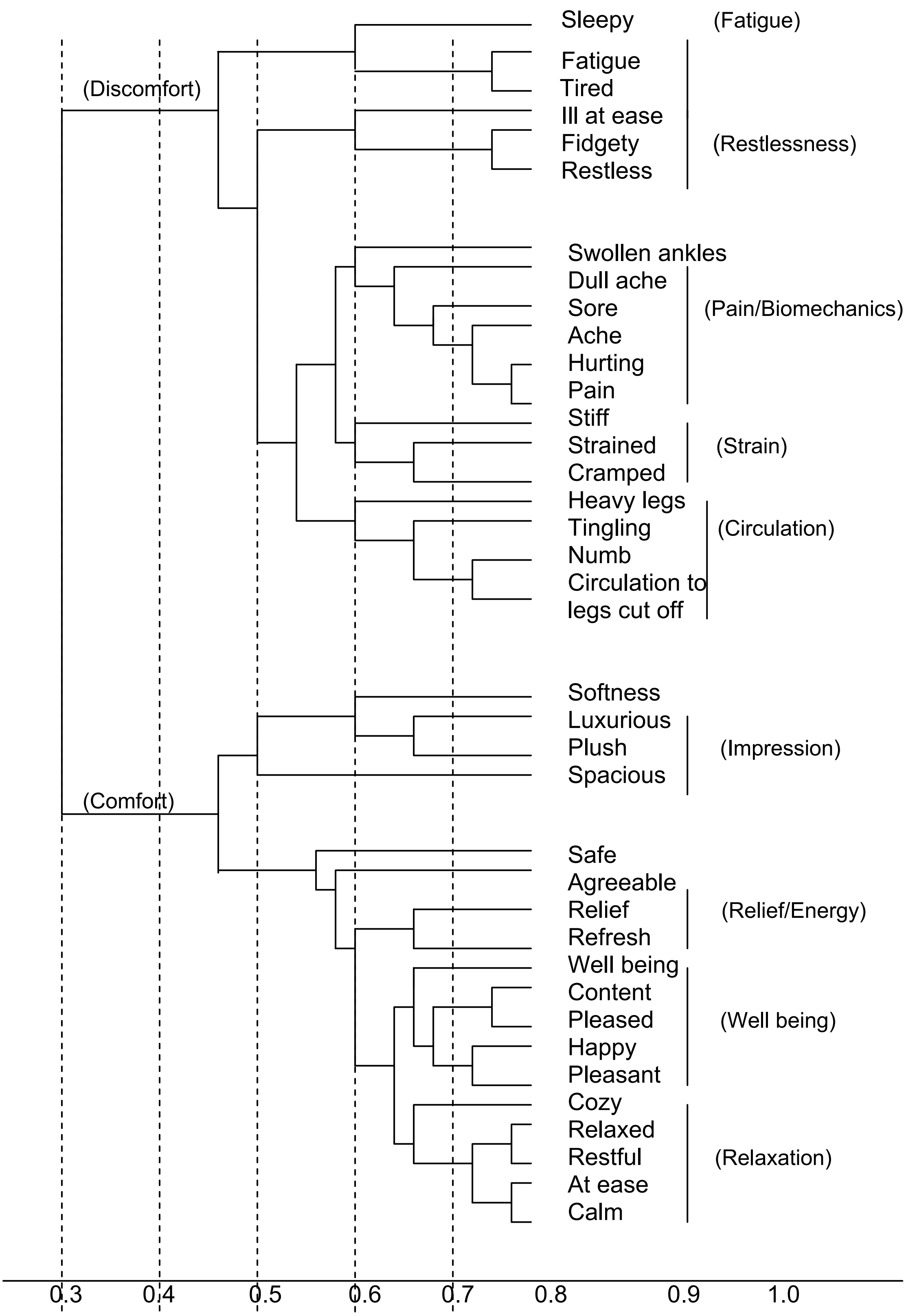


Figure 3.6: Simplified structure of cluster analysis of final descriptors (From Zhang et al, 1996, p.387)

To understand diverse factors underlying sitting comfort/discomfort more deeply, Looze et al (2003) have built a model as presented in Figure 3.7:

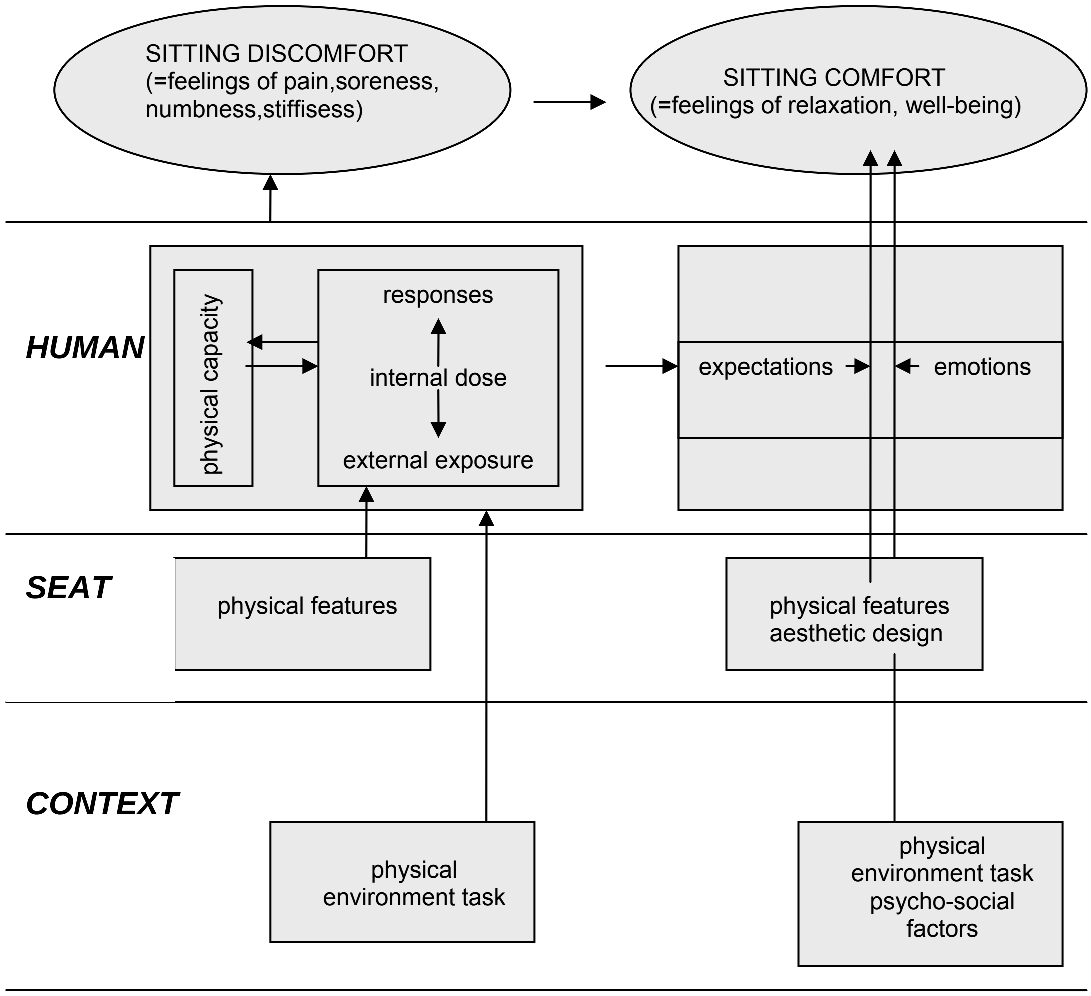


Figure 3.7: Theoretical model of comfort and discomfort and its underlying factors at the human, seat and context level (From Looze et al, 2003, p.988)

This theoretical model is analyzed in two parts. As can be seen, the left part of the model deals with discomfort. Winkel and Westgaard (1992) and Armstrong et al (1993) developed models on the etiology of work-related physical complaints. They think the terms “exposure”, “dose”, “response” and “capacity” are primary subjects. Armstrong et al (1993) define that exposure refers to the external factors producing a disturbance of the internal state (dose) of an individual. Looze et al (2003) evaluate that “The dose may evoke a cascade of mechanical, biochemical or physiological responses. The extent to which external exposure leads to an internal dose and responses depends on the physical capacity of the individual (p. 988). In other words, it can be mentioned that the structural features of any seat, the atmosphere and the task affect directly on a seated person and they lead to extreme loads on bone and joint angles of the body. With Looze et al (2003) words:

> "These loads may yield an internal dose in terms of muscle activation, internal force, intra-discal pressure, nerve and circulation inclusion, and skin and body temparature rise, provoking further chemical, physiological and biomechanical responses. By extrocepsis (stimuli from skin sensors), propriocepsis (stimuli from sensors in the muscle spindle, tendons and joints), interocepsis (stimuli from internal organ systems) and nocicepsis (stimuli from pain sensors), the perception of discomfort might be established" (p. 988).

The right parts of the model cope with comfort and it is presented external and influential factors on comfort at the stages of seat and context. When looked to context stage, it can be realized that in addition to role of physical factors, psycho-social factor like family or job environment also may be influential. On the other hand, at the seat level, aesthetic factors and design of the seat may be added to these two basic factors. Finally, at the human level, thanks to the internal or personal factors defined as the individual expectations and other individual feelings and emotions, comfort can be started to be felt. Looze et al (2003) put forward what can be inferred from this model as follows:

> "From this model it can be expected that for discomfort, the relationship of objective measures with discomfort would be stronger than for comfort, as the link between discomfort and objective measures of physical exposure, dose or response is more direct" (p. 988).

When investigated, it is observed that studies on comfort and/or discomfort focus mainly on the evaluation and the correlation between objective and subjective measures. According to Looze et al (2003), it may be aligned these objective measures as measurements of posture, number of body movements, estimations of muscle activation and muscle fatigue by electromyography (EMG), measurements of stature loss (spinal shrinkage) and foot volume change. Additionally, in many researches, subjective measurements may be achieved as one variable on a single scale from excessive discomfort to excessive comfort. Furthermore, there are no studies in which comfort and discomfort are evaluated one by one on different scales. Another interesting point is that the anthropometric aspects in the evaluation process of comfort and discomfort are neglected in almost all these studies.

3.1.2.1 Passenger comfort

In transportation vehicles, the formation of comfort and discomfort of a passenger pursues a similar line as the formation of general concept of comfort and discomfort. However, a journey has a complex structure and it can be evaluated as, before, during and after the journey. Mayr (1959) who has studied about passenger comfort introduces the term ‘traveling comfort’ which, he considers, is composed of three sub-factors: Riding comfort, Local comfort and Organizational comfort.

Mayr (1959) has developed a diagram to show the interrelationship of factors inside the vehicle atmosphere that supply to passenger comfort (Figure 3.8).

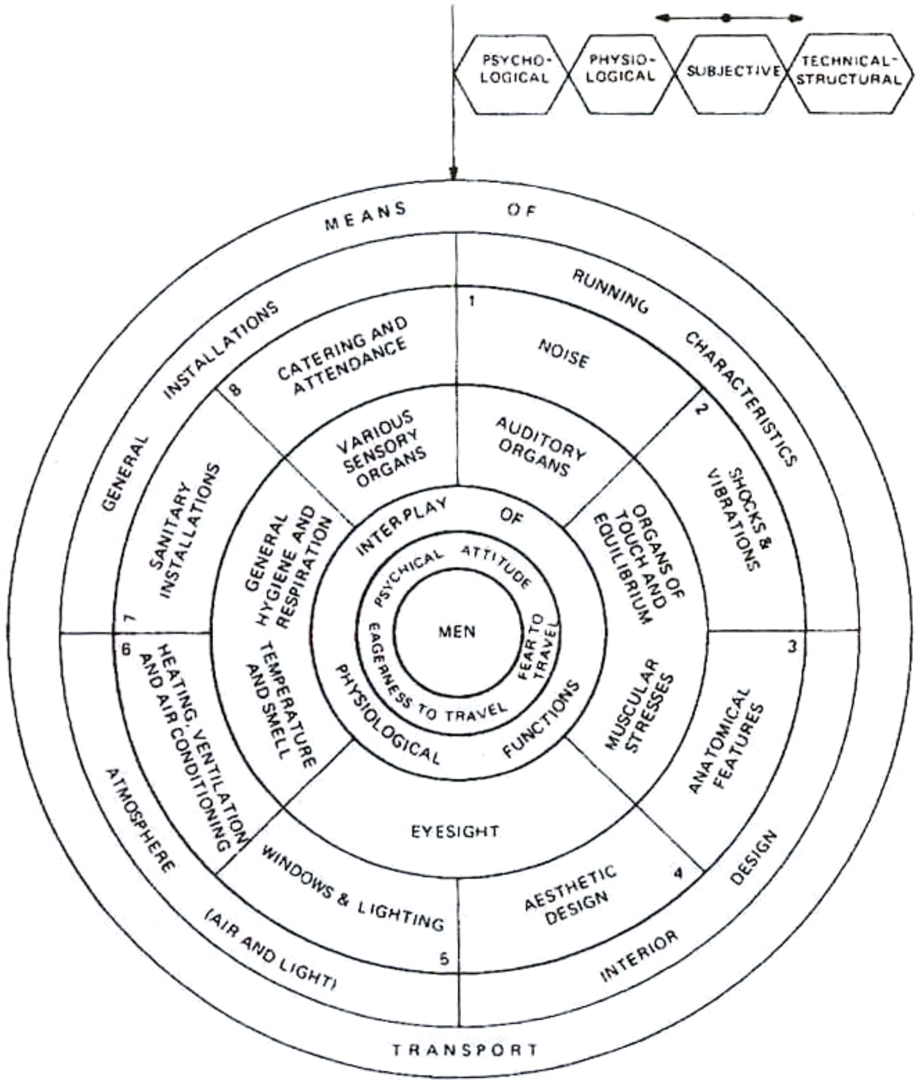


Figure 3.8: Mayr’s circle of riding comfort (From Oborne, 1978, p. 2)

Local comfort can be felt at stations, airports and interchange points. It includes experience of short, dependable and comfortable transfers, apparent signs and fine waiting rooms. Organizational comfort includes factors of an organizational source such as good connections, and acceptable frequency and trustworthiness of service. In addition, the passenger's subjective trade-off between the journey time, cost, the reason for the journey, and the passenger' expectation of the journey comfort influence the comfort level (Oborne, 1978).

3.2 The anthropometric dynamics of seating

Providing or feeling comfort depends on a perfect harmony of many physical and psychological factors. Generally these points are interlaced or chained to each other. On the other hand, physical factors have also natural and chained sub-groups within. For seating or in seat design, anthropometry may be one of the most powerful ring of this chain. It is because when designed any kind of seat for any place, the shape of the seat must be defined according to anthropometric data of the related population. However, depending on the purpose of the seat, some anthropometric data may or may not be used in the design process. Thus, before starting such a design process, it is first needed to define the user, the purpose of the seat and the appropriate data. For this study, as the subject is about the passenger seats in intercity coaches, anthropometric measurements are chosen and matched with seat components based on this fact.

It is observed that there are few studies on anthropometric aspects of passenger seats in the literature. Studies related with anthropometry of seats are generally done on driver's seats or for better office environment; they are done on visual display terminals (VDT). Similarly, for passenger seats in intercity coaches, there is hardly a direct standard that may be determinative and helpful to the designers. Nevertheless, for selecting related anthropometric, population and postural variables, there are some standards developed by International Organization for Standardization (ISO) that are **ISO 7250:1996** Basic human body measurements for technological design, **EN ISO 9241-5:1999 part 5** Ergonomic requirements for office work with visual display terminals (VDTs)-workstation layout and postural requirements and **ISO 15537:2004** Principles for selecting and using test persons for testing anthropometric aspects of industrial products and designs contain useful information. In addition, the study of Jung et al (1998) one of the most related study in the literature that is performed on anthropometric features and their influences on designing of passenger seats for Korean high speed train coaches is an important starting point.

The primary aim of all seats is sitting. However, according to the place of usage, person and duration, the shapes of these seats vary from one to another. For passenger seats in intercity coaches, parts that will be analyzed and their anthropometric equivalents are shown in Table 3.1:

Table 3.1: Parts, dimensions and their anthropometric variables of passenger seats

Main Seat Parts	Dimensions	Anthropometric Variables
Seat Pan	Height Width Length	Popliteal Height, Sitting Hip Breadth, Sitting Buttock to Popliteal Length, Sitting
Backrest	Height Width	Eye Height, Sitting Body Breadth, Maximum
Armrest	Height Width Length	Elbow Height, Sitting Wrist Breadth Elbow-Wrist Length

Anthropometric variables for each seat part shown in this table are standardized and published by ISO with two standards-ISO 7250:1996 and EN ISO 9241-5:1999 part 5. According to these standards, descriptions, acquiring methods and instruments to take measurement can be shown in the following figures:

1- Popliteal height, sitting

Description: Vertical distance from the foot-rest surface to the lower surface of the thigh immediately behind the knee, bent at right angles.

Method: Subject holds thigh and lower leg at right angles during measurement. Subject may sit, or stand with the foot placed on a raised platform. The movable arm of the measuring instrument is pushed gently against the tendon of the relaxed biceps femoris muscle.

Instrument: Anthropometer.

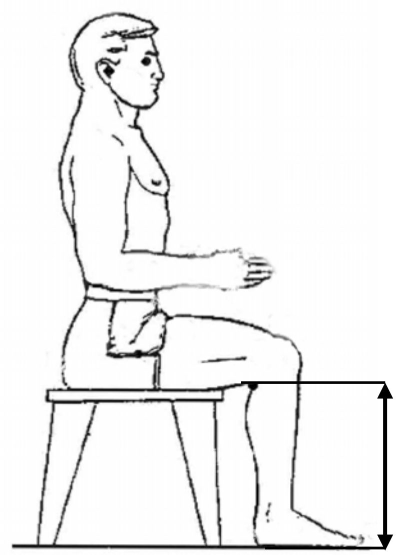


Figure 3.9: Popliteal height, sitting (Definition from ISO 7250, 1996, p. 10; Illustration from Hsiao et al, 2005, p. 328).

2- Hip breadth, sitting

Description: Breadth of the bodv measured across the widest portion of the hips.

Method: Subject sits with thighs fully supported and lower legs hanging freely, knees together. Measurement is taken without pressing into the flesh of the hips.

Instrument: Large spreading caliper.

