Designing for comfort

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Abstract
In this paper human factors in designing of a more comfortable aircraft cabin for passengers are described. Comfort is a complex concept, consisting of both objective ergonomics requirements and subjective impressions. Elements of comfort can be described by four different models: 1) The passenger bubble, in which the passenger is isolated from disturbances and can pursue his/her own activities; 2) The health model, where the focus is on absence of discomfort, potential health dangers and annoyance, and on physical well-being; 3) The community model, in which passengers belong to a public-transport group, who communicate and share common experiences; 4) The aesthetic-economical model, in which comfort is perceived as being in an interesting, advanced and beautiful environment, for a reasonable price. All these models put different requirements on the passengers’ environment, sometimes overlapping, but sometimes also conflicting. In order to support designing for comfort, we present a model in which these requirements can be combined based on cognitive function analysis. Four principles are identified that should guide design: affordance, situational awareness, individualisation and customisation, and variability and flexibility. The paper concludes with a discussion on the design process.

Introduction
If you ask airplane passengers in economy class how their comfort can be enhanced most of them will probably say: make the seats larger and put more space between them. This, however, is not a very viable solution, as it means less seats in the plane, and thus higher costs. If we want to enhance passenger comfort, other measures may be envisaged. In order to investigate what measures to take, the main question is what do we mean by comfort? Although nearly anyone is capable of saying whether he or she feels comfortable, comfort is not a one-dimensional concept that can be measured in a simple way, as the temperature can. In this paper, we will discuss how to model the comfort concept, and which kinds of improvements will follow directly from these models. Next, we will discuss ways in which designers may go about designing a comfortable environment, providing design principles.

According to dictionaries, comfort is a complex concept consisting of a mix of feelings, perception, mood and situation. It can be defined as follows. Comfort is:

- The pleasant and satisfying feeling of being physically or mentally free from pain and suffering, or something that provides this feeling;
- A feeling of freedom from worry or disappointment;
- Freedom from financial difficulty promoting a comfortable state;
- A state of quiet enjoyment, freedom from pain, want, or anxiety, and also whatever contributes to such a condition;
- Material well-being, conveniences that make life easier and more pleasant.

What is interesting about these definitions is that both a negative approach is taken (such as absence of pain) and a positive one (such as quiet enjoyment). Comfort is a very old word. It comes from the Latin “confortare” which meant help, assistance, courage, aid. The notion has evolved and is now linked primarily to material aspects. Actually the notion of material well-being in comfort is recent; it appeared in the middle of the XIX-th century with the industrial revolution and the availability of manufactured objects (le Goff, 1994).

In this paper we focus on the comfort of passengers in an aircraft cabin, taking into account both positive and (the absence of) negative aspects. By developing models of comfort, we want to get a better hold on the slippery comfort concept, arrive at a better understanding of the elements which influence comfort and subsequently try to formulate recommendations to enhance comfort. Although we focus on aircraft cabins, we aim to develop models which can be generalised to other areas, for example to other means of transport.

Enhancing comfort in aircraft cabins is important for several reasons. Comfort is an important aspect of competitiveness between airlines. An increasing part of the population is using air transport, including elderly people and people with handicaps, and people are flying more frequently. A comfortable flight is thus becoming more important for a growing number of the passengers. If passengers feel comfortable, their behaviour will probably cause less trouble to aircrews, thus avoiding problems in aircrafts and ultimately enhancing safety. Several large European projects are currently investigating the amelioration of comfort for aircraft passengers, such as FACE (Friendly Aircraft Cabin Environment, G4RD-CT-2002-00764) and HEACE (Health effects in aircraft cabin environment, G4RD-CT-2001-00611).

To get a better understanding of comfort, we will start with describing the general concept of comfort from different scientific points of view. Next four more specific models of comfort in aircraft cabins are constructed and examples of measures are given that can be taken to improve the comfort for each of the four models. As these models do not give a sufficient view on how to design cabins taking into account the different, and sometimes conflicting, requirements from all the cabin models, we model comfort in terms of cognitive functions. These functions form the basis of design principles. After explaining these design principles, the design process is shortly discussed.

The concept of comfort

The general concept of comfort can be studied from different scientific points of view, the psychological, the physical, the sociological, and the technological point of view (see also Sèze, 1994).