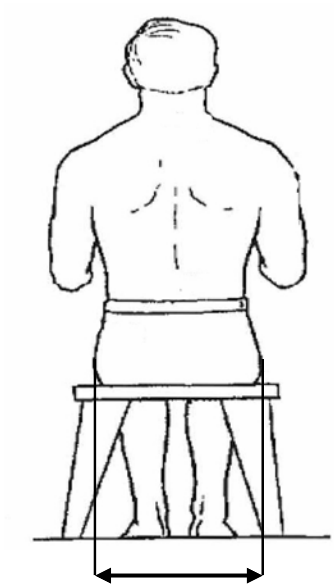


Figure 3.10: Hip breadth, sitting (From ISO 7250, 1996, p. 10; Illustration from Hsiao et al, 2005, p. 328).

3- Buttock to popliteal length, sitting

Description: Horizontal distance from the hollow of the knee to the rearmost point of the buttock. See figure 48.

Method: Subject sits fully erect with thighs fully supported and the sitting surface extending as far as possible into the hollow of the knee, lower legs hanging freely. The position of the rearmost point of the buttock is vertically projected onto the sitting surface by means of a measuring block which touches the buttocks. Distance is measured from the measuring block to the forward edge of the sitting surface.

Instrument: Anthropometer, measuring block.

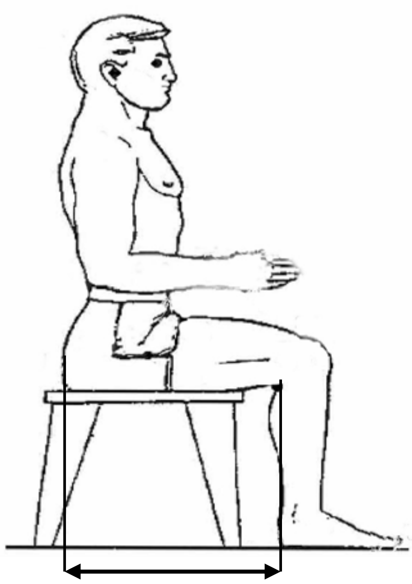


Figure 3.11: Buttock to popliteal length, sitting (From ISO 7250, 1996, p. 18; Illustration from Hsiao et al, 2005, p. 328).

4- Eye height, sitting

Description: Vertical distance from a horizontal sitting surface to the outer corner of the eye.

Method: Subject sits fully erect with thighs fully supported and lower legs hanging freely. Head is orientated in the Frankfurt plane.

Instrument: Anthropometer.

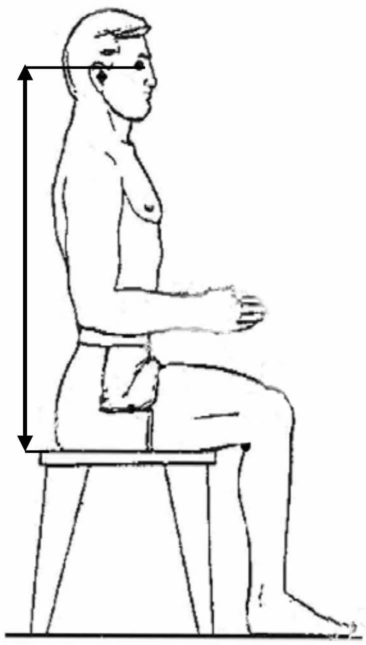


Figure 3.12: Eye height, sitting (From ISO 7250, 1996, p.7; Illustration from Hsiao et al, 2005, p. 328).

5- Body breadth, maximum

Description: Distance across the maximum lateral protrusions of the right and left deltoid muscles.

Method: Subject sits or stands fully erect with shoulders relaxed.

Instrument: Large sliding caliper or large spreading caliper.

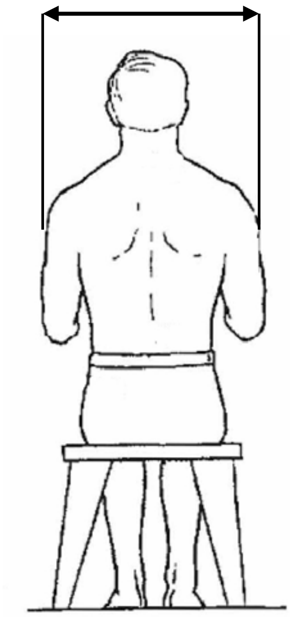


Figure 3.13: Body breadth, maximum (From ISO 7250, 1996, p. 9; Illustration from Hsiao et al, 2005, p. 328).

6- Elbow height, sitting

Description: Vertical distance from a horizontal sitting surface to the lowest bony point of the elbow bent at a right angle with the forearm horizontal.

Method: Subject sits fully erect with thighs fully supported and lower legs hanging freely. Upper arms hang freely downwards and forearms are horizontal.

Instrument: Anthropometer.

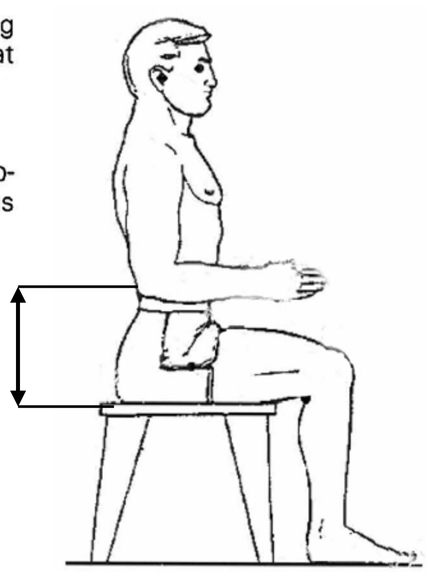


Figure 3.14: Elbow height, sitting (From ISO 7250, 1996, p.8; Illustration from Hsiao et al, 2005, p. 328).

7- Wrist breadth

Description: The distance between the radial and ulnar styloid prominences.

Method: Subject stands, with his upper arm hanging at his side and his elbow bent. Using the sliding caliper, with maximum pressure to compress the flesh and measure.

Instrument: Sliding caliper

Figure 3.15: Wrist breadth (From Hertzberg et al, 1963, p. 161; Illustration from Hsiao et al, 2005, p. 328).

8- Elbow-wrist length

Description: Horizontal distance from wall to wrist (ulnar styloid process).

Method: Subject sits or stands erect, back to wall. Upper arms hanging freely downwards, elbows touching wall, forearms horizontal.

Instrument: Anthropometer.

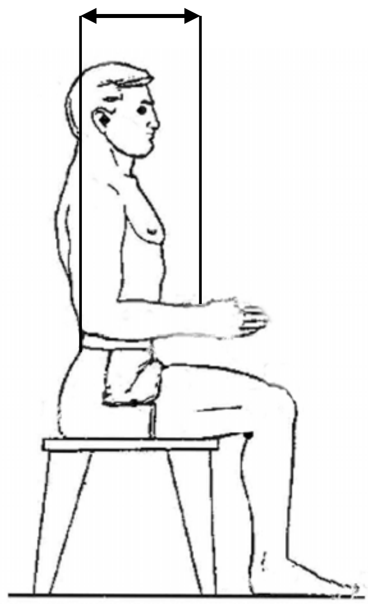


Figure 3.16: Elbow-wrist length (From ISO 7250, 1996, p.8; Illustration from Hsiao et al, 2005, p. 328).

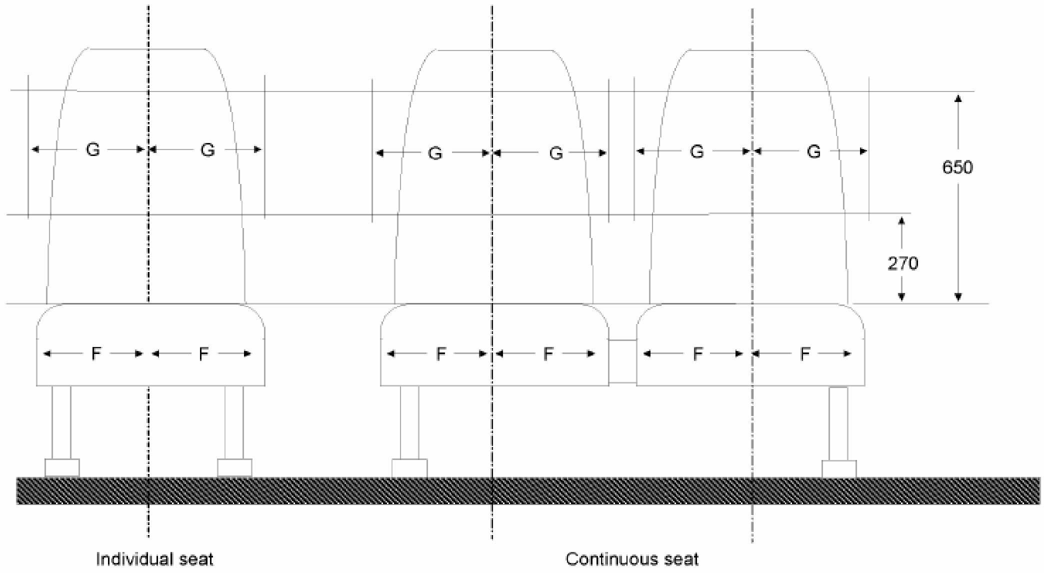
3.3 Seats in inner-city and long-time travel vehicles and their differences from each other

Before starting a design process for any kind of product, the purpose and the user of this product has to be made clear appropriately. Likewise, the differences between public human transportation and for the purpose of long-time travel one, while the common point for both seems human transportation, vehicles used for such purpose can be separated from each other with different structures and characteristics. In European countries, specifications of any public or long-time travel human transportation vehicles may be arranged in the directive 2001/85/EC relating to special provisions for vehicles used for the carriage of passengers comprising more than eight seats in addition to the drivers' seat by European Commission (EC). This regulation is also accepted without changing anything and put into practice by Ministry of Industry and Trade in Turkey. According to the directive, vehicles are categorized whether exceeding 22 passengers in addition to the driver or not. Since the subject in this study related with long time travel coaches, proper comparisons among short and long time travel coaches can only be achieved with vehicles exceeding 22 passengers in addition to driver. In the directive, this type of vehicles is divided three sub-groups based on their classes:

> "Class 1: Vehicles constructed with areas for standing passengers, to allow frequent passenger movement
>
> Class 2: Vehicles constructed principally for the carriage of seated passengers, and designed to allow the carriage of standing passengers in the gangway and/or in an area which does not exceed the space provided for two double seats
>
> Class 3: Vehicles constructed exclusively for the carriage of seated passengers" (p. 8).

Thus, inner-city vehicles may be entitled as Class 1 or 2. On the other hand, long time travel vehicles may be involved to Class 3. Naturally, the factors such as travel time, road structure, intended transportation capacity determine the inner and outer characteristics and therefore standards of vehicles. In terms of passenger seats, same factors are also effective for constituting their shapes and spaces for seated passengers. In the directive 2001/85/EC, the seat shape differences among classes of coaches are also regulated comprehensively in Annex 1, Paragraph 7.7.8 and its explanatory diagrams (See Appendix A). According to this:

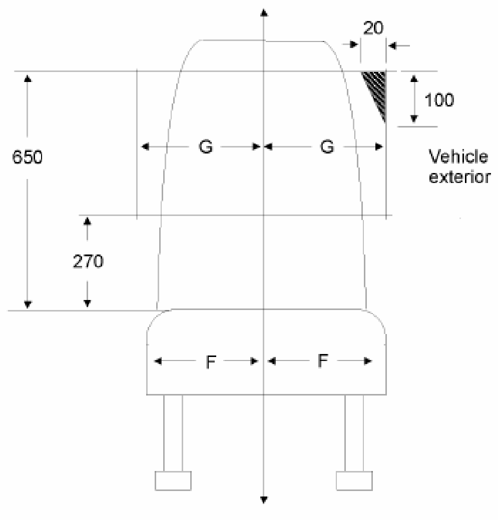
3.3.1 Minimum seat width



	G (mm) min	
F (mm) min	Continuous seats	Individual seats
200 (*)	225	250

(*) 225 for Class III

Figure 3.17: Dimensions of passenger seats (From directive 2001/85/EC).



G = 225 mm if continuous seat
G = 250 mm if individual seat
G = 200 mm for vehicles less than 2,35 m wide

Figure 3.18: Permitted intrusion at shoulder height-transversal section of the minimum available space at shoulder height for a seat adjacent to the wall of the vehicle (From directive 2001/85/EC).

The minimum width of the seat cushion, dimension F (See Figure 3.17), measured from a vertical plane passing through the centre of that seating position, will be for:

Class 1, 2, A, B → 200 mm
Class 3 → 225 mm

The minimum width of the available space for each seating position, dimension G (See Figure 3.18) measured from a vertical plane passing through the centre of that seating position at heights between 270 and 650 mm above the uncompressed seat cushion will be not less than:

Individual seats → 250 mm
Continuous rows of seats → 225 mm

For vehicles having a capacity not exceeding 22 passengers, in the case of seats adjacent to the wall of the vehicle, the availability space does not include, in its upper part, a triangular area 20 mm wide by 100 mm high (See Figure 3.18). In addition, the space needed for safety belts and their anchorages and for the sun visor should be considered as exempted.

3.3.2 Minimum depth of seat cushion (dimension K)

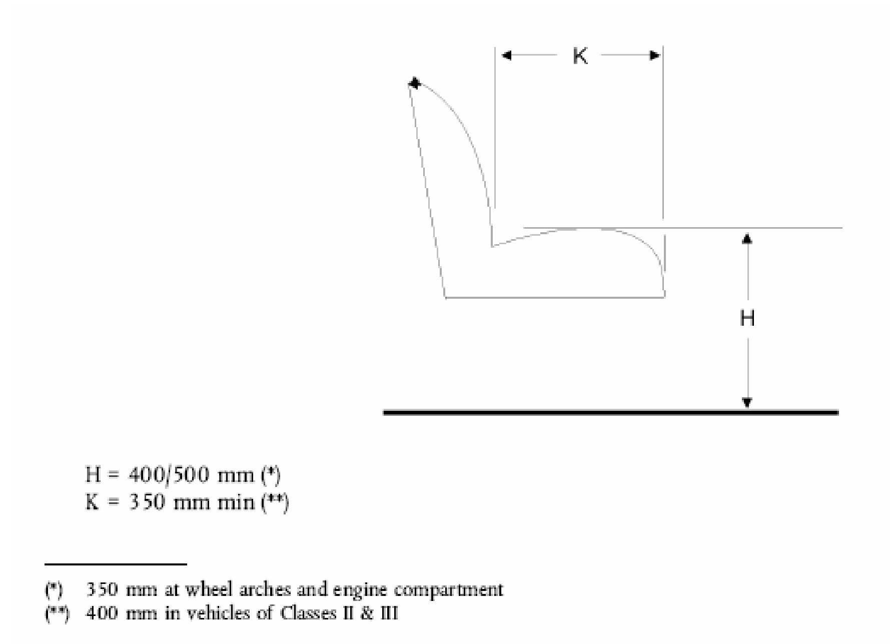


Figure 3.19: Seat cushion depth and height (From directive 2001/85/EC).

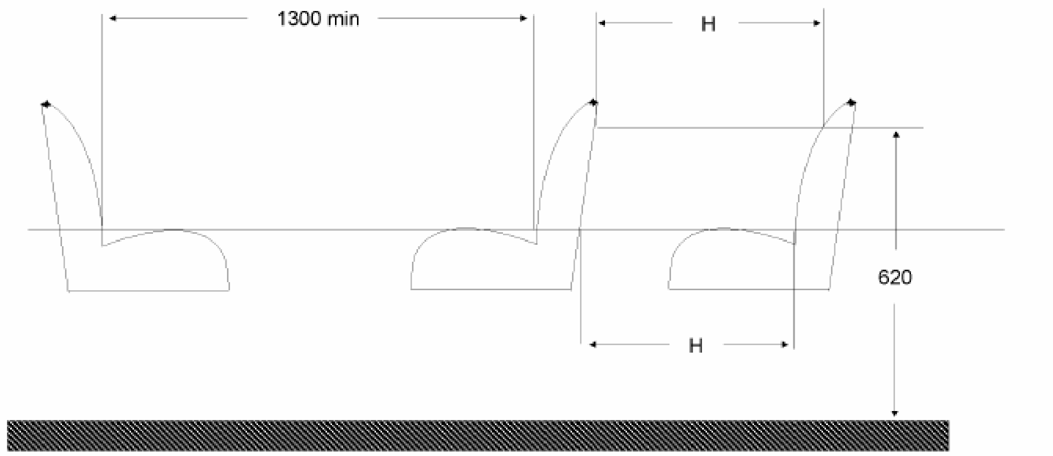
The minimum depth of a seat cushion (See Figure 3.19) will be:

350 mm in vehicles of Class 1, A and B
400 mm in vehicles of Class 2 and Class 3

3.3.3 Height of seat cushion (dimension H)

The height of the uncompressed seat cushion relative to the floor will be such that the distance from the floor to a horizontal plane tangential to the front upper surface of the seat cushion (See Figure 3.19) is between 400 and 500 mm: this height may however be reduced to not less than 350 mm at the wheel arches and the engine compartment.

3.3.4 Seat spacing



	H
Classes I, A and B	650 mm
Class II and Class III	680 mm

Figure 3.20: Seat spacing (From directive 2001/85/EC).

In the case of seats facing in the same direction, the distance between the front of a seat squab and the back of the squab of the seat preceding it (dimension H), shall, when measured horizontally and at all heights above the floor between the level of the top surface of the seat cushion a point 620 mm above the floor, not less than.

All measurements shall be taken, with the seat cushion and squab uncompressed, in a vertical plane passing through the centre line of the individual seating place.

Where transverse seats face one another the minimum distance between the front faces of the seat squabs of facing seats, as measured across the highest points of the seat cushions, shall be not less than 1 300 mm.

Measurements shall be taken with reclining passenger seats and adjustable driving seats with their seat backs and other seat adjustments in the normal position of use specified by the manufacturer.

Measurements shall be taken with any folding table fitted to a seat back in the folded position.

Seats which are mounted on a track or other system which permits the operator or the user to easily vary the interior configuration of the vehicle shall be measured in the normal position of use specified by the manufacturer in the application for the approval.