1. The psychological point of view

Psychologically, the feeling of comfort is connected to a state of quiet enjoyment, a feeling of freedom from worry, disappointment, boredom, financial difficulty etc. From this point of view, comfort for humans is related to perception, both mental and physical, and emotions. Different comfort aspects play a role:

- Material comfort, satisfying basic needs for things like food, hygiene and security, and thus defining a minimum external condition of comfort. We have to take into account that people live in different material conditions, and that what is basic for people in wealthy cultures and conditions is not necessarily the same for people who live in poorer conditions.
- Aesthetic comfort, which is subjective and depends on taste, and on personal perceptions and sensations of forms, materials, colours, lights, smells, sounds etc.
- Socialisation comfort: the need to be with others and the need for privacy. People want to communicate with others, but they also want to be able to isolate themselves. In an aircraft cabin an equilibrium between these needs has to be found.
- Conformity comfort: people want to feel they belong to a group, and do not like being outsiders. In an aircraft cabin, a strange environment with strange people, conformity comfort may play an important role in order for people to feel safe.

Everyone tries to satisfy these four comfort categories. They are interdependent and can be complementary or conflicting. No one comfort definition will be fitting for everybody. Everyone has his/her own conception of comfort depending on his/her education, experience, history, and living conditions.

2. The physical point of view

The physical state of comfort of a person concerns freedom from pain and suffering, being relaxed, feeling pleasant and satisfied, feelings of physical well-being. Being in an airplane for a prolonged period of time is not a natural human state, and it has physiological consequences, which may even be dangerous, as when deep venous thrombosis is caused. Air quality, pressure, noise, lack of movement, anxiety about the flight, etc., influence the well-being and the health of passengers. We can distinguish between:

- The physiological state of comfort: related to factors which influence the physiological state of persons such as noise, air quality, pressure, etc. People differ in how they are influenced by these factors, however, standards exist on the level of acceptability. Also other factors may influence comfort, such as motion sickness. Several of these factors are caused by the construction and the functioning of the aircraft system itself, but improvement of the cabin climate can be realised.
- The bio-mechanical state of comfort: dealing with the posture of people. Passengers have to sit, especially during long-haul flights, in a rather restricted posture for a long period, which may cause pain in the neck, shoulders, back, knees etc. Also equipment such as videos screens can cause problems if they are not well placed.
- Comfort for people with health problems and handicaps. Many passengers have health problems, often small ones, but also people with more severe handicaps use air transport. As the population is becoming older, more passengers will have health problems or potential health problems.

3. The sociological point of view

Even if each individual pursues his/her own idea of comfort, it is conditioned by belonging to a group, a family, a culture. Different backgrounds determine different perceptions of comfort. Two major classifications may be distinguished:

- Geographic and ethnic perception of comfort. The notion of comfort varies largely between different countries. For example, in many non-western civilisations, rest postures are very different from those in Europe or the USA. For example in India or in Africa many people are used to sitting cross-legged or on the soles of their feet. In Europe people prefer to be seated on a chair. When looking at ways of eating in different areas, comfort in western countries is associated with table and chairs. Also cabin features such as the colours of seats and walls mean different things in different cultures: the colour red, for example, has a very different meaning in Chinese and European cultures.
- Social class perception of comfort. In some social classes of the population, comfort is related to luxury, pomp and ceremonial. In other classes, it is related to showing off or having the newest gadgets. As it is no longer true that people from the higher classes fly only business or first class and those from the lower classes fly economy, the question of what is comfortable is further complicated. The perception of comfort is also related to the perception of value-for-money, which is different for people in different financial circumstances. To make a typology of comfort related to social classes is very difficult, because the notion of comfort is also influenced by individual life-styles.