3.3.5 Space for seated passengers

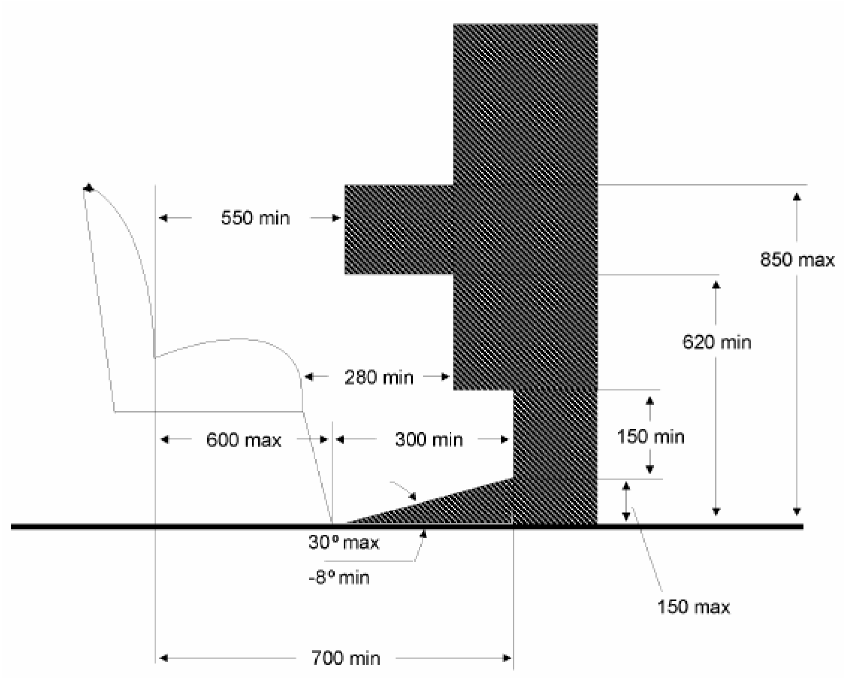


Figure 3.21: Space for seated passengers (From directive 2001/85/EC).

A minimum clear space in front of each passenger seat shall be provided as shown in Figure 3.21. The seat back of another preceding seat or a partition whose contour corresponds approximately to that of the inclined seat back may intrude into this space as provided by seat spacing (See section 3.3.4). The local presence in this space of seat legs shall also be permitted provided that adequate space remains for the passenger's feet. In the case of seats alongside the driver's seat in vehicles with up to 22 passengers, intrusion of the dashboard, instrument panel, windscreen, sun visor, seat belts and seat belt anchorages will be allowed.

As can be seen in directive 2001/85EC, absolute differences can be realized in almost all dimensions of passenger seats among Class 1-2 and Class 3 coaches. In addition, it can be without doubt that the minimum and maximum dimensions of seats of Class 3 coaches have bigger values than other Classes. Seat cushion depth is an obvious example to this fact-50mm plus for Class 3 than Class 1, A, B (See section 3.3.2)- The fundamental reasons of this lie under the aim of vehicles aforementioned. However, for Turkey, the subject becomes more important than another European country due to higher usage frequency in all Classes.

3.3.6 The evaluation of the directive called 2001/85/EC

It is observed that the regulations mentioned in the European directive called 2001/85/EC shows general guidelines rather than representing specified comfort margins. In this directive, it is not discussed the sources of these guidelines, if any, which anthropometric studies used for or how to combined them. In addition, there seems not any reference at the end of this directive. Therefore, it is not possible to define a comfort bound based on this directive for passenger seats easily. The guidelines represented in the directive also offer to all countries without a difference. Such an approach makes difficult for reflecting anthropometric differences amongst populations when specifying seat dimensions. To prevent this problem, further comparative studies have to be performed among the regulation, the local anthropometric studies and the seats.

CHAPTER 4

INTERCITY COACHES IN TURKISH TRANSPORTATION SYSTEM AND THEIR PASSENGER SEATS

4.1 The overview of transportation system in EU and Turkey and the position of intercity coaches

The word “transportation” contains wide meanings for many disciplines. However, in everyday life, it is used for carrying persons and/or goods from one point to another by means of various equipment that are passenger cars, buses, lorries, trains (composed of locomotive and wagons), inland waterway vessels, aircrafts, road trailers and semi-trailers, rail goods vehicles, bicycles and powered two-wheelers. Human transport, on the other hand, has an undeniable share in total transport activity. Within human transport, firstly, the majority of the share belongs to passenger cars. The constantly growing demand for personal mobility leads to an important increase in the number of passenger cars world wide. For instance, In 2000, 177 million passenger cars were registered for use on European Union-15 roads, an impressive 184 % growth in three decades (annual average growth rate: 3.5 %).

Buses and coaches are secondary equipments on the roads of EU countries. In these countries, the amount of buses and coaches developed less than passenger cars. Nevertheless, a 62% increase at EU-15 level was recorded for the 1970-2000 period. On the other hand, in Central European countries with Turkey, the fleet of bus and coach increased especially between 1995 and 2001. In 2001, nearly 360.000 bus and coaches registered in Turkey. This number shows an impressive stock of buses and coaches also means around two-thirds of the entire bus fleet of the both EU members and Central European EU candidates.

According to 2002 data gathered by DIE, totally, 7.475.043 vehicles are registered in Turkey. From 2000 to 2002, total passenger transport for all systems shows a drop based on the last economic crisis. However, passenger transport by using roads maintains its dominant role (a share of 95% in total). Within this value, for example in 2001, 76.800.000.000 passengers/km carried by coaches and buses (EC, 2003) that corresponds to 45.66%.

The second statistical information that conveys better the importance and the place of buses and coaches in Turkey is the number of seats of passenger motor vehicles given by Prime Ministry of State Institute of Statistics. The data gives numbers relating to the year of 2003. Thus, it shows the latest condition in the country. According to the statistics, the total number of coaches from each class is 123.500 and that corresponds to 3.283.402 total passenger seats. When this data are divided into two groups based on whether below 22 passenger seats (Class A-B) or above (Class 1-2-3) as the directive of 2001/85 EC, then it may be indicated that 38.593 coaches which belong to Class A and B have minimum 578.895 passenger seats. Conversely, 84.907 coaches which belong to Class 1-2 and 3 have minimum 2.704.507 passenger seats (See Figure 4.2).

Figure 4.2: The total number of passenger seats, according to the classes of coaches registered in 2003 in Turkey (From DIE, 2003).

All these statistics for both European countries and Turkey suggest that buses and coaches with their minimum 3.283.402 passenger seats are second fundamental transport equipments in Turkey. With their 2.704.507 passenger seats, Class 1, 2 and 3 coaches have an overwhelming share than other two classes. In addition, they address to a wide crowd. In other words, their usage frequency and time span by society during a day are relatively high. This also explains why that segment of coaches is selected for the aim of the study.

4.2 The overview of intercity coaches that are currently used in Turkey

Class 3 coaches are the most preferred vehicles by travel companies in the traveling between two cities in Turkey and generally, these vehicles have not under thirty passenger seats. The growing tendency to passenger coaches and different expectations of customers enforces many manufacturers to produce various models. However, it may be stated that fleet managers of the travel companies or individual coach buyers are more influential on coach manufacturers than passengers in Turkey. In other words, manufacturers modify, for instance, the numbers or their emplacements in the vehicle of seats based on the buyers' wishes. In terms of comfort, manufacturers that produce top segment coaches prefer instant solutions. In this way, they have more determinative role on buyers than middle segment ones.

When the Turkish coach market is analyzed, it may be seen that two major coach manufacturers (Mercedes and MAN) have dominant market share with their wide product ranges and other luxury brands that are Setra and Neoplan. In addition, Mitsubishi-Temsa is another manufacturer whose coaches are preferred frequently in the market. Three manufacturers, Mercedes, Man and Mitsubishi-Temsa, have domestic production plants. However, Setra and Neoplan coaches are imported from Germany. It might be inferred from the statistics of DIE (2003), models of aforementioned manufacturers hold almost all of the Turkish intercity coach markets. The market share of coaches that have 41 and up seats according to the manufacturer are shown in the Figure 4.3

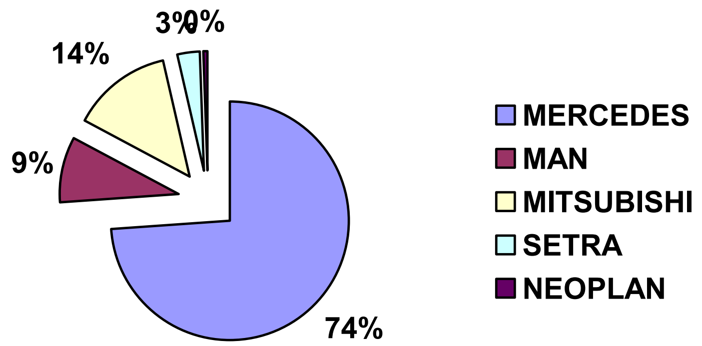


Figure 4.3: The market shares of coaches that have 41 and higher passenger seats in Turkey (From DIE, 2003).

Another point is except limited number of double decker Setra and Neoplan coaches that are preferred by two top class travel companies; this kind of coach is not to be in product ranges of manufacturers due to absence of a general demand by other travel companies in Turkey. The models of these five brands and their number of seats are listed in Table 4.3 below.

Table 4.3: The most preferred intercity coaches in Turkey based on their models and the number of passenger seats.

The Coach Brand	The Coach Model	The Number of Seats
MERCEDES	O-403	46
	INTOURO	46
	TRAVEGO	54
MAN	S2000	46
	FORTUNA	44-54
MITSUBISHI-TEMSA	SAFIR	46
	DIAMOND	54
SETRA	S 400’s	38-54-78
NEOPLAN	516 SHD-OM 442	48-76

For this study, the seats of Mercedes O-403-SETRA S400, MAN Fortuna Mitsubishi-Temsa Safir and Neoplan 516 SHD coaches are chosen based on their multitude within total product range of the related brand.

4.3 The overview of passenger seats that are currently used in intercity coaches in Turkey

The manufacturers of passenger seats may be divided with regard to origin as domestic based and foreign based. Two domestic based manufactures are Kiel and Grammer; manufacture their products in Bursa in Turkey. The seats of Man's Fortuna are developed by Kiel (See Appendix B). The ones of Mitsubishi-Temsa's Safir are developed by Grammer (See Appendix B). In addition to these two separate manufacturers, Mercedes may be accepted as a domestic seat manufacturer because all seats for its products are developed depending on inner organization in Istanbul. As Setra belongs to Mercedes group, it uses the seats that have same dimensions but different quality than Mercedes coaches (See Appendix B). Finally, Fainsa is another seat manufacturer that is a foreign (Spain) origin brand and whose seats are used in Neoplan models (See Appendix B).

CHAPTER 5

FIELD STUDY

5.1 The overview of anthropometric studies performed in Turkey

Before starting the field study, it is going to be meaningful to mention about the development phases of these studies in Turkey. In the literature, it may be seen that studies performed using anthropometry concentrate more on the growth and development of human body. In this subject, first study was carried out by Nafi Atuf Kansu in 1917. After that, in Istanbul, more than 4000 children from Turkish, 2200 from Greek, 1600 from Armenian, 1340 from Jewish and 720 from other ethnic groups were measured by Nureddin et al (1926). Especially after 1950s the number of studies shows an increase with the influence of studies from other branches such as pediatricians or dieticians. On the other hand, in almost all of these studies, newborns or primary school children are selected as the sample (Duyar, 1999).

There are few studies for 18 and older ages which have wide sample in Turkey. Still, some studies are sufficient to understand the both anthropometric development in the country due to their sample size and the number of measures taken from that sample. The study of Hertzberg et al (1963) is one of them carried out among Turkish army soldiers. Özok (1980) measured 1000 workers and took 50 different dimensions from them. Kayış (1991) investigated the dimensions of 5109 Turkish soldiers. Pekintürk (1968) and Su (1986) performed anthropometric surveys for army clothing. In addition, Aydın (1989) studied about 12500 females that are 18 and older to take measures from 26 dimensions for the aim of clothing.

5.1.1 The overview of two Turkish anthropometric studies selected

For this study, through limited number of anthropometric studies, the data in the studies of Hertzberg et al. (1963) and Kayış (1991) are selected in order to compare with the dimensions of four passenger seats. The basic reasons of this decision focus on three main points that respectively both studies have a wide sample, defined anthropometric variables or measures are compatible and adequately with the dimensions of passenger seats and finally, the measurement methods that are accepted in these studies are appropriate with the core of this study.

In the studies of Hertzberg et al (1963), it is presented that the data for 150 body dimensions taken on 3356 military personnel. Within this sample, 915 are Turks. Moreover, the data gathered include socio-demographic and military information, somatotype photographs, skinfold thicknesses are presented. The tabulated data include the means, standard deviations and coefficients of variation of 150 body dimensions, as well as selected percentiles of each from the 1st to the 99th, for each total national sample and subsample. On the other hand, in the studies of Kayış (1991), it is selected 5109 Turkish army personnel as a sample, aged between 18-26 years old by a random sampling method. A total of 51 measurements are obtained from each subject and the mean value, the standard deviation, skewness and kurtosis values of these measurements are tabulated. Furthermore, 5th, 25th, 30th, 75th, 95th and 99th percentile values of the anthropometric variables that are directly related to various design issues are represented in the tables.

In order to understand the subject more deeply and interpret the existing circumstance, a field study which compared the findings of these two scientific studies and the apparent dimensions of four different passenger seats was carried out.

5.2 The aim and the questions of the study

The aim of this study was to analyze current passenger seats on the market of Turkish intercity coaches, based on their importance in total transportation that was discussed previously. Moreover, it was to compare the dimensions of these seats, with the help of studies that contain anthropometric dimensions of Turkish people. In this way, to define what the dimensions of the seats should become and then to provide insides for future to designers so as to what should be paid attention in the design process of passenger seats.

5.3 The material and the method

The main study materials were selected from the most preferred four intercity coaches by travel companies in Turkey (See section 4.2). At the same time, each of them had passenger seats that belong to different seat brands. From these seats, eight parts were set. All of the seat parts are illustrated in Figure 5.1 and then the seat dimensions of four manufacturers-Kiel, Grammer, Mercedes and Fainsa-are specified and listed in Table 5.1 according to matching parts that are mentioned in Table 3.1:

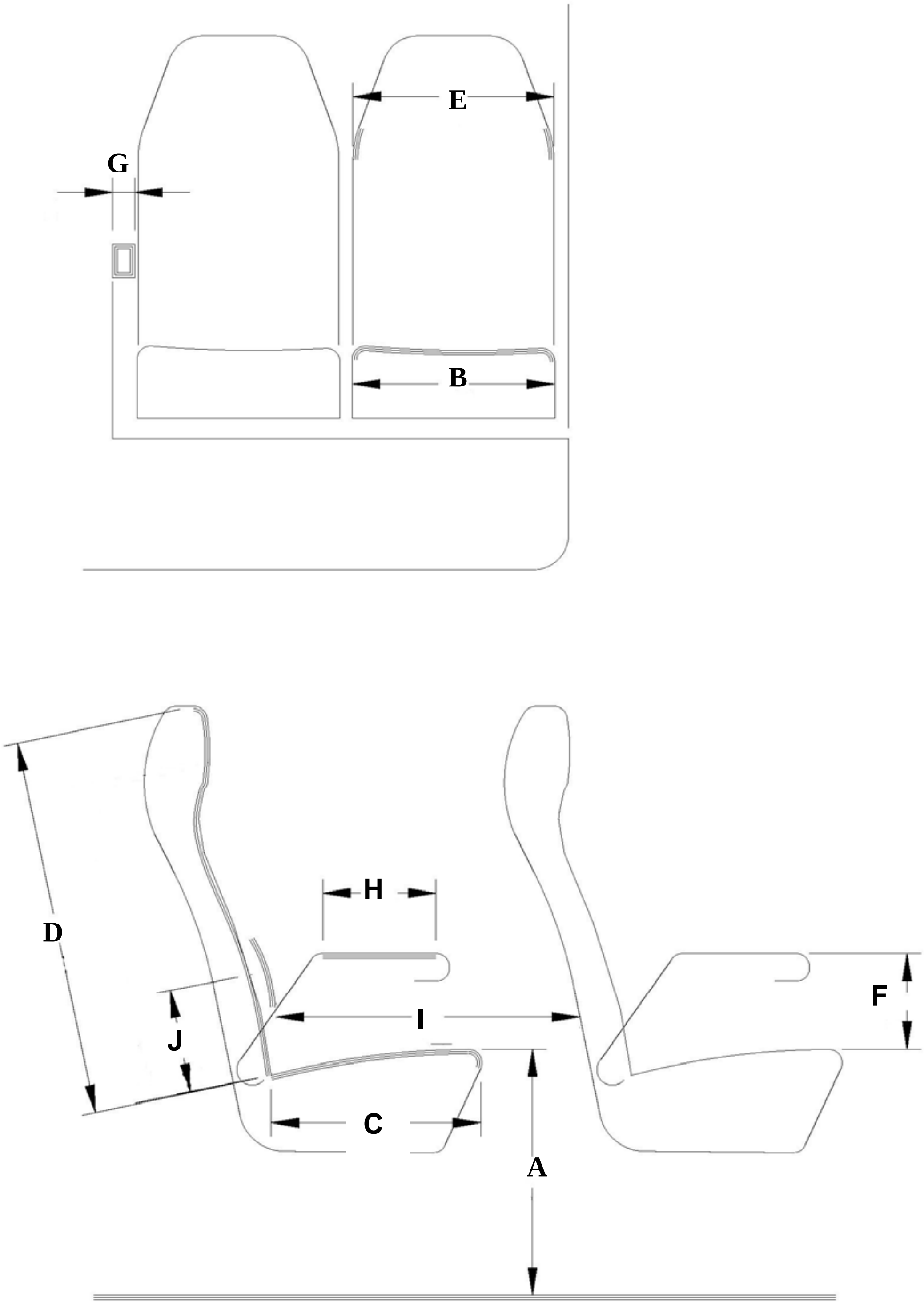


Figure 5.1: Related seat parts with their identifiers.

Table 5.1: The seat dimensions of four seat manufactures which are used in selected coaches.

Seat Part Identifiers	*Equivalent Seat Parts*	*Dimensions (mm)*			
		Kiel	*Grammer*	*Mercedes*	*Fainsa*
A	Seat Pan Height	460	462	460	450
B	Seat Pan Width	430	450	430	418
C	Seat Pan Length	440	430	442	435
D	Backrest Height	768	744	660	771
E	Backrest Width	450	410	505	435
F	Armrest Height	180	209	219	216
G	Armrest Width	38	35	35	40
H	Armrest Length	230	250	245	275

The seat dimensions were acquired by measuring these on the seats from the related each coach in the intercity coach terminal of Ankara. Although it was also gathered official technical documents of the seats of Mercedes, Kiel and Grammer from their producers (See Appendix C), the lack of dimensions for some parts in these documents necessitated to measure all seats personally. Therefore, these measured dimensions were evaluated throughout this study. All measurements were taken with the help of 150 cm and 50 cm plastic-based rulers. Moreover, to control each value, it was used a 150 cm oilcloth-based tapeline. The seats were just upright position (See Appendix A) during the measuring sessions. Furthermore, for each seat part, landmarks were chosen based on minimum and maximum active surfaces that affect directly on sitter.