4. The technological point of view

The material state of comfort refers to conditions in a person’s environment: being surrounded by commodities and services that make life easy and pleasant. Comfort can be objectified in its notion of material well-being. In the physical point of view, the emphasis is on absence of pain and on physical well-being; the technological point of view focuses on providing pleasure and agreeable sensations. Comfort is provided by technological means, by manufactured objects that have (or lack) comfortable characteristics, which are measurable. Such objects in the aircraft cabin can be seats, and video screens, and also the walls and the general lay-out of the cabin. But there is a gap between the measured comfort set up by the engineer, and the comfort experienced by the user. On the one hand, measured comfort is a purely technical notion (concerning for example noise level or available space

for legs), but on the other hand, comfort is a subjective feeling, related to approval or even seduction (le Goff, 1994). From the technological point of view two trends can be distinguished:

- Comfort of efficiency and management: comfort based on ergonomic features, such as the rational organisation of an in-flight entertainment screen and control panel, good accessibility of seats, acceptable noise level, etc. In order to be comfortable, everything should work properly, be easy to operate and not cause any harm (for guidelines on ergonomic requirements see for example: Scapin & Bastien, 1997 and Woodson & Conover, 1973).
- Comfort of pleasure and sensation: this refers to the sensitive and body perception, for example a soft lighting or a smooth seat. Gadgets, such as videos and games etc. can play a role in the comfort perception. In order to be comfortable, artefacts should be attractive, at least for the majority of passengers, although this will mean something different for different people.

From a technological point of view all technical and functional aspects of artefacts are important as well as the visual, tactile, kinaesthetic, and symbolic aspects.

**Models of comfort in the cabin**

In this paper we describe human factors in designing a more comfortable aircraft passenger cabin. Although comfort is important in all flights, we focus on the middle and long haul flights with modern aircraft. The model of the newest aircraft of the Airbus family, the A380, is a good reference when looking into comfort aspects (see Airbus 2003). The arrangement of the cabins is the responsibility of the airlines and will differ from one plane to another. However, these aircraft have in common that they can transport a large number of passengers (550 or more) and will be used for long haul flights, of even 18 hours duration. In such situations, an acceptable level of comfort for the majority of the passengers is essential, in order to avoid serious problems, for the individual passengers, for their fellow passengers and for the crews.

As we stated before, comfort is a complex concept, consisting of both objective ergonomic requirements and subjective impressions. We address comfort for passengers in an aircraft cabin, focussing on how to design the passenger environment so that it becomes more comfortable. We focus on elements that may be changed by cabin design, and ignore those aspects which are more inherent to the design of the structure of the aircraft structure itself and to the flight process. For example, turbulence and bad weather are important causes for uncomfortable feelings, but the construction of an aircraft that is less liable to suffer from turbulence is not related to cabin design, and thus out of the scope of this paper. The same holds for the lack of comfort caused by delays in flights, strikes, missing connections etc. These are factors caused by the operation of airline companies and air traffic control and also not related to cabin design. Also aircrew service practices are left aside. Leaving out these elements means that an amelioration of comfort can only be partially achieved. Someone worrying about her connecting flight, in a condition of high turbulence, will never feel comfortable, even if the cabin design is perfect.

The elements we take into account are, amongst others, seats, cabin lay-out, noise, lights, in flight entertainment, laptop connections, access to phones and internet. We focus on the economy class cabins of middle and long haul flights, the required amelioration of comfort of which will be the most challenging. In order to describe what designing for comfort may enhance, we first present four different models of comfort, specific for aircraft cabins.

1. **The passenger bubble**: a space in which the passenger is isolated from disturbances and can pursue his/her own activities. The passenger wants to be in a space as private as possible. He/she does not want to be disturbed by others and wants to pursue his/her own activities undisturbed. These activities may consist of reading, writing, working on a laptop, listening to music, watching a film, eating or sleeping. The passenger prefers to have his/her own screen for in-flight entertainment, and to be able to personalise the choice, the sound level, contrast etc. Comfort for the passenger requires that he/she can feel as if alone in a private room. To satisfy this requirement it is
necessary to individualise passenger facilities and to make sure passengers do not disturb each other with light, sounds etc.

2. The health model: here the focus is on absence of discomfort, of potential health dangers and annoyance, and on physical well-being. In this model comfort means the absence of nuisance and (potentially) harmful situations. This means that the seats should be so constructed that even after long flights passengers do not have back pains, that they could sleep comfortably, and that the screen for the in-flight entertainment is at the right distance. Special attention should be paid to avoiding deep venous thromboses and wrong postures (e.g. Bagshaw et al., 2002). Passengers should be induced to leave their seats regularly and in doing so should not be hindered by equipment and seats. Measures taken to enhance comfort should be first of all ergonomically sound. Boredom and stress should be avoided.