After the measurement phase, the dimensions of seats were compared with the aforesaid findings of two Turkish anthropometry studies based on their related percentiles. In this point, “related percentiles” were defined as 50^{th} for such anthropometric variables that are buttock to popliteal length, elbow height-sitting, wrist breadth and elbow-wrist length. On the other hand, it was 95^{th} for popliteal height, hip breadth, eye height sitting and body breadth maximum. This distinction was accepted based on the recommendations presented by Grandjean (1987) and

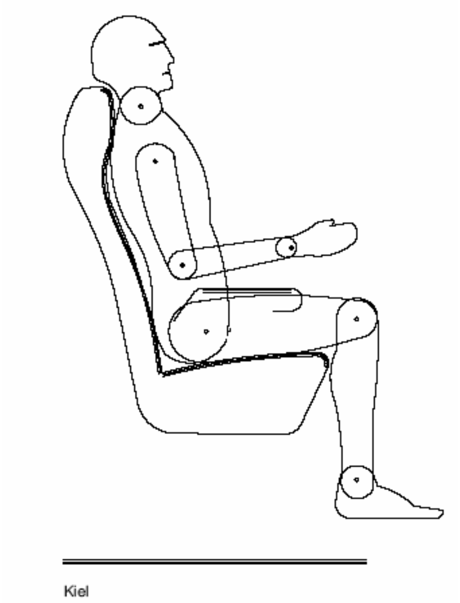
Pheasant (1996). On seat pan height, Pheasant (1996) recommends that this height should be as close as maximum popliteal height of the sitter. Higher and lowest value increase tissue pressure on thighs. In contrast, seat pan length should be lower value than the maximum buttock to popliteal length of the sitter. If this depth were greater than the buttock to popliteal length, the sitter would not use the backrest of the seat. If the seat pan length were significantly less than the buttock to popliteal length of the sitter, the thighs would not be supported in the sitting posture. On elbow height sitting, Grandjean (1987) states that if the sitting elbow height were significantly greater, the sitter would be required to work with both arms in a degree of “abduction or scapular elevation” (as cited in Milanese and Grimmer, 2004). Therefore, armrest height was defined as 50th percentile. In a similar sense, percentiles of other anthropometric variables were specified based on the viewpoints of Grandjean (1987) and Pheasant (1996). 95th percentile was adopted for seat pan width to be adequate thigh support for all sized sitters. On backrest; all heights and widths were defined as 95th percentile to provide comfortable sitting for the highest and the widest person throughout the travel. On the contrary, for armrest width and armrest length, 50th percentile was adopted since armrests affect directly on the movements of passengers on the corridor of coach as well as transition between the seats and the corridor. Because of this fact, they should not block such transitions.

5.4 The results and the findings

The following table represents the comparison among the dimensions of four passenger seats and the results of two anthropometric studies. All dummies represented in this table are same sizes that correspond to the values of Hertzberg et al (1963) based on the related percentiles.

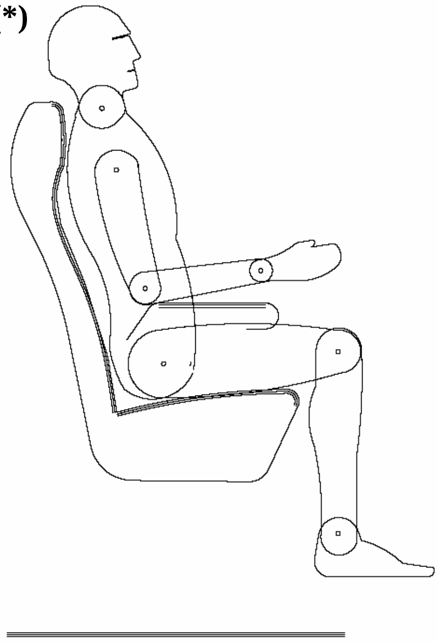
Table 5.2: The dimensions of evaluated seat brands and the findings that belong to related percentile of two anthropometric studies.

KIEL (*)



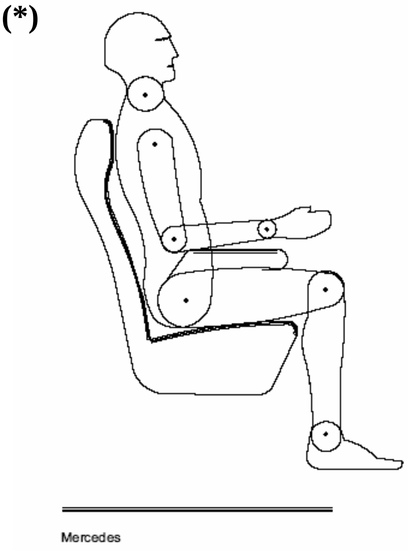
Related Seat Parts with Their Identifiers		Anthropometric Variables (mm)	Related Seat Part Dimensions (mm)	Percentiles (%)	Kayış (1989) (mm)	Hertzberg et al (1963) (mm)
A	Seat Pan Height	Popliteal Height	460	95	455	449
B	Seat Pan Width	Hip Breadth	430	95	364	371
C	Seat Pan Length	Buttock to Popliteal Length	440	50	440	474
D	Backrest Height	Eye Height Sitting	768	95	870	826
E	Backrest Width	Body Breadth Maximum	450	95	-	492
F	Armrest Height	Elbow Height Sitting	180	50	233	224
G	Armrest Width	Wrist Breadth	38	50	-	58
H	Armrest Length	Elbow-Wrist Length	230	50	-	275

GRAMMER (*)



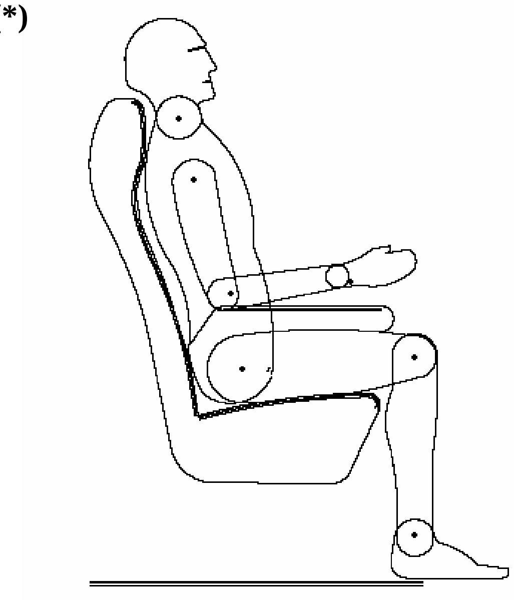
Related Seat Parts with Their Identifiers		Anthropometric Variables (mm)	Related Seat Part Dimensions (mm)	Percentiles (%)	Kayış (1989) (mm)	Hertzberg et al (1963) (mm)
A	Seat Pan Height	Popliteal Height	462	95	455	449
B	Seat Pan Width	Hip Breadth	450	95	364	371
C	Seat Pan Length	Buttock to Popliteal Length	430	50	440	474
D	Backrest Height	Eye Height Sitting	744	95	870	826
E	Backrest Width	Body Breadth Maximum	410	95	-	492
F	Armrest Height	Elbow Height Sitting	209	50	233	224
G	Armrest Width	Wrist Breadth	35	50	-	58
H	Armrest Length	Elbow-Wrist Length	250	50	-	275

MERCEDES (*)



Related Seat Parts with Their Identifiers		Anthropometric Variables (mm)	Related Seat Part Dimensions (mm)	Percentiles (%)	Kayış (1989) (mm)	Hertzberg et al (1963) (mm)
A	Seat Pan Height	Popliteal Height	460	95	455	449
B	Seat Pan Width	Hip Breadth	430	95	364	371
C	Seat Pan Length	Buttock to Popliteal Length	442	50	440	474
D	Backrest Height	Eye Height Sitting	660	95	870	826
E	Backrest Width	Body Breadth Maximum	505	95	-	492
F	Armrest Height	Elbow Height Sitting	219	50	233	224
G	Armrest Width	Wrist Breadth	35	50	-	58
H	Armrest Length	Elbow-Wrist Length	245	50	-	275

FAINSA (*)



Related Seat Parts with Their Identifiers		Anthropometric Variables (mm)	Related Seat Part Dimensions (mm)	Percentiles (%)	Kayış (1989) (mm)	Hertzberg et al (1963) (mm)
A	Seat Pan Height	Popliteal Height	450	95	455	449
B	Seat Pan Width	Hip Breadth	418	95	364	371
C	Seat Pan Length	Buttock to Popliteal Length	435	50	440	474
D	Backrest Height	Eye Height Sitting	771	95	870	826
E	Backrest Width	Body Breadth Maximum	435	95	-	492
F	Armrest Height	Elbow Height Sitting	216	50	233	224
G	Armrest Width	Wrist Breadth	40	50	-	58
H	Armrest Length	Elbow-Wrist Length	275	50	-	275

(*): All dummies are same sizes that correspond to the values of Hertzberg et al (1963) based on the related percentiles.

Each table consists of six columns. The seat parts and their anthropometric equivalences are presented at first and second ones respectively. Then, the other columns in which given numerical data are explained based on the selected seat brands in the four lines. The third column demonstrates the values of related seat dimensions in the unit of millimeter. The fourth column belongs to the percentiles of anthropometric variables which are collected from the two studies. Finally, the fifth and the sixth columns illustrate the consequences of the studies performed by Kayış (1989) and Hertzberg et al (1963) for the same measures and the percentiles.

As can be seen from the table, the percentile value of some anthropometric variables are lacking since they were not measured by Kayış (1989) in her study. Furthermore, especially for two anthropometric variables those are buttock to popliteal length and eye height sitting; significant differences are found between the results of two studies. To understand the main reasons of these differences, it should be analyzed the findings of variables called the buttock to popliteal length and the buttock to knee length for the same percentile of the studies of Hertzberg et al (1963) and Kayış (1989). Similarly, it should be compared the values of eye height sitting and sitting height for same studies. Kayış (1989) specifies the value of buttock to knee length as 566 mm for 50th percentile in her study. On the other hand the value of buttock to popliteal length is defined as 440 mm for the same percentile. When it is subtracted these values from each other, the difference can be found as 126 mm. Likewise, for the same variables and the percentile, Hertzberg et al (1963) represents the value of buttock to knee length as 569 mm and 474 mm for buttock to popliteal length. When it is subtracted these values, it can be found that the difference corresponds to 95 mm. Finally, when it is compared the differences between the studies of Hertzberg et al (1963) and Kayış (1989), it can be observed that 126 mm seen in the study of Kayış (1989) is a significant difference than 95 mm gathered from the study of Hertzberg et al (1963) (See Table 5.2). However, in terms of the differences between sitting heights and the eye height sittings of two studies, 125 mm can be seen as a difference when the sitting height (951 mm) is subtracted from the eye height sitting (826 mm) in the study of Kayış (1989) for 95th percentile. In contrast, 75 mm can be seen as a difference in the study of Hertzberg et al (1963) when the value of sitting height (945 mm) is subtracted from the one of eye height sitting (870 mm) for the same percentile (See Table 5.2).

Similar to the differences between the buttock to knee length and the buttock to popliteal length, 125 mm is found in the study of Kayış (1989) as the difference between the sitting height and the eye height sitting that is a significant value than 75 mm that belongs to the study of Hertzberg et al (1963) as the difference (See Figure 5.2).

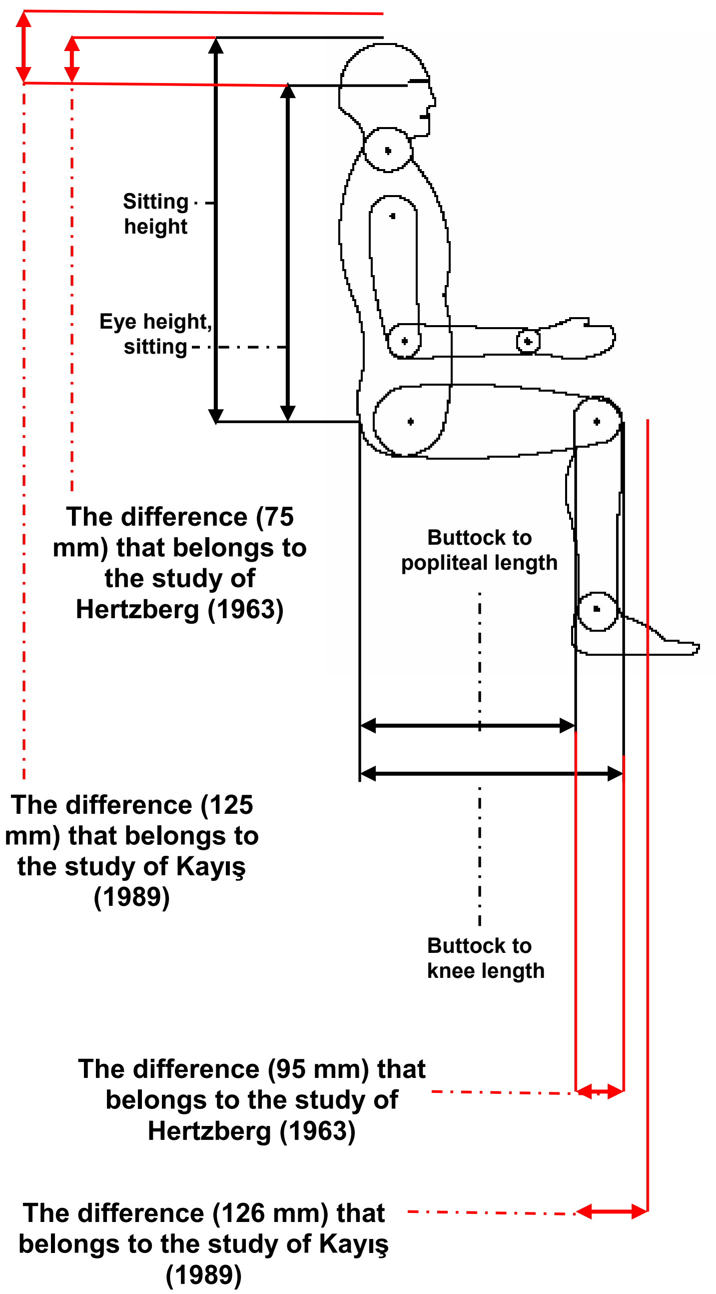


Figure 5.2: The differences between the studies of Hertzberg et al (1963) and Kayış (1989) in terms of their differences between buttock to knee and popliteal lengths in addition to sitting height and eye height, sitting.

In summary, it seems consistency problems in the values that belong to the study of Kayış (1989) in terms of two anthropometric variables that are eye height sitting and buttock to popliteal length. Due to either lacking of data about such anthropometric variables that are body breadth maximum, wrist breadth and elbow wrist length or aforementioned consistency problems related with the variables called eye height sitting and buttock to popliteal length, The data offered in the study of Hertzberg et al (1963) is chosen as a main source for the suggestions of seat dimensions that will be performed in this study.

To be able to understand better the differences among seat brands represented in Table 5.1, the differences between each seat part dimension and each result of the anthropometric study based on seat brands are shown in the following figures:

1: KIEL

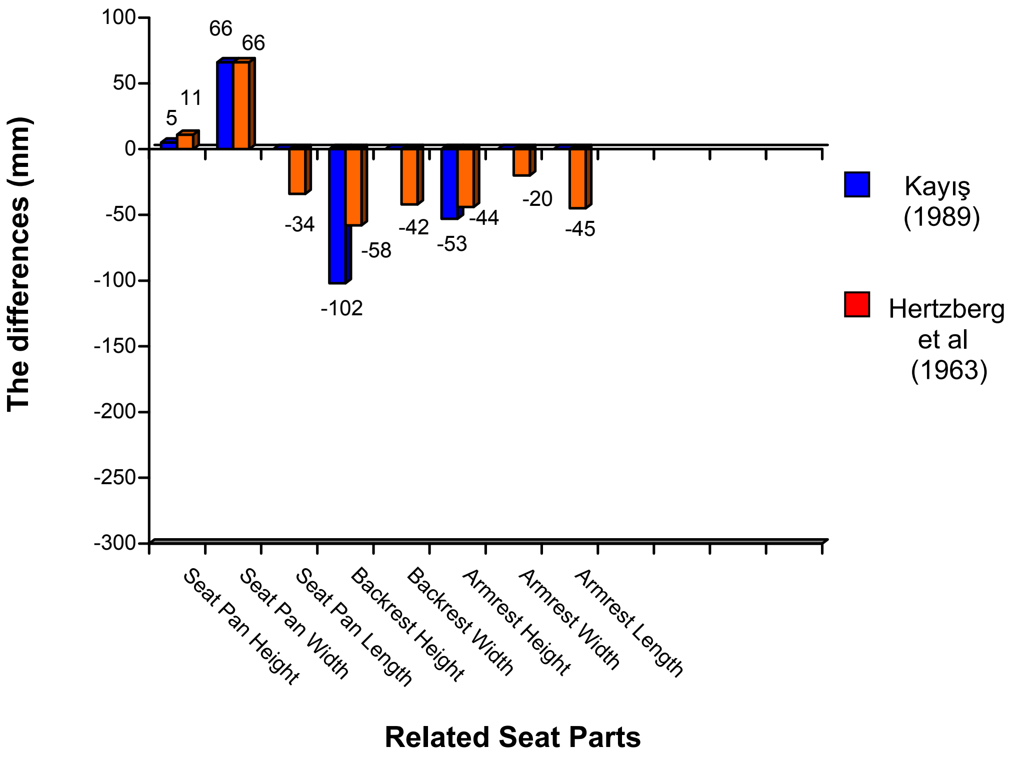
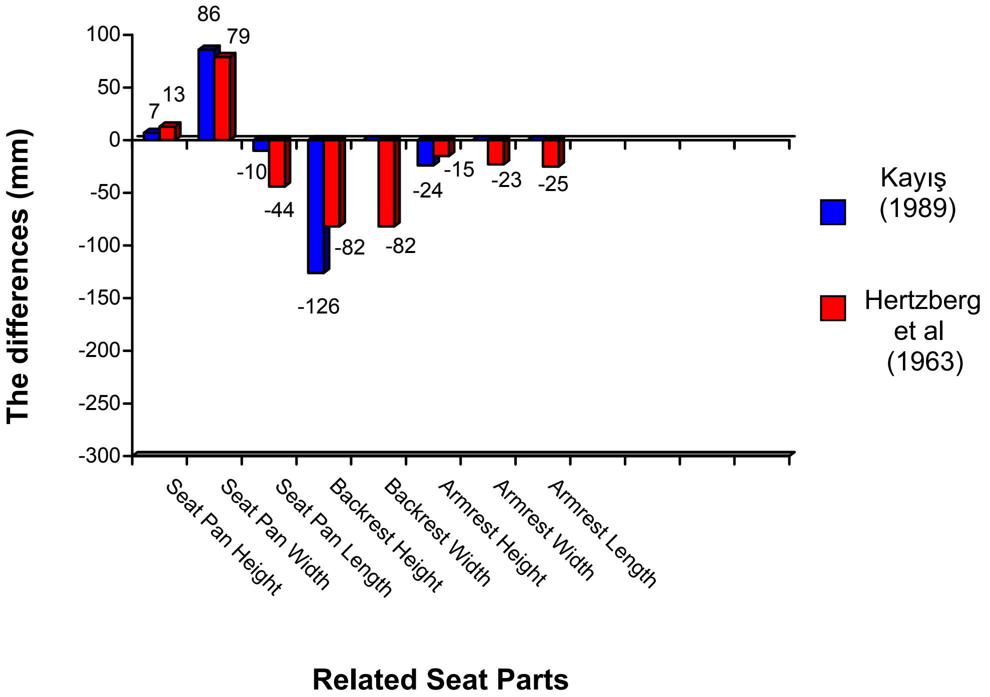


Figure 5.3: The differences among related seat parts that belong to four seats and the findings of two studies.