3. The community model: passengers belong to a public-transport group, communicating and sharing common experiences. Flying in an airplane is a form of public transport and thus a social situation. Comfort means that passengers can behave socially, that people travelling together can talk to each other, and can interact with their neighbours, so that they can have the sensation that all passengers, or those within the same compartment, form a group sharing a common experience. In this model being aware of the activities of the neighbours poses no problem, as long as it is not too obtrusive. For people travelling together it should be possible to have common activities such as playing games, attending to the children, leaning on each other while sleeping etc.

4. The aesthetic-economical model: here comfort is perceived as being in an interesting, advanced and beautiful environment, at a reasonable price. Passengers perceive the flight as an experience for which a rather large amount of money is paid. This experience should be enjoyable and therefore the quality of the service should be good and the environment should be aesthetically pleasing, attention should be paid to details. Everything should work properly and should be clean. There is a relation between price, image of the airline and expectations. Passengers will demand less on a flight with a cheap carrier than on a flight with an airline that promises luxury.

These four models are not mutually exclusive, and an individual passenger does not necessarily fit into one model only. Maybe during a part of the flight he/she will want to be in a private bubble, while at another stage he/she will want to have a conversation with his/her neighbour. And no one wants back pain.

Improvement of comfort for the four models

Aircraft and equipment manufacturers and airlines are constantly searching for measures to improve passengers’ comfort. For different models, different improvement measures can be taken. Below we give some examples.

In the passenger bubble the focus is on the activities the passenger performs with equipment made available. Examples of improvements of comfort could be: Sound isolation, Good connections for laptops and telephones, Internet connection, Light and sound levels to be individualised, Information programs about flight status, connections, weather situation on arrival, etc., and a Personal card on which the preferences of the passenger are registered for services offered such as IFE (In Flight Entertainment) and configuration of the seats, which can be read by a card reader.

In the health model the focus is on the interaction between the passenger and his/her specific characteristics and the equipment to be used, especially the seats. Examples of improvement of comfort could be: Seats that offer enough space for everyone (see Quigly et al. 2001). Adaptable seats, head and armrests, Equipment within reach, adjustable positions, Space to move around in the cabin, and encouragement to do so, Equipment that is ergonomically sound and does not cause painful movements, IFE possibilities to avoid stress and boredom, Seats that can move vertically upward, so as to help people get out of their seat, allowing for more space for passing, and Tele-medicine, the possibility (for the crew) to consult a doctor on-line in case of medical problems.

In the community model, the emphasis is on the way in which the passengers interact with other passengers and the environment. Examples of improvement of comfort could be: Specific cabin areas for receiving groups, families and different types of people: bar, electronic areas to work in, play areas for children, Adaptable cabin layout to organise seats and equipment so as to facilitate communication between people, Possibilities for playing and chatting with others, both physically and virtually, Different arrangements of seats allowing for common activities such as eating and playing, Seats allowing people to sit close together, Organisation of group activities in IFE such as quizzes and competitions.

In the aesthetic-economical model, the emphasis is on how passengers experience the environment and the available artefacts. Examples of improvement of comfort could be: Cabin decoration and design that give an impression of luxury, different decorations in different aircraft, realised by artists, A completely different lay-out of the cabin or an aesthetic environment that looks like or makes references to other transportation (cars, busses, trains), Aesthetic design of all equipment, Use of sophisticated and clear symbols and pictograms, Outside view, either virtual or real, Different kinds of windows, and Service paying attention to small details, pleasant presentation of food and drinks.

The measures to enhance comfort for the different models may be contradictory. If the passenger bubble is made so comfortable that the passenger does not feel any necessity or inclination to leave his/her seat, this may cause medical problems. If ergonomically sound armrests, which can be made to adjust to the size of the passenger, are installed between the seats, two passengers travelling together may not be able to lean on each other. If a passenger wants to talk to his/her neighbour, if only to ask whether he/she may pass, and the neighbour is completely isolated because of the perfect headset proposed by the bubble model, this interaction might be more uncomfortable for both passengers than it would be in the old situation.