2: GRAMMER



3: MERCEDES

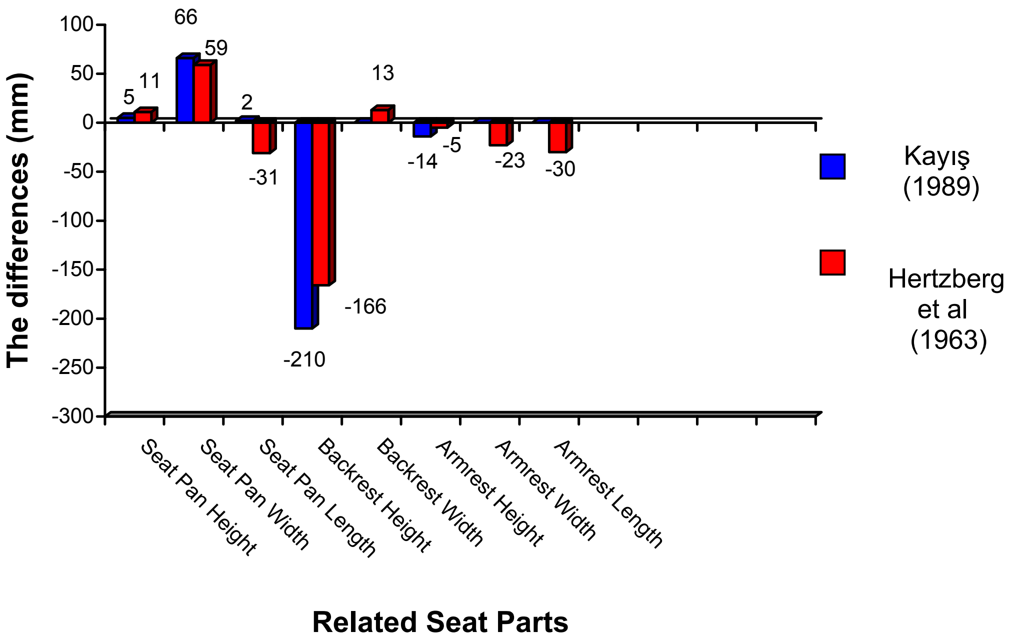


Figure 5.3: The differences among related seat parts that belong to four seats and the findings of two studies (Cont.)**.**

4: FAINSA

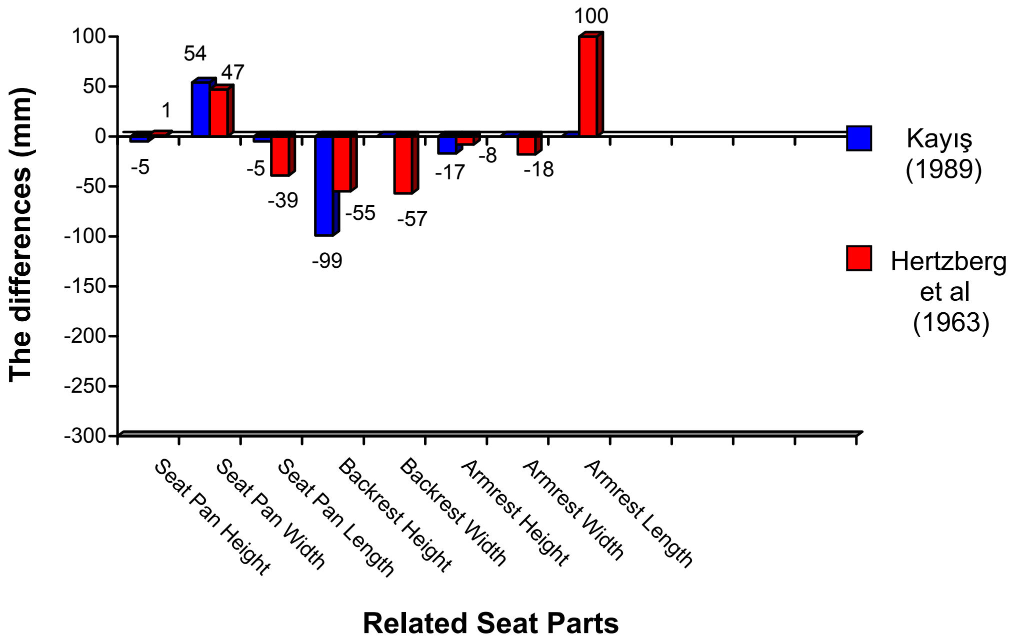


Figure 5.3: The differences among related seat parts that belong to four seats and the findings of two studies (Cont.)**.**

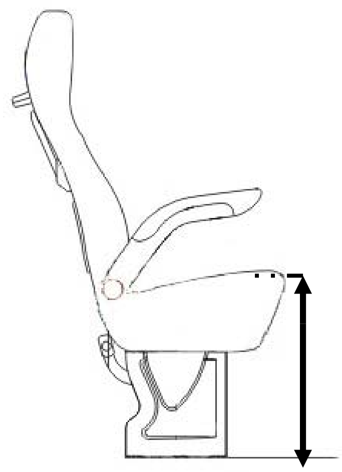
It can be observed that only the seat pan widths of the selected seats among other parts have much higher value than the hip breadths of two anthropometric studies. Nevertheless, seat pan lengths have similar value with the buttock to popliteal length of Kayış's (1989) study but lower than the outcome of Hertzberg et al (1963). In contrast, backrest heights, backrest widths except Mercedes, armrest widths and armrest lengths except Fainsa have considerably lower value than the eye heights sitting, body breadths maximum, wrist breadths and elbow-wrist lengths of the two studies. Furthermore, armrest heights are slightly lower than the elbow heights sitting of the two studies.

Seats that are evaluated in this study show dissimilar value with each other for many dimensions. The seat of Fainsa has maximum backrest height (771 mm), armrest width (40 mm) and length (275 mm). On the other hand, it has the minimum seat pan width (418 mm). Grammer, however, has the maximum seat pan height (462 mm) and width (450 mm). In contrast it has the minimum backrest width (410 mm) amongst other seat brands. In addition, Mercedes has the longest seat pan (442 mm) as well as widest backrest (505 mm). Conversely, its backrest is shortest (660 mm).

5.5 Discussion

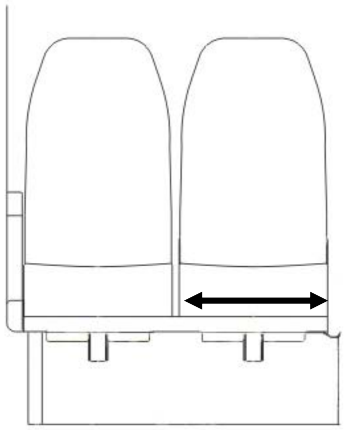
Regarding the Table 5.1 and the Table 5.2, the following evaluations and suggestions can be made for each measured seat part:

A) Seat pan height



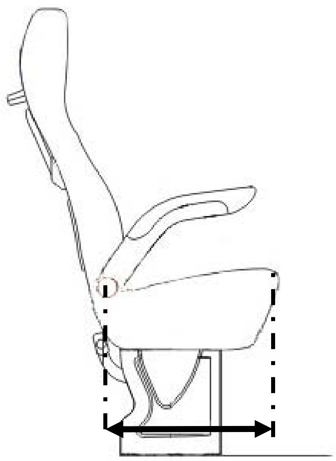
For this seat part, it is seen that three seat brands except Fainsa have higher values than the popliteal heights of two Turkish studies. In contrast, Fainsa has a value (450 mm) between the findings of these studies. All of the seat pan heights that belong to the seats show a range between -5 mm and +13 mm than the popliteal heights of two Turkish studies (See Figure 5.3). Thus, it can be stated that all seat pan heights are coincide with the findings of two Turkish studies due to being not higher or lower than. According to the results of Central Europe anthropometric values compiled by Jurgens et al (1990), popliteal heights for the same percentile (95^{th}) correspond to 500 mm for males and 460 mm for females. On the other hand, 400-500 mm is defined as seat pan height in the directive of 2001/85/EC by European Commission (See Section 3.3.2). With this information, it can be stated that seat pan heights of selected four seats are compatible with the European directive. Although these heights remain under the value of popliteal height that belongs to male from 95^{th} percentile compiled by Jurgens et al (1990), they are coincide with female's popliteal height that corresponds to 95^{th} percentile.

B) Seat pan width



In this width, all seats have higher value than the hip breadths of two Turkish studies. In the compilation of Jurgens et al (1990), minimum hip breadth shows as 390 mm for 95th percentile male and 440 mm for female in same percentile. Based on the directive- 2001/85/EC, minimum seat pan width is specified as 450 mm for Class 3 coaches (See Section 3.3.1). Among analyzed seats, only Grammer (450 mm) is coincide with the value of European regulation. Moreover, it has the highest comfort level among other seats (+86 mm higher than the hip breadth that belongs to Kayış (1989) and +79 mm higher than Hertzberg et al (1963)). On the other hand, Fainsa has the lowest value (418 mm that corresponds to +54 mm higher than the hip breadth that belongs to Kayış (1989) and +47 mm higher than Hertzberg et al (1963)). Finally, it can be concluded that the values of all seat pan widths are close to hip breadth of females of Central European region.

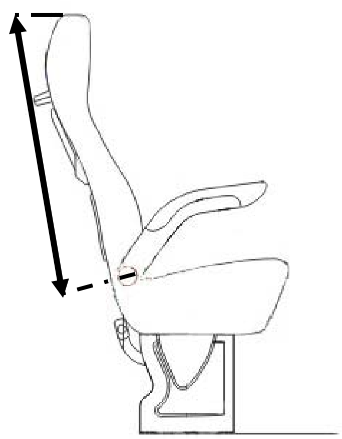
C) Seat pan length



In this dimension, because of the aforementioned consistency problem between the buttock to popliteal lengths of the studies that belong to Kayış (1989) and Hertzberg et al (1963), the comparisons will be performed based on the study that belongs to Hertzberg et al (1963). It can be seen that all of the seat pan lengths have significantly lower value than the buttock to popliteal height of the study of Hertzberg et al (1963). On the other hand, Grammer has the lowest value (430 mm, -44 mm lower than the value that belongs to Hertzberg et al (1963)). In contrast, in the directive- 2001/85/EC, this length is specified for Class 3 coaches as minimum 400 mm.

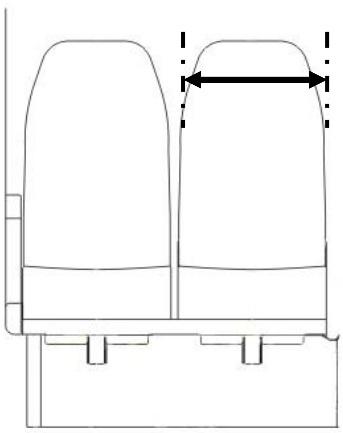
(See Section 3.3.2) Therefore, it can be realized that same seats have longer seat pan than the value mentioned in European directive.

D) Backrest height



In this dimension, owing to a consistency problem related with the sitting height and the eye height sitting of the study of Kayış (1989) as mentioned in the seat pan length section, the eye height sitting of the study of Hertzberg (1963) will be preferred to compare the values of the seats. According to this fact, it can be said that all seats have sizes that their measures are lower than the eye height sitting of the study of Hertzberg et al (1963) significantly. However, the backrest height of Mercedes seems the shortest among other brands (660 mm, -166 mm lower than the value that belongs to Hertzberg et al (1963)). In any case, however, when it is compared the backrest heights of the seats with the eye height sitting of Central European region compiled by Jurgens et al (1990) , it can be realized that all seat brands have lower backrest heights than 850 mm for men and 810 mm for female that correspond to 95th percentile.

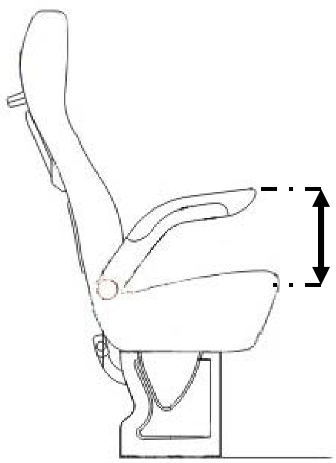
E) Backrest width



For this width, the seats of three brands have lower values than the value of body breadth for 95th percentile in the study of Hertzberg et al (1963). However, Grammer has the lowest (410 mm, -82 mm lower than the value that belongs to Hertzberg et al (1963)). In contrast, Mercedes has the highest value (505 mm, +13 mm higher than the value of Hertzberg et al (1963)).

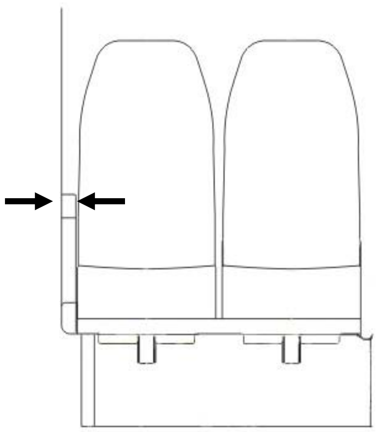
At the same time, it is the only seat whose backrest width has higher value than the breadth of Hertzberg et al (1963). For same width, 450 mm is specified in the directive- 2001/85/EC (See Section 3.3.1). According to the fact, Grammer and Fainsa (435 mm) have lower values than the value of the directive.

F) Armrest height



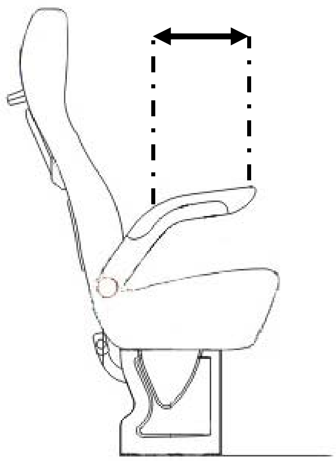
The armrest heights of all seats have lower value than the elbow heights, sitting of the studies of Hertzberg et al (1963) and Kayış (1989). As regards the directive 2001/85/EC, this height is specified as maximum 270 mm. (See Section 3.3.1). Therefore, armrest heights of all seats have lower values than 270 mm. For this part, Kiel is the shortest (180 mm, -53 mm lower than the value that belongs to Kayış (1989) and -44 mm lower than the value that belongs to Hertzberg et al (1963)) significantly, and Mercedes is the highest (219 mm, -14 mm lower than the value that belongs to Kayış (1989) and -5 mm lower than the value that belongs to Hertzberg et al (1963)) among the other seats.

G) Armrest width



For this width, the armrests of all brands have lower values than the wrist breadth of the study of Hertzberg et al (1963) and they have values that are close to each other. On the other hand, these differences are not significant than the wrist breadth of the study of Hertzberg et al (1963). Fainsa has the widest (40 mm, -18 mm lower than the wrist breadth that belongs to Hertzberg et al (1963) amongst other seats.

H) Armrest length



In this length, all armrest lengths except Fainsa are significantly shorter than the elbow-wrist length of Hertzberg et al (1963). In contrast, Fainsa has an armrest whose value (275 mm) is same as the elbow-wrist length of Hertzberg et al (1963). On the other hand, Kiel has the lowest value (230 mm, -45 mm lower than the elbow-wrist length that belongs to Hertzberg et al (1963)). When designed armrests, using actual elbow-wrist length in the design process is recommended. Nonetheless, on account of simplifying movements in the coach, defining a value that is a few cm lower is acceptable.

5.6 Additional dimensions

In addition to investigated eight seat parts, two dimensions called seat to seat distance (identified with the letter (**I**)) and lumbar support height (identified with the letter (**J**) are represented in Figure 5.1. Although, it is not taken any measurements on the related seats for these two parts due to lacking of any reference points on the ground and the backrest, it is thought that these parts are important in the design process of backrest and the assembly phase of the seats into the coaches. The anthropometric variable called buttock to knee length that belongs to 95th percentile can be equivalent to seat to seat distance for continuing seats to specify minimum seat to seat distance. On the other hand, elbow height, sitting for 50th percentile (that the upper reference point of this height corresponds to 5th lumbar vertebra (See Figure 3.1)) can be equivalent to lumbar support height. Even though, it is not given any data about these anthropometric variables up to now, it will be presented as suggested dimensions in Figure 5.4 based on the values that belong to Hertzberg et al (1963) for related percentiles.

5.7 General discussion

In brief, it was seen that the dimensions of all seats demonstrated no significant differences among each other in terms of belonging to the domestic based or foreign based seat manufacturers. In other words, there was no significant difference among middle or luxury segment coaches in terms of their single seats. In the part called seat pan width, all seats had higher values than the hip breadths of both anthropometric studies. Conversely, for other seat parts other than the seat pan widths, dimensions of almost all seats had lower values than the anthropometric variables that were obtained from both studies. An interesting point was that although all seats showed approximate values with specified seat parts of the European directive- 2001/85/EC generally, all seats except Grammer had lower value than the seat pan width mentioned in this regulation.

Another point was a harmony problem between the findings of two Turkish studies and the regulation about seats represented in the document-2001/85/EC. For instance, for the parts those are seat pan length and backrest width, related values that are specified in the directive had lower value than the outcomes of two anthropometric studies. In contrast, for backrest height, the eye heights, sitting of both anthropometric studies had significantly higher values than the related backrest height mentioned in the directive. The backrest heights of all measured seats also confirm this fact. In other words, the values of all backrest heights that belong to four seats were the lowest among the other seat parts based on the studies of Hertzberg et al (1963) and Kayış (1989). This fact indicates that regulations for Turkey that relates with seats should be issued based on the anthropometric studies which performed on Turkish people. To contribute this aim, it is prepared a figure that contains recommended data about each seat part. These suggested values are defined according to the findings of the anthropometric study of Hertzberg et al (1963). For each seat part, the recommended values that belong to their related percentiles are represented in the following figure:

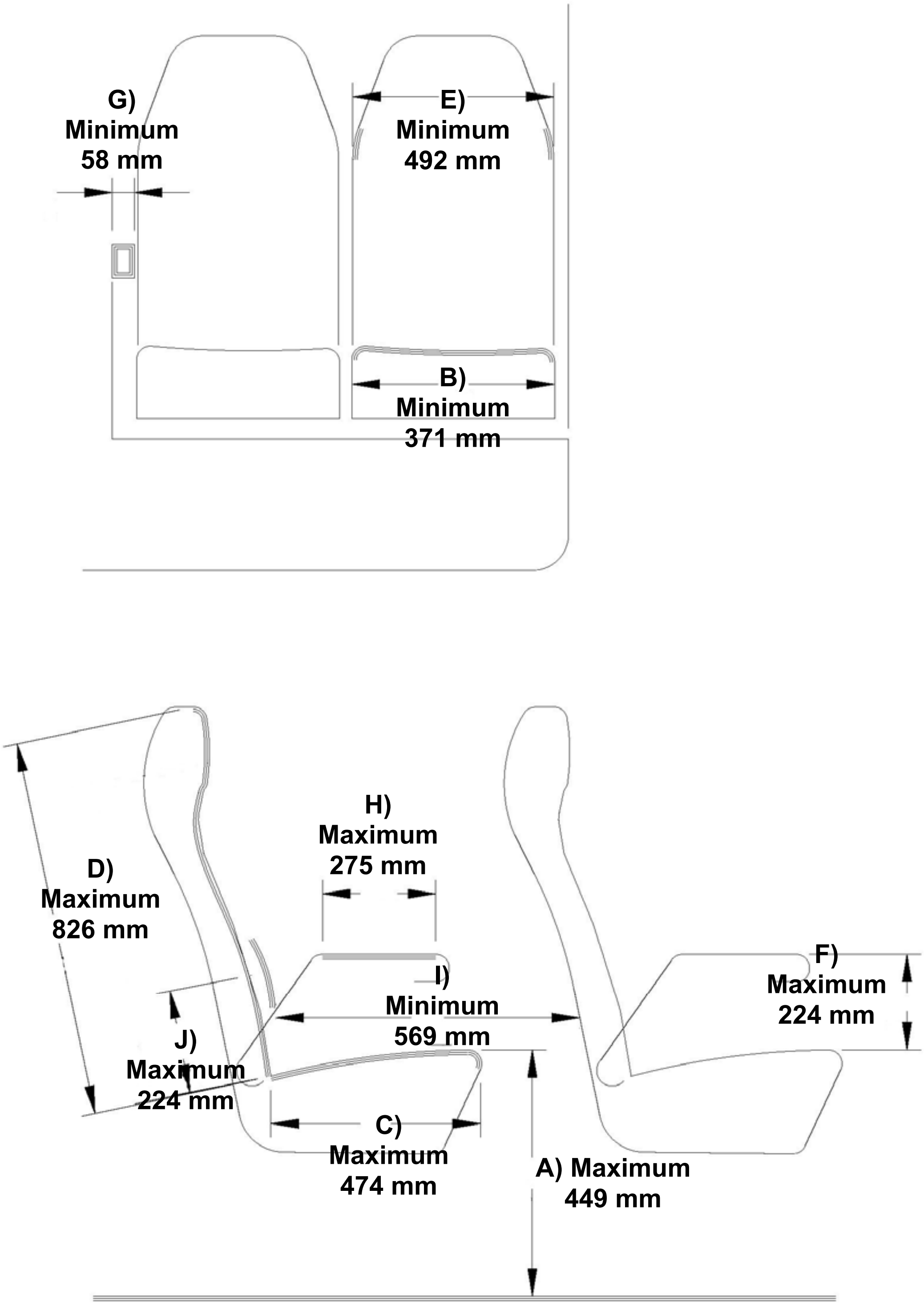


Figure 5.4: The recommended value of the seat components based on Hertzberg (1963) et al (Unit=mm).

5.8: Limitations of the study

There are a number of limitations in this study that are mainly due to the accessibility problem to adequate information from manufacturers as well as the inadequacies within the evaluation methodology. Two different methods were followed to gather raw data about seats throughout the study. First one was going to each of domestic-based seat and coach manufacturers personally. The aim was accessing detailed information about the related seats, their dimensions, design processes and obligatory internal and external regulations or standards. Even though it could be observed that almost all manufacturers had no detailed or instant precisely documents about their products, some technical documents could be collected from Kiel, Grammer and Mercedes represented in Appendix C. The second method was measuring selected seats personally. At this point, the difficulty was in measurement equipments and the environment. Today more definite and accurate measurements can be taken with the help of 3-D measurement techniques and CAD solutions done by computers on lab conditions (Hsiao et al, 2005; Bubb, 2004). Since the coaches had narrow interiors, taken measurements from the seats in such an environment led to difficulties especially for the parts that were backrest height and headrest height throughout the measurement sessions. In addition, being few, only on males and having prominent time difference anthropometric studies performed on Turkish people in the literature brought about evaluation deficiencies. Nonetheless, being two sufficient anthropometric studies that are Hertzberg et al (1963) and Kayış (1989) in terms of sample size and measurement methods in the literature of Turkish anthropometric studies makes possible this study.

CHAPTER 6

CONCLUSION

In this chapter, a brief summary of issues discussed from the beginning of thesis to the end will be explained by evaluating the outcomes of the field study. The main ideas of each chapter will be mentioned.

This thesis is organized in three main parts, that are, information about the basic discipline that form the seating concept, the seating concept itself, its product-problem and evaluating the problem in special of Turkey.

6.1 Information about ergonomics that forms the seating

In the first part of the thesis, the discipline of ergonomics and its sub fields that affected the concept of seating were stated through a literature review. Accordingly, it was pointed out that, physical ergonomics, as one of the main domains of ergonomics, is concerned with characteristics such as anatomical, anthropometric, physiological and biomechanical that relate to physical activities of human. Anthropometry, however, assists to physical ergonomics to give information about dimensions of the users of the product. Utilizing these data in the design process with the help of other aspects lead to the product that will be designed especially for a specific population qualifying as an “ergonomic product”. In this sentence, the word “population” is the key to define the main problem of this thesis. Because the products like seats are used by many people, anthropometric knowledge of the potential users become more important. Therefore, the first part of the study was concluded by analyzing the anthropometric data for designers to benefit from them.

6.2 The seating itself and its product-seat

In the second phase of the study, the concept i.e. seating was stated through various perspectives that each of them affects the concept separately. It was concluded that, although one and all perspectives were vital to describe the final product i.e. seat "ergonomic", anthropometric dynamics of seating was more dominant than other aspects'. The important aspects were reviewed as:

The anatomical and physiological aspects of seating: Vertebral column and pelvis that are two main structure that belong to human skeleton system carry out seating on account of physical. Without understanding the relations among inter vertebral discs and/or muscles, the form or angles of seats cannot be defined properly.

The psychological aspects of seating and passenger comfort: The psychological aspects of seating is described with two opposite concepts that are comfort and discomfort. These two concepts are assessment criteria of seats as well as influencing the preferences of consumers in any product buying stage. The descriptions of comfort and discomfort and various techniques to measure comfort/discomfort level were discussed. However, it was pointed out that the anthropometric aspects in the evaluation process of comfort and discomfort were not directly measured in almost all studies using these techniques.

The anthropometric dynamics of seating: Feeling comfort by users depends on blending physical and psychological factors. Anthropometric factors are described as one of the most important physical factors especially for seating and seat design. Before starting a design process, it is first needed to define the user, the purpose of the seat and the appropriate data. However, depending on the purpose of the seat, some anthropometric data may be or not used in the design process. In this direction, eight seat dimensions and their anthropometric equivalents were selected and represented by means of figures (See part 3.2 of chapter 3).

For this study, as the product of the concept are chosen as seats of intercity coaches, diversities between the seats of long time travel coaches and public coaches were analyzed with the help of the directive 2001/85/EC by European Commission. They can be separated from each other with different structures and characteristics. As states in the directive, passenger coaches can be evaluated in three groups based on their classes that are Class1, Class 2 and Class 3. It was concluded that intercity coaches belonged to Class 3 and the shapes of their seats had more than the other two classes (See part 3.3 of chapter 3).

The fourth chapter of thesis mainly considered the influences of the buses and coaches on European and Turkish transportation system. Even though the statistics indicate that these vehicles are second transportation equipments for European countries and Turkey, the numbers imply that Turkey alone has an excessive stock of buses and coaches that means two-thirds of the entire bus fleet of the both EU members and Central European EU candidates. In addition, majority of this fleet regards to intercity coaches (Class 3).

Also in this chapter, intercity coaches and their passenger seats that are currently used in Turkey were investigated. In this subject, it was found that the coaches of manufacturers, Mercedes, Man, and Mitsubishi were predominant in point of total market share in Turkey. The most used products of these manufacturers were selected that are Mercedes O403, Setra S400, Man Fortuna and Mitsubishi Safir to compare their seats with the anthropometric studies. Nevertheless, when it is looked to the seat manufacturers of these coaches, it was observed that they could be divided with regard to origin as domestic based and abroad based. Kiel and Grammer were domestic. On the other hand, Fainsa was abroad origin firms.

6.3 Evaluating the problem in case of Turkey

In the fifth chapter, a field study was carried out to understand the anthropometric conditions of currently used passenger seats in Turkey. The comparison was carried out among the data of two anthropometric studies performed on Turkish population by Hertzberg et al. (1963) and Kayış (1989) and the dimensions of four passenger seats were measured personally from each seat that were Kiel, Grammer, Mercedes and Fainsa. It was concluded that dimensions of all seats demonstrated no significant differences among each other in terms of belonging to the domestic based or foreign based seat manufacturers. In other words, there was no significant difference among middle or luxury segment coaches in terms of their single seats. Only in the part called seat pan width, all seats had higher values than the hip breadths of both anthropometric studies to provide more feeling of comfort. Conversely, for other seat parts other than the seat pan widths, dimensions of almost all seats had lower values than the anthropometric variables but close to 50^{th} percentiles that were obtained from both studies. An interesting point was that although all seats showed approximate values with specified seat parts of the European directive called 2001/85/EC generally, these seats except Grammer had lower value than the seat pan width mentioned in this regulation. Another point was a harmony problem between the findings of two Turkish studies and the regulation about seats represented in the document-2001/85/EC. For instance, for the parts those are seat pan length and backrest width, related values that are specified in the directive had lower value than the outcomes of two anthropometric studies. Similarly, for backrest height, the eye heights, sitting of both anthropometric studies had significantly higher values than the related backrest height mentioned in the directive. The backrest heights of all measured seats also confirm this fact. In other words, the values of all backrest heights that belong to four seats were the lowest among the other seat parts based on the studies of Hertzberg et al (1963) and Kayış (1989). This fact indicates that regulations for Turkey that relates with seats should be issued based on the anthropometric studies which performed on Turkish people.

6.4 Further studies

Although it could not be gathered concrete information from the official documents or the speeches of authorized people of the seat manufacturers, design criteria of these seats are an important issue. In other words, conceptions such as safety, comfort or emotion that are adopted by designers or manufacturers of the coaches affect directly on the form of the passenger seats. In this point, it can be seen a gap between these concerns and the available anthropometric knowledge especially in Turkey. Therefore it should be made more comparative studies to play a more active role of anthropometry in the process. Moreover, it should be defined new reference points for the static and dynamic anthropometric measures from seats and coaches and finally, it should be arranged wide-ranging national directives.

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APPENDIX A

THE SEAT SHAPE DIFFERENCES AMONG CLASSES OF COACHES BASED ON EUROPEAN DIRECTIVE CALLED 2001/85/EC

13.2.2002 EN Official Journal of the European Communities L 42/31

7.7.8. Passenger seats and space for seated passengers

7.7.8.1. Minimum seat width

7.7.8.1.1. The minimum width of the seat cushion, dimension F (Annex III, figure 9), measured from a vertical plane passing through the centre of that seating position, shall be:

Class I, II, A, B	200 mm
Class III	225 mm

7.7.8.1.2. The minimum width of the available space for each seating position, dimension G (Annex III, figure 9) measured from a vertical plane passing through the centre of that seating position at heights between 270 and 650 mm above the uncompressed seat cushion shall be not less than:

individual seats:	250 mm
continuous rows of seats for 2 or more passengers:	225 mm

7.7.8.1.3. For vehicles 2,35 m in width or less, the width of the available space for each seating position, measured from a vertical plane passing through the centre of that seating position at heights between 270 and 650 mm above the uncompressed seat cushion shall be 200 mm (see Annex III, figure 9 bis). In case of compliance with this paragraph the requirements of paragraph 7.7.8.1.2. shall not apply.

7.7.8.1.4. For vehicles having a capacity not exceeding 22 passengers, in the case of seats adjacent to the wall of the vehicle, the available space does not include, in its upper part, a triangular area 20 mm wide by 100 mm high (see Annex III, figure 10). In addition, the space needed for safety belts and their anchorages and for the sun visor should be considered as exempted.

7.7.8.2. Minimum depth of seat cushion (dimension K, see Annex III, figure 11)

The minimum depth of a seat cushion shall be:

7.7.8.2.1. 350 mm in vehicles of Class I, A and B, and

7.7.8.2.2. 400 mm in vehicles of Class II and Class III.

7.7.8.3. Height of seat cushion (dimension H, see Annex III, figure 11)

The height of the uncompressed seat cushion relative to the floor shall be such that the distance from the floor to a horizontal plane tangential to the front upper surface of the seat cushion is between 400 and 500 mm: this height may however be reduced to not less than 350 mm at the wheel arches and at the engine compartment.

7.7.8.4. Seat spacing (see Annex III, figure 12)

7.7.8.4.1. In the case of seats facing in the same direction, the distance between the front of a seat squab and the back of the squab of the seat preceding it (dimension H), shall, when measured horizontally and at all heights above the floor between the level of the top surface of the seat cushion and a point 620 mm above the floor, not be less than:

H	
Class I, A and B	650 mm
Class II and III	680 mm

7.7.8.4.2. All measurements shall be taken, with the seat cushion and squab uncompressed, in a vertical plane passing through the centre line of the individual seating place.

7.7.8.4.3. Where transverse seats face one another the minimum distance between the front faces of the seat squabs of facing seats, as measured across the highest points of the seat cushions, shall be not less than 1 300 mm.

7.7.8.4.4. Measurements shall be taken with reclining passenger seats and adjustable driving seats with their seat backs and other seat adjustments in the normal position of use specified by the manufacturer.

7.7.8.4.5. Measurements shall be taken with any folding table fitted to a seat back in the folded position.

7.7.8.4.6. Seats which are mounted on a track or other system which permits the operator or the user to easily vary the interior configuration of the vehicle shall be measured in the normal position of use specified by the manufacturer in the application for the approval.

7.7.8.5. Space for seated passengers (see Annex III, figure 13)

7.7.8.5.1. A minimum clear space in front of each passenger seat shall be provided as shown in Annex III, figure 13. The seat back of another preceding seat or a partition whose contour corresponds approximately to that of the inclined seat back may intrude into this space as provided by paragraph 7.7.8.4. The local presence in this space of seat legs shall also be permitted provided that adequate space remains for the passenger's feet. In the case of seats alongside the driver's seat in vehicles with up to 22 passengers, intrusion of the dashboard, instrument panel, windscreen, sun visor, seat belts and seat belt anchorages shall be allowed.

7.7.8.5.2. However, at least two in Class I and Class II and one in Class A forward or rearward facing seats specifically intended and marked for passengers with reduced mobility other than wheelchair users shall be provided in that part of the bus which is most suitable for boarding. These seats shall be designed for passengers with reduced mobility so as to provide enough space, shall have suitably designed and placed handholds to facilitate entry and exit of the seat, and provide communication in accordance with paragraph 7.7.10 from the seated position.

7.7.8.5.2.1. These seats shall provide at least 110 % of the space specified in item 7.7.8.5.1.

7.7.8.6. Free space above seating positions

7.7.8.6.1. Over each seating position and, except in the case of the front row seats in a vehicle up to 22 passengers, its associated foot space, there shall be measured a free space with a height of not less than 900 mm measured from the highest point of the uncompressed seat cushion and at least 1 350 mm from the mean level of the floor in the foot space. In the case of vehicles to which paragraph 7.7.1.10. applies, this dimension may be reduced to 1 200 mm measured from the floor.

7.7.8.6.2. This free space shall be extended over the zone defined:

7.7.8.6.2.1. by longitudinal vertical planes 200 mm either side of the median vertical plane of the seating position, and

7.7.8.6.2.2. by a transverse vertical plane through the rearmost upper point of the seat back and by a transverse vertical plane 280 mm in front of the foremost point of the uncompressed seat cushion, measured in each case at the median vertical plane of the seating position.

7.7.8.6.3. From the edges of the free space defined by paragraphs 7.7.8.6.1 and 7.7.8.6.2, the following zones may be excluded:

7.7.8.6.3.1. in the case of the upper part of outboard seats, a zone with a rectangular cross-section 150 mm in height and 100 mm in width (see Annex III, figure 14);

7.7.8.6.3.2. in the case of the upper part of outboard seats, a zone with a triangular cross-section whose apex is situated 650 mm from the floor and whose base is 100 mm in width (see Annex III, figure 15);

7.7.8.6.3.3. in the case of the footwell of an outboard seat, a zone of a cross-sectional area not exceeding 0,02 m^2 (0,03 m^2 for Class I low-floor vehicles) and having a maximum width not exceeding 100 mm (150 mm for Class I low-floor vehicles) (see Annex III, figure 16);

7.7.8.6.3.4. in the case of a vehicle for up to 22 passengers, in the case of the seating places nearest to the rear corners of the body, the outer rear edge of the free space, viewed in plan, may be rounded to a radius not exceeding 150 mm (see Annex III, figure 17).

7.7.8.6.4. In the free space defined by paragraphs 7.7.8.6.1, 7.7.8.6.2 and 7.7.8.6.3, the following additional intrusions shall be permitted:

7.7.8.6.4.1. intrusion of the back of another seat, its supports and its attachments (e.g. folding table);

7.7.8.6.4.2. in the case of a vehicle for up to 22 passengers, intrusion of a wheel arch provided that one of the following two conditions is fulfilled:

7.7.8.6.4.2.1. the intrusion does not extend beyond the median vertical plane of the seating position (see Annex III, figure 18), or

7.7.8.6.4.2.2. the nearest edge of the area 300 mm in depth available for the feet of the seated passenger is advanced no more than 200 mm from the edge of the uncompressed seat cushion and to not more than 600 mm in front of the squab of the seat, these measurements being made in the median vertical plane of the seating position (see Annex III, figure 19). In the case of two seats facing each other this provision shall apply to only one of the seats and the remaining space for the feet of seated passengers must be at least 400 mm;

7.7.8.6.4.3. in the case of seats alongside the driver's seat in vehicles with up to 22 passengers intrusion of hopper-type windows when open and their fittings, of the dashboard/instrument panel, windscreen, sun visors, seat belts, seat belt anchorages and front dome.