The design process of an aircraft cabin is a complex one, and can be viewed as the solving of an ill-defined problem. There is not a single, optimal solution. The designer has to find solutions for sub-problems, for example a comfortable seat or video screen that is conveniently located, and consequently determine whether these solutions are not conflicting, for example a comfortable seat which can be moved backwards may not have a comfortable screen for the video on its back, because the movement of the passenger in front makes looking at the screen uncomfortable for the passenger behind. The design process is therefore an iterative process and conflict resolution is an important part of it. In practice, the designer does not start from scratch to design a completely new cabin, but uses already existing cabins and artefacts and ameliorates and adjusts them.

Modelling in terms of cognitive functions

In the four models described above, different measures for improving comfort have been mentioned. Several of these measures may be conflicting, such as, for example, sound isolation and being able to be in contact with neighbours. In this section we sketch a model in which the different requirements from the different models are taken into account in an integrated manner. It will not always be possible to avoid conflicting requirements, but they can be studied in context and then a decision can be made about the most desirable design. We decompose the passenger's situation in the aircraft in four elements, derived from the AUTO (Artefact-User-Task-Organisational Environment) model of Boy (1998), see figure 1.

The User: the passenger. The passenger is a human being with a variety of stable characteristics, however during a flight his/her interests and needs may change. For example a passenger may work during one part of the flight and want to relax during another. The variety of passengers is huge: varying in age, goals and needs, cultural backgrounds, body features etc.

The Artefact: the facilities in the cabin used by the passenger, such as seats, tables, video-screens etc.

The Task: the activity the passenger performs such as watching a video, using the internet, eating, sleeping etc.

The Organizational Environment: the environment of the cabin, including the crew and other passengers, the duration of the flight etc.

In table 1 we give a non-exhaustive list of these four elements:

<table>
<thead>
<tr>
<th>AUTO elements</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger variables</td>
<td>Age; Gender; Travel purpose (business, holidays); Passenger accommodation (alone, with family, colleagues); Handicaps; Experience with air travel; Size and other anthropometric and morphological features</td>
</tr>
<tr>
<td>Artefact</td>
<td>Seat: including armrest, headrest, footrest, controls; Table; Seat belt; Light; IFE (in flight entertainment) plus control panel, including music, video, games, weather report; Flight information; Laptop connection; Internet; Telephone; Air-conditioning; Luggage compartment; Journals and books; Food and drink tray; Crew alert; Smart card reader</td>
</tr>
<tr>
<td>Activities (see also Hadibroto, 1992)</td>
<td>Sleeping; Reading; Working (with a laptop or other personal electronic tool; writing, with paper and pencil, reading document); Being entertained and playing (music, video, games); Eating; Communicate with others passengers, with crew and with exterior; Move around the cabin; Act on seat, environment and IFE parameters; Follow security demands: fasten seat belts, listening to security announcements; Shopping (tax free, services)</td>
</tr>
<tr>
<td>Environment variables</td>
<td>Crew; Other passengers; Decoration; Flight duration; Point of departure and destination; Connections; Cabin layout; Turbulence; Physical conditions within the cabin (temperature, light, noise, air quality)</td>
</tr>
</tbody>
</table>

Table 1: examples of elements from the AUTO (Artefact, User, Task, Organisational environment) for the aircraft cabin

To support a design team to take into account the factors influencing comfort, the AUTO (Artefact-User-Task-Organisational Environment) pyramid model can be used as a conception tool. The Eliane Dumur, Yvonne Barnard & Guy Boy (2004). Designing for comfort. In D.de Waard, K.A. Brookhuis, and C.M. Weikert (Eds.), Human Factors in design (pp.111-127). Maastricht, the Netherlands, Shaker Publishing.
The pyramid model represents the relations between users, artefacts, environments and tasks. In designing a cabin, all four elements should be taken into account interconnectedly, in order to arrive at an integrated product, in which the relations between the four elements form a harmonious whole. When one element is to be improved (especially an artefact), the influence on the other elements should be investigated. For example, determining for an artefact such as a seat, which activities should be more comfortable for which passengers, for example sleeping for people with back difficulties, should take into account the environmental consequences.

**Design principles**

The model can be used to analyse current design and its use, for making functional specifications and for evaluating a design. We can, however, go one step further with this model and relate design principles to the AUTO pyramid. This pyramid can be decomposed into four triangles, which are related to different design principles for comfort: (1) Affordance, (2) Situational awareness, (3) Individualisation and customisation and (4) Variability and flexibility.

1. **Affordance**

For the *affordance design principle* we concentrate on the activities the passenger is performing with the available equipment (see figure 2).

![Figure 2: Affordance: the Artefact-User-Task-triangle](image)

Many objects in the physical world have characteristics which indicate what to do with them. For example door handles have different shapes. A horizontal flat door handle that is located in the middle of a door suggests to push. A vertical cylindrical door handle that is located on one side of a door suggests to pull. Human beings establish a relationship between door handles and the appropriate action to open doors, i.e., push or pull. The kinds of relationships between humans and objects are defined by Gibson as affordances (Gibson, 1977). Objects have affordances whether they are natural or artificial. Systems should be designed using the notion of affordances, avoiding the development of systems which have counter-intuitive ways of operating (Boy, 1998; Rasmussen, 1999). In an environment, people immediately have ideas on how different elements may be used for different purposes. They have expectations of what could happen in this environment. Some of these ideas are personal and are inspired by the goals of the one perceiving the environment. Other ideas are more invariant properties of objects themselves.

So for all passenger activities with all artefacts, it must be clear what to do with the artefact and how to operate it. For example devices for using the IFE, the light, the sound level etc. should have an interface with which it will immediately be clear how to operate the different functions. The affordance principle is not only concerned with ease-of-use and the availability of intuitive commands, but also with inviting the use of a certain set of artefacts. For example adjustable head- and footrests should invite the passenger to use and adjust them in order to have a comfortable seat.

The affordance principle is most important for the passenger bubble model: creating a comfortable bubble in which all functions are easy and inviting to use, and for the health model: creating a Eliane Dumur, Yvonne Barnard & Guy Boy (2004). Designing for comfort. In D.de Waard, K.A. Brookhuis, and C.M. Weikert (Eds.), *Human Factors in design* (pp.111-127). Maastricht, the Netherlands, Shaker Publishing.
situation for the passenger without stress and annoyance because it is obvious how to operate all artefacts and inviting to have activities which contribute to avoiding unhealthy situations.

2. Situational awareness

For the situational design principle we concentrate on the activity a passenger is performing in the environment (see figure 3).

![Image of User-Task-Organisational environment triangle]

Figure 3: Situational awareness: the User-Task-Organisational environment triangle

Situational awareness ensures that people know where they are located in a changing environment and how their activities influence their environment. The passenger should be aware of the things that go on around him/her, and of other passengers and the cabin crew in order not to feel lost or confused and be confident that everything is under control. The passenger should have information about what may be expected, for example how long the remaining flight will take, meals to be served, the situation at the airport of arrival etc. People feel more comfortable if they can place themselves in a group and situate themselves in an environment and a timeframe and are not uncertain about what is happening or going to happen. For this principle it is important that the cabin is so designed that the passenger can have a clear view of its lay-out, including of course emergency exits and toilets, that he/she can have an outside view, that any information announced is clear etc.

The situational awareness principle is especially important for the community model, in which it is important to be aware of other people and to be able to communicate with them, and for the health model, reducing stress due to uncertainty and feelings of being in unfamiliar and insecure surroundings.

3. Individualisation and customisation

For the individualisation and customisation design principle we concentrate on the passenger in the environment, and the available equipment (see figure 4).

![Image of User-Artefact-Organisational environment triangle]

Figure 4: Individualisation and customisation: the User-Artefact-Organisational environment triangle

Individualisation and customisation address the individual differences in comfort needs for different passengers. Design should not be standardised for everyone, but allow people to change things so as to suit their needs. Passengers should be able to perform activities using artefacts that are geared towards their personal needs, enabled by the organisational environment. Artefacts should be adjustable to serve people with different backgrounds, needs and body features. For example, seats, head-, feet- and armrests should be adjustable, all equipment should be flexibly located so that it can be brought within easy reach of small as well as large passengers, people should be able to choose their own videos, games, etc. People will feel more comfortable when they may arrange their own environment, can feel at home in it and can use their own personal equipment. Therefore the notion of ubiquitous computing may be introduced into the cabin. This means that people can use their own devices such as laptops and electronic devices and log-in to their own sites. Other devices should be connectable, such as phones and games, and people could bring their own CD-ROMS and DVD’s etc.