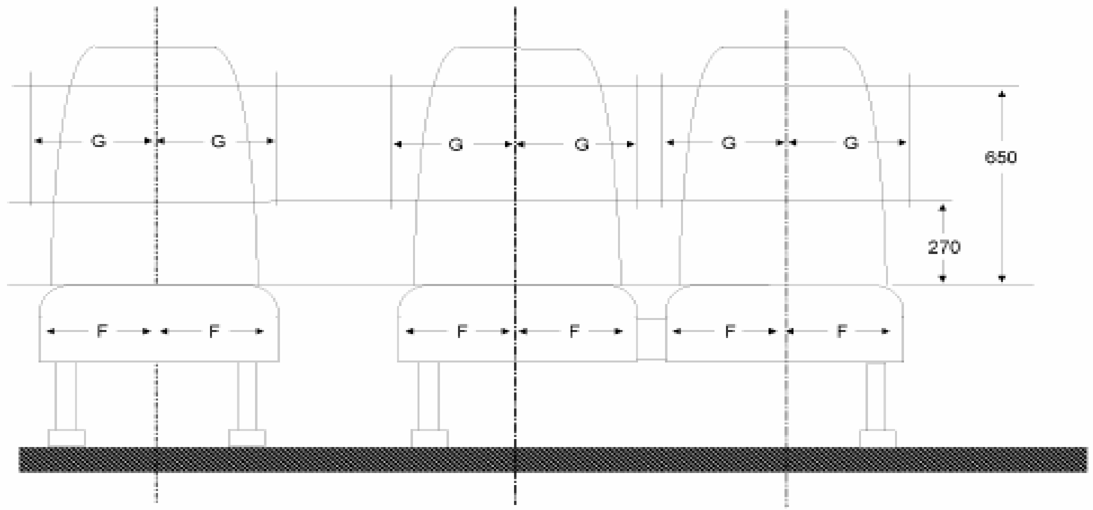
Figure 1: Annex 1 paragraph 7.7.8 of the European directive-2001/85 EC

(Original document, p. 33-35).

Figure 9

Dimensions of passenger seats

(see Annex I paragraph 7.7.8.1)

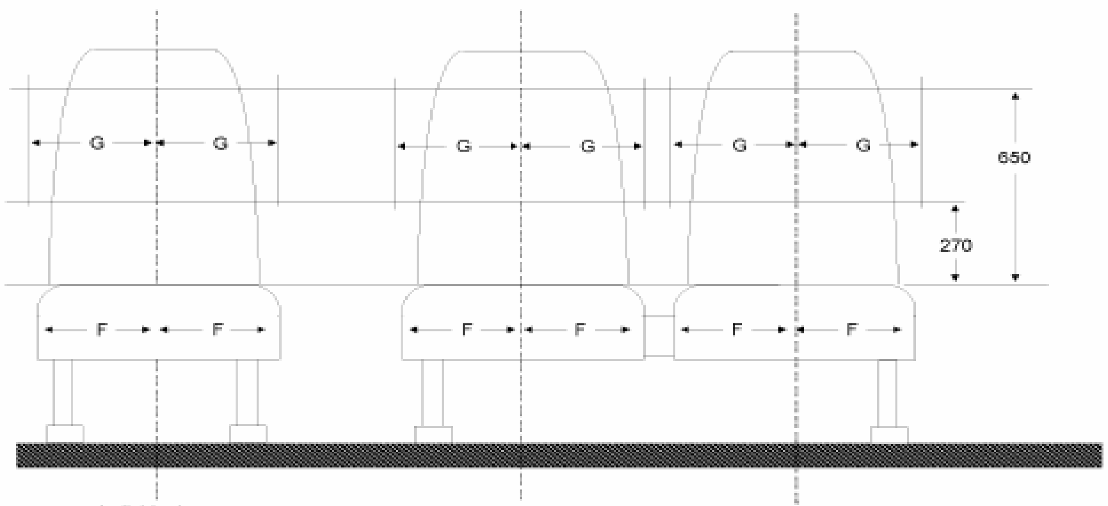


	G (mm) min	
F (mm) min	Continuous seats	Individual seats
200 (*)	225	250

(*) 225 for Class III

Figure 9 bis

Dimensions of passenger seats
(see Annex I paragraph 7.7.8.1.3)



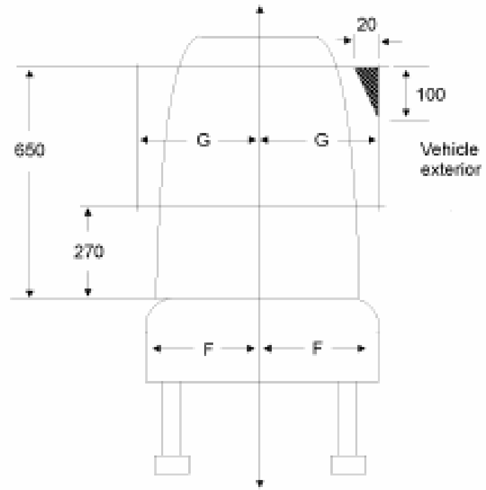
	G (mm) min	
F (mm) min	Continuous seats	Individual seats
200	200	200

Figure 10

Permitted intrusion at shoulder height

Transversal section of the minimum available space at shoulder height for a seat adjacent to the wall of the vehicle

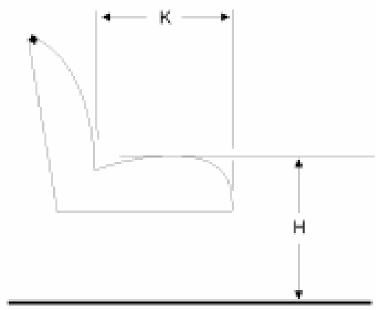
(see Annex I paragraph 7.7.8.1.4)



G = 225 mm if continuous seat
G = 250 mm if individual seat
G = 200 mm for vehicles less than 2,35 m wide

Figure 11

Seat-cushion depth and height
(see Annex I paragraphs 7.7.8.2 and 7.7.8.3)

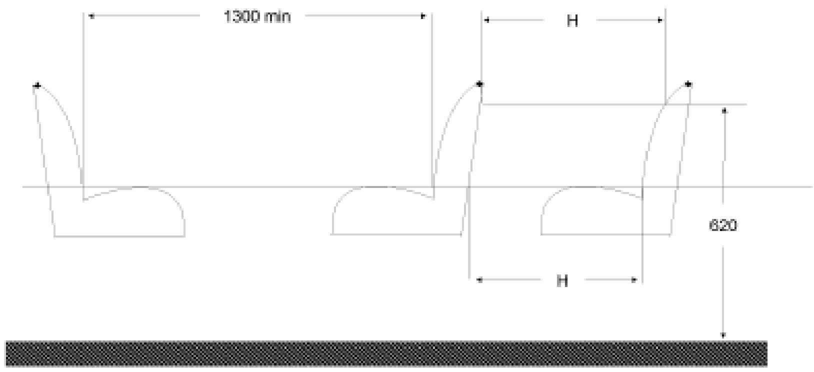


H = 400/500 mm (*)
K = 350 mm min (**)

(*) 350 mm at wheel arches and engine compartment
(**) 400 mm in vehicles of Classes II & III

Figure 12

Seat spacing
(see Annex I paragraph 7.7.8.4)



	H
Classes I, A and B	650 mm
Class II and Class III	680 mm

Figure 13

Space for seated passengers
(see Annex I paragraph 7.7.8.5)

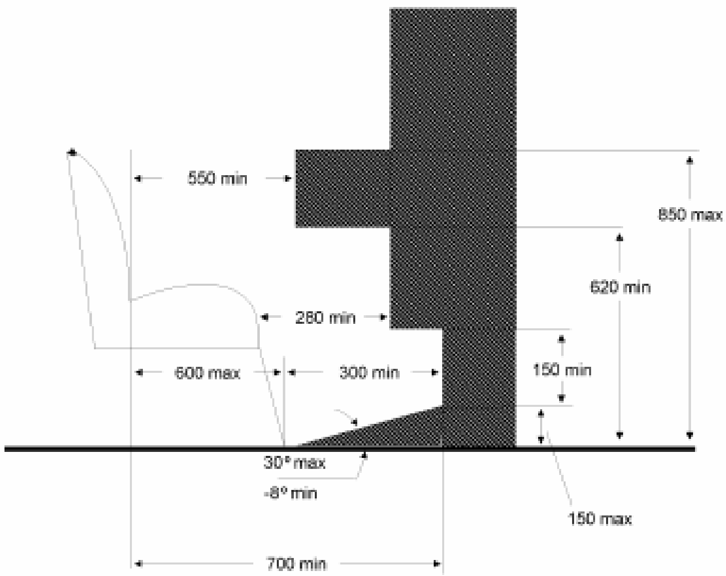


Figure 14

Permitted intrusion into space above seat
Transversal section of the minimum free space above a seating place adjacent to the wall of the vehicle
(see Annex I paragraph 7.7.8.6.3.1)

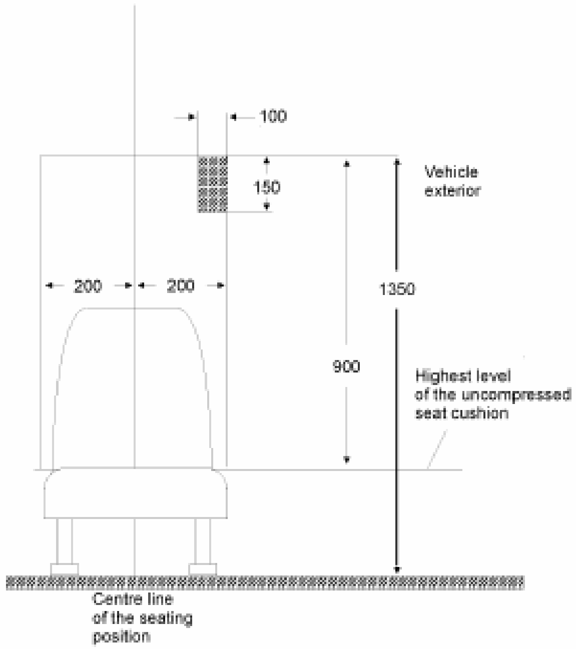


Figure 15

Permitted intrusion above a seating position
(see Annex I paragraph 7.7.8.6.3.2)

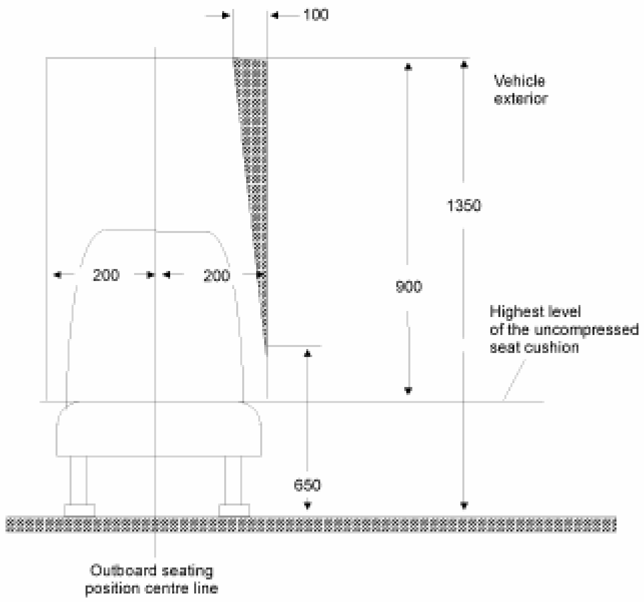
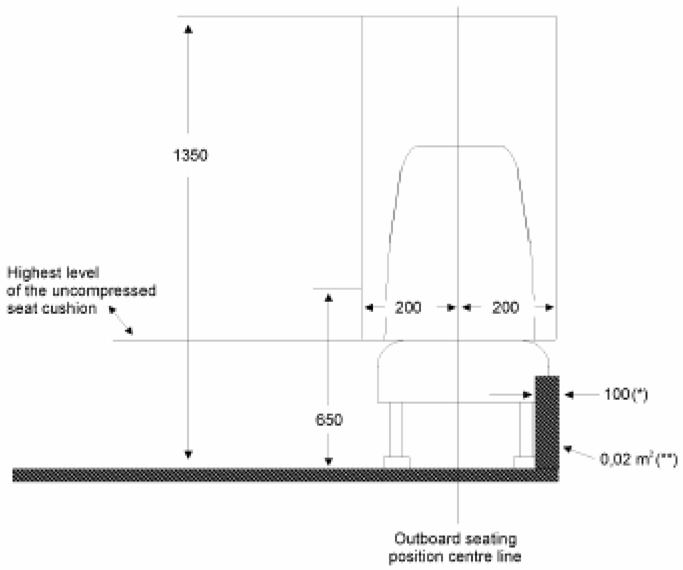


Figure 16

Permitted intrusion in lower part of passenger space
(see Annex I paragraph 7.7.8.6.3.3)



(*) 150 mm in the case of Class I low-floor vehicles
(**) 0,03m² in the case of Class I low-floor vehicles

Figure 17

Permitted intrusion at rear corner seats
View of the prescribed area of the seat (two side seats at the rear)
(see Annex I paragraph 7.7.8.6.3.4)

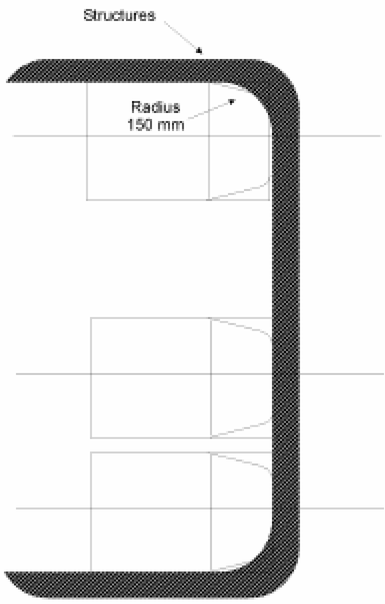


Figure 18

Permitted intrusion of a wheel arch not extending beyond the vertical centre line of the side seat
(see Annex I paragraph 7.7.8.6.4.2.1)

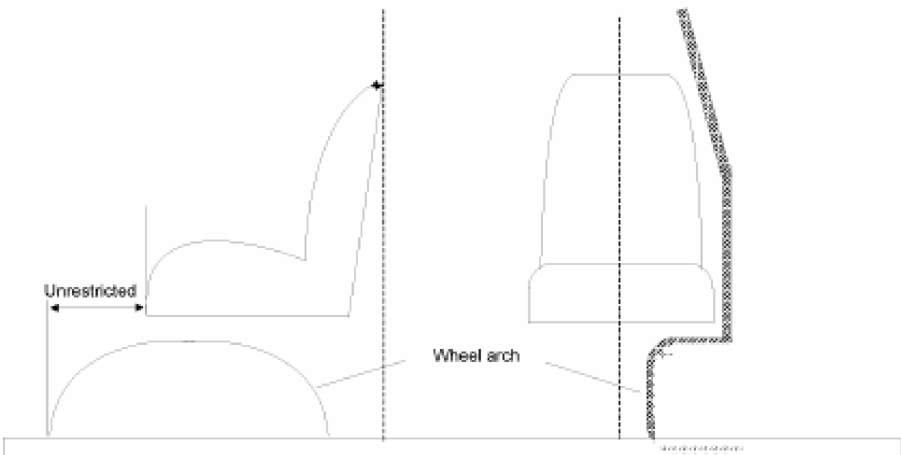


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Figure 19

Permitted intrusion of a wheel arch extending beyond the vertical centre line of the side seat
(see Annex I paragraph 7.7.8.6.4.2.2)

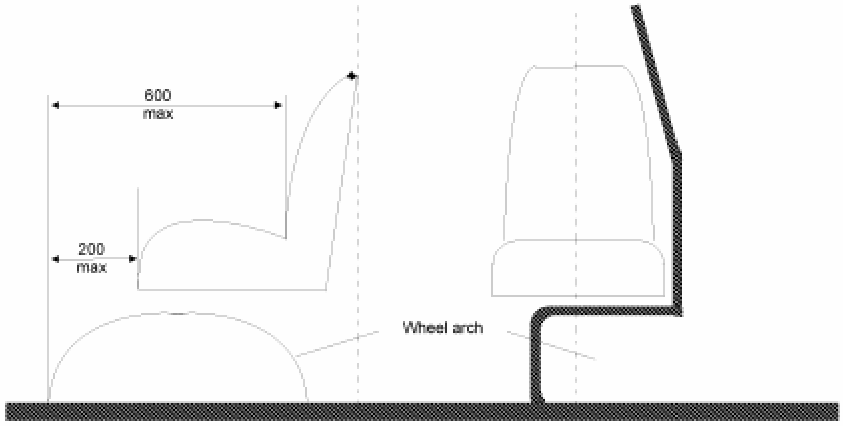


Figure 2: Figures of Annex 1 paragraph 7.7.8 of the European directive-2001/85 EC (Original document, p. 61-69).

APPENDIX B

FOUR PASSENGER SEATS SELECTED FROM INTERCITY COACHES

Figure 1: The passenger seat of Kiel (Photos were acquired from the coach of Man Fortuna in 28.09.2005).

Figure 1: The passenger seat of Kiel (Photos were acquired from the coach of Man Fortuna in 28.09.2005-Cont.).

Figure 2: The passenger seat of Grammer (Photos were acquired from the coach of Man S2000 in 28.09.2005).

Figure 2: The passenger seat of Grammer (Photos were acquired from the coach of Man S2000 in 28.09.2005-Cont.).

Figure 3: The passenger seat of Mercedes (Photos were acquired from the coach of Mercedes O403 28.09.2005).

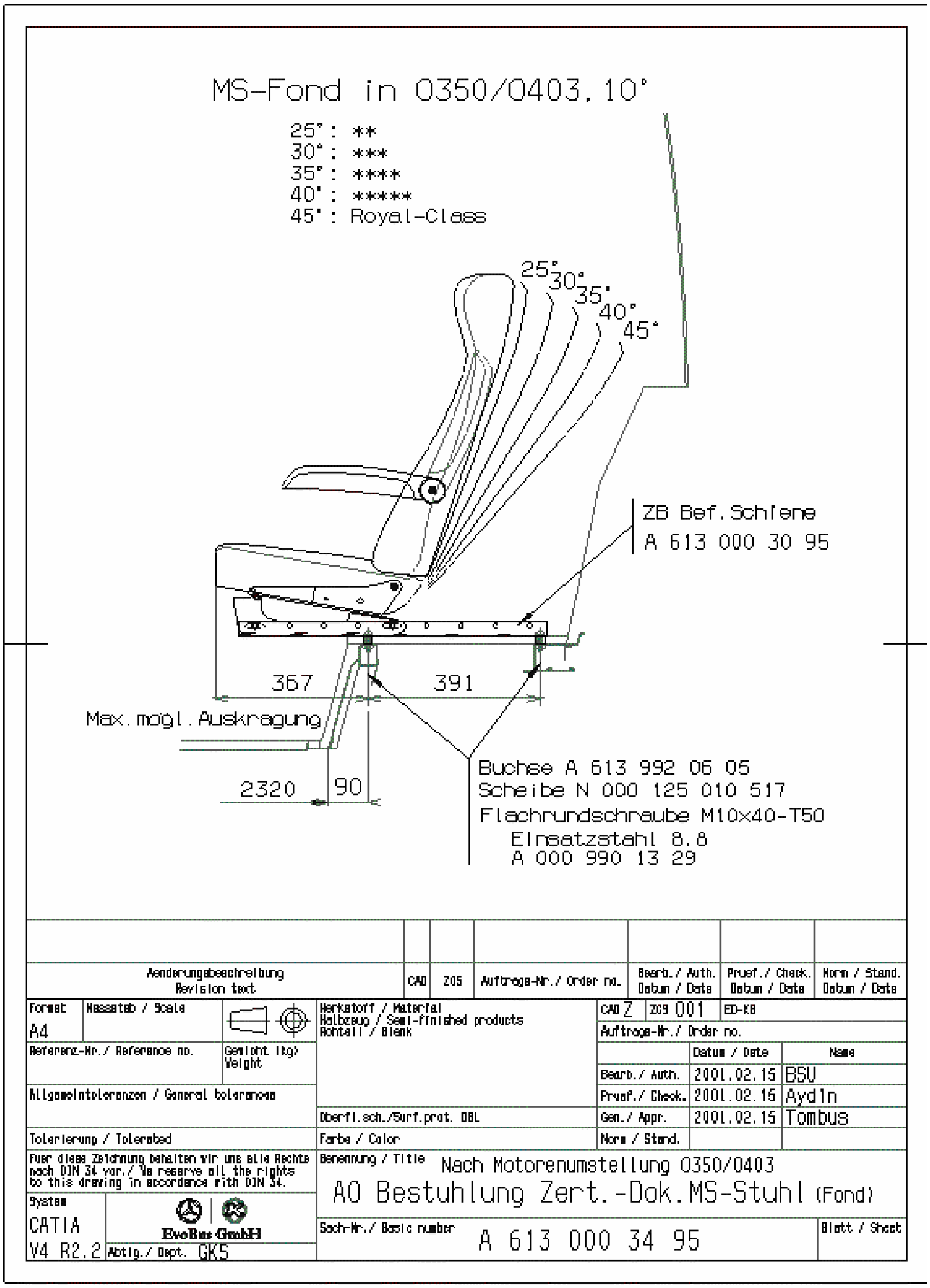
Figure 3: The passenger seat of Mercedes (Photos were acquired from the coach of Mercedes O403 28.09.2005-Cont.).

Figure 4: The passenger seat of Fainsa (Photos were acquired from the coach of Neoplan 516 SHD in 28.09.2005).

Figure 4: The passenger seat of Fainsa (Photos were acquired from the coach of Neoplan 516 SHD in 28.09.2005).

APPENDIX C

THE OFFICIAL TECHNICAL DOCUMENTS OF THE SELECTED SEATS



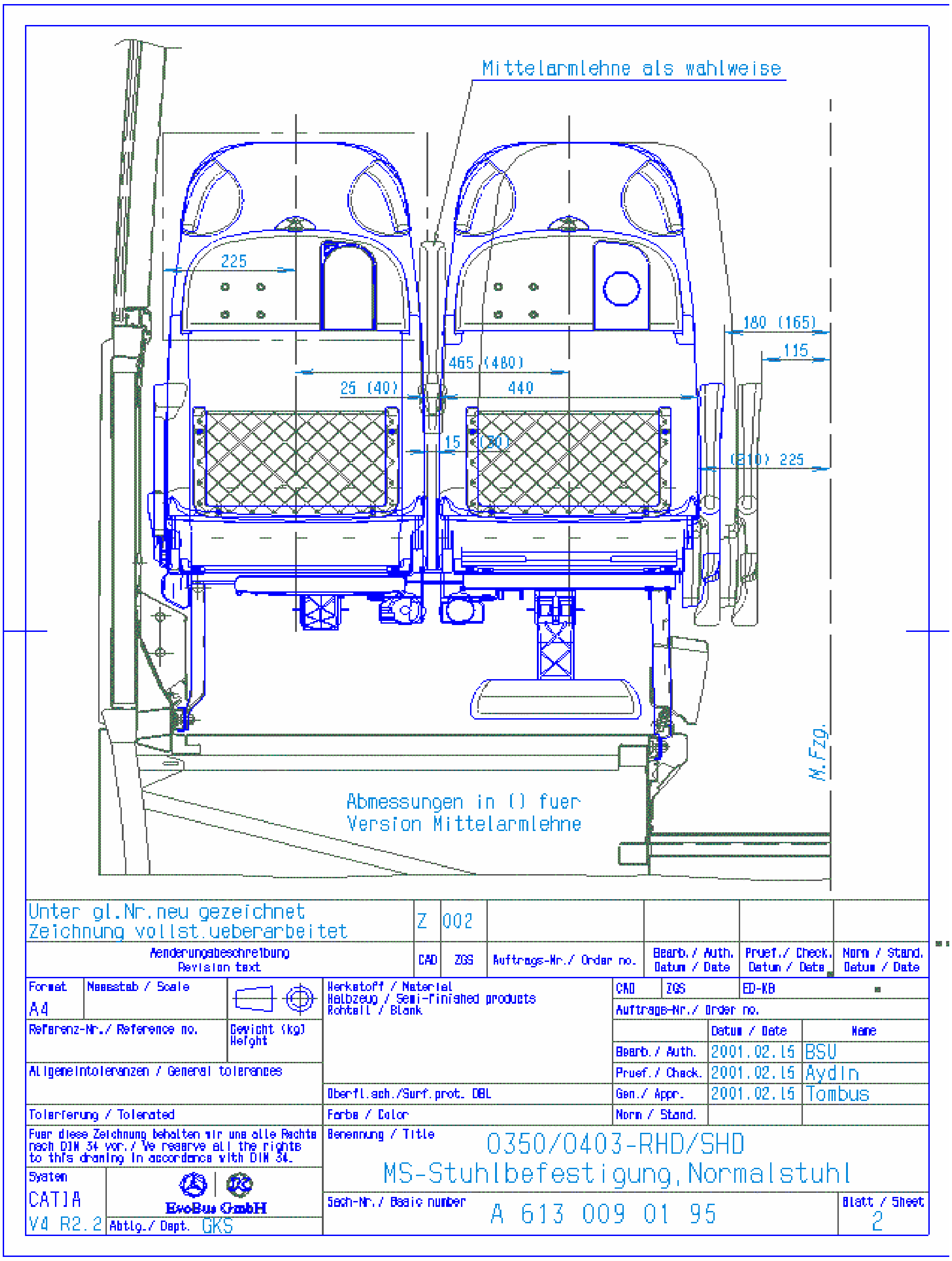


Figure 1: The official technical documents of seat of Mercedes (Cont)**.**

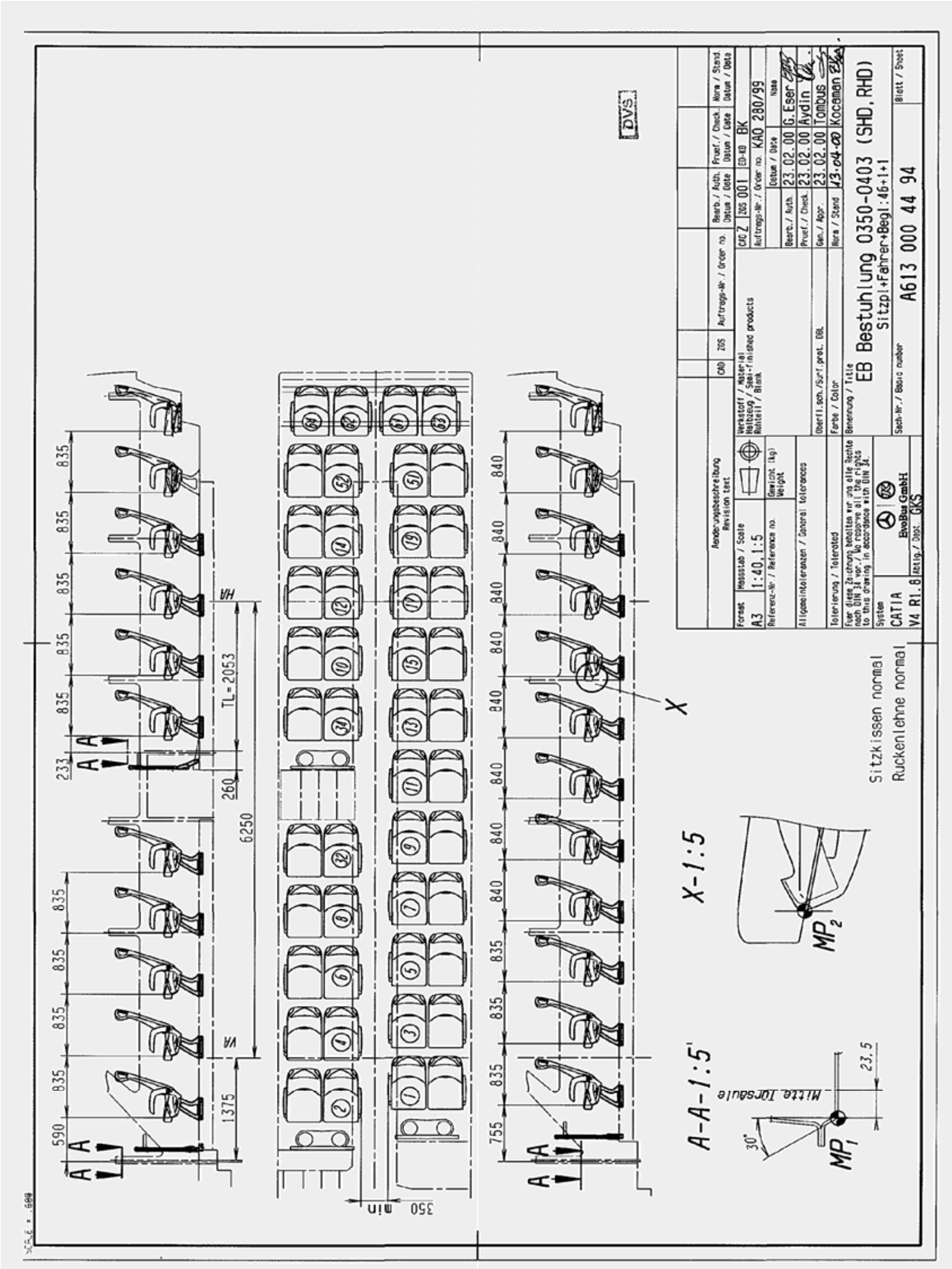


Figure 1: The official technical documents of seat of Mercedes (Cont)**.**

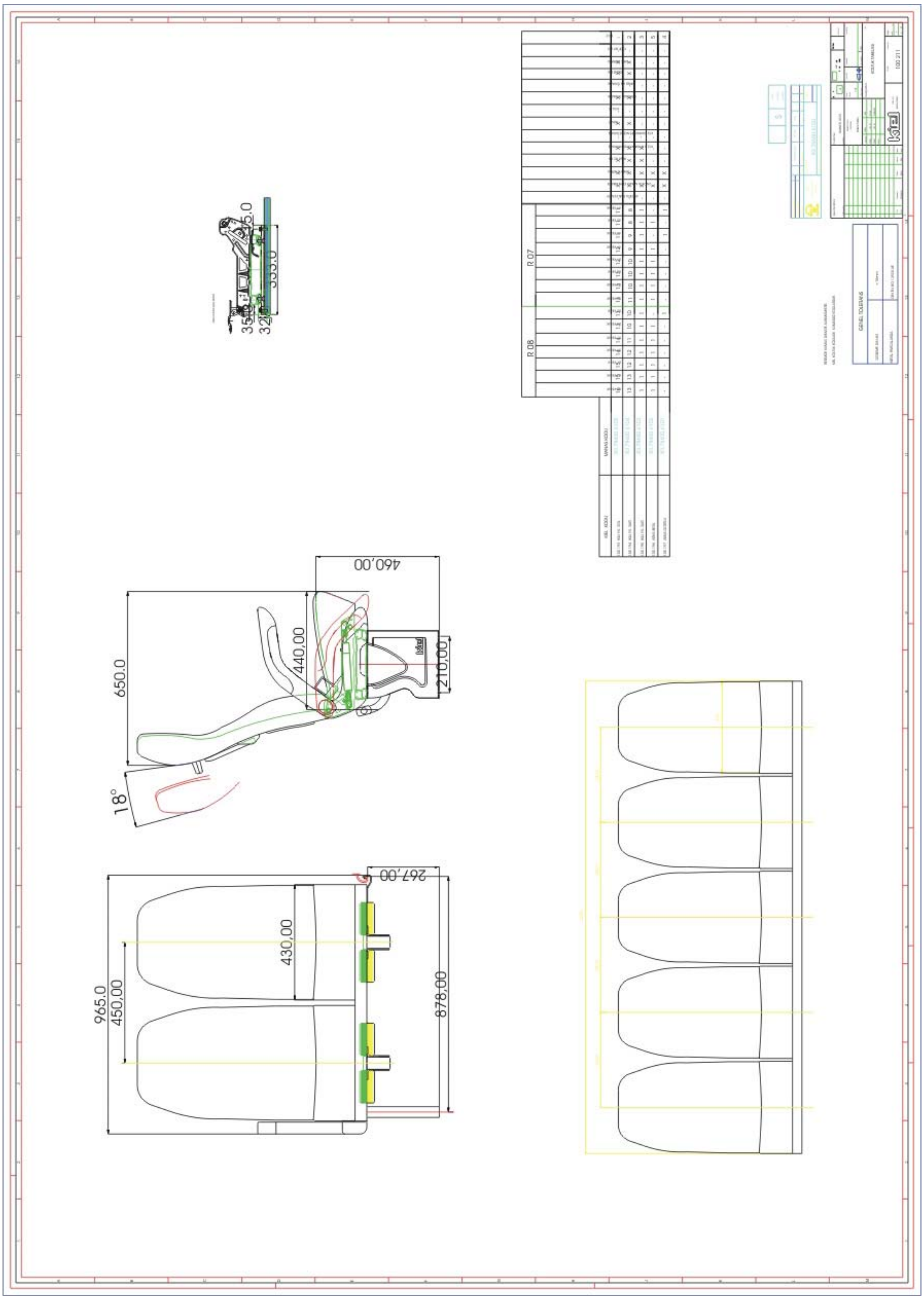


Figure 2: The official technical document of seat of Kiel.

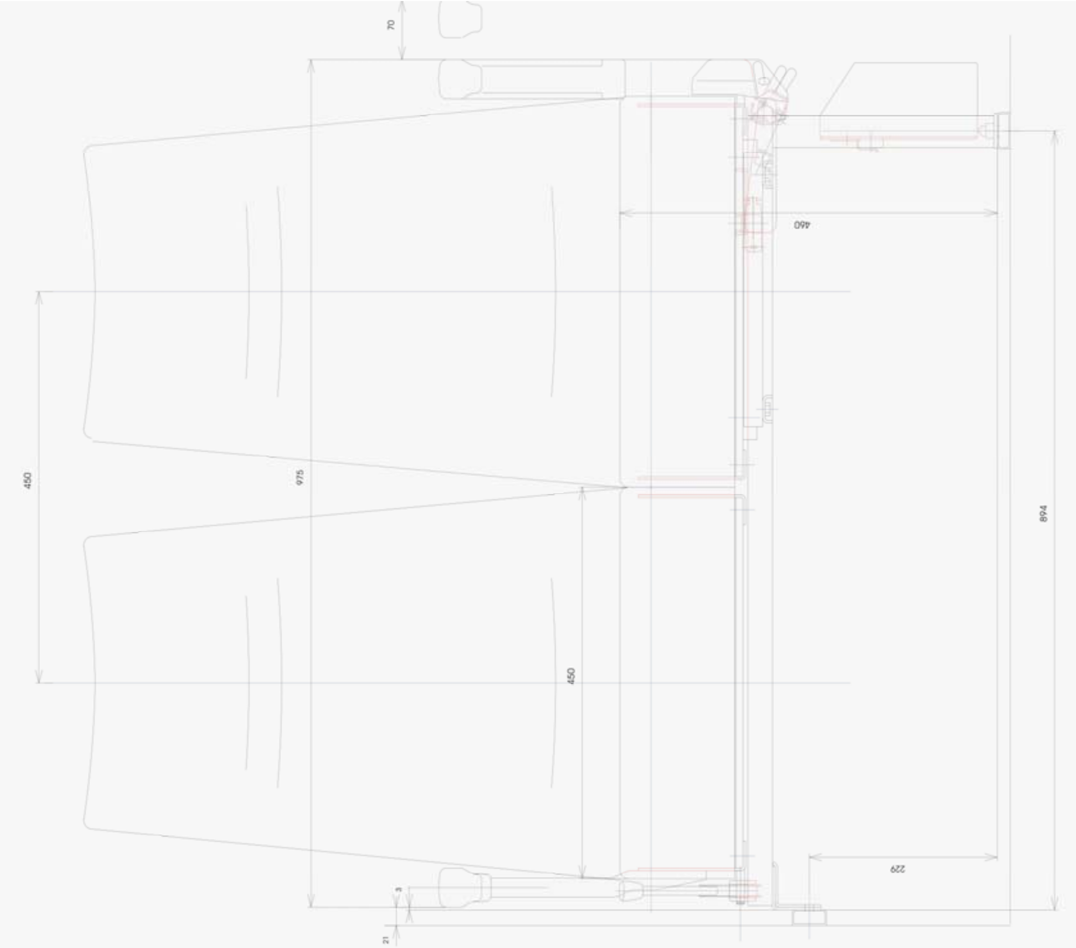


Figure 3: The official technical document of seat of Grammer.