The individualisation and customisation principle is especially important for the passenger bubble model, in which passengers want to perform their personal activities, and for the aesthetic-economical model, in which the availability of advanced services and devices is relevant to their perception of the economic value.

4. Variability and flexibility

For the variability and flexibility design principle we concentrate on the activities that can be performed with equipment available in the environment (see figure 5).

![Variability and flexibility: the Artefact-Task-Organisational environment triangle](image)

Passengers have different needs that may vary during the flight. Therefore the cabin should offer a variety of possible activities. However, these do not always have to be performed in the same place. Different areas can be created in the cabin, where different activities can take place, for example silent areas, or areas with a variety of electronic connections. Passengers can opt for different facilities at their seat, either before or during the flight, for which they pay. The environment of the passenger should be flexible, so that he/she can switch from one model to another, both in the direct environment of his/her seat or in the cabin as a whole. For example after having worked on a laptop (the passenger bubble model), the passenger wants to change activities and play a game with other passengers (the community model). Offering variability and flexibility contributes to a feeling of comfort because it reduces annoyance and the feeling of being confined in a limited space, and it addresses the different needs at different times during the flight as well as the different needs of different passenger types.

The variability and flexibility principle is especially important for the aesthetic-economical model, and for allowing passengers to be in different models, especially for switching between the passenger bubble and the community model.

The design process

Comfort implies objective as well as subjective factors. Usually ergonomics defines objective criteria and principles that guide the design process. Such criteria and principles can be seen as constraints, setting limits on the design of an artefact. However, emotion and aesthetics are important factors that should also guide design. They are more subjective factors. Following ergonomic principles is only one part of the design process. Even if objective ergonomic guidance can be given for individual pieces of an artefact being designed, it is difficult and often even impossible to provide a global prediction of artefact usability and usefulness without testing. Human-centred design is an iterative process that requires constant thinking, doing, trying and evaluating. Designing for comfort also means combining ergonomic requirements with technologically innovative ideas. Designing systems such as cabins of aircrafts, also has to take into account standards, safety requirements, and economic constraints. All these requirements may make the design space very limited. The constraints may be so compulsory that the designer can no longer be creative and innovative. The requirements may also be conflicting to a degree that no easy solution can be found. For example, the requirements for a seat from an ergonomic point of view require a maximal flexibility to adjust the seat to the huge variety in human body proportions. This means that all seats can be adjusted individually and do not share common elements with other seats such as armrests. The economical requirements mean having as many seats as possible, which is more difficult with individualised seats and with space requirements serving even the largest passengers. Asking the designer to find a solution, also taking into account the safety (and several other) requirements, may look like asking for the impossible. There are, however, several ways out. The designer may decide to drop some requirements, also based on the policy of his/her customer, for example not to serve extremely large passengers. Or the designer may look into radically new directions, for example, having different types of seats, arranging them differently, searching for new materials etc. (See for example Carter, 2001, who proposes radically different ways of placing seats). This last way of working will only be possible if the designer stops improving on the existing product and adjusting it to new requirements, and looks into new directions. Creativity is therefore an absolutely necessary part of innovative design.

The model we presented here for the design requirements may support the design process. Creative design is not an unguided process. Designers should be stimulated to think about requirements in a open way, not only in terms of how many centimetres are needed for armrests, but in terms of what the armrest means for passengers in their different activities. When the design has reached a first level of maturity, than the requirements should be used again to evaluate it, and at that stage also detailed requirements should be taken into account, measuring the conformity of the design to the norms.

Final remarks

Designing for comfort is a difficult process. Perception of comfort is a very vague and subjective concept, and comfort will have different meanings for different persons, and will even have various meanings during different time periods for the same individual. In addition, comfort is related to price, both for airlines and for the perception of the passenger. Therefore, designing for comfort might be considered to be a badly defined activity which should for that reason not be addressed as such at all. The paradox is, however, that comfort (or the lack of comfort) is the most important feature of air travel for passengers. With this paper we hope to contribute to obtaining a better understanding of this complex concept and to contribute to the design process by providing models and principles which may guide the designer to create and evaluate the designed product. In this paper, we have provided principles to be used by design teams in the development of comfortable artefacts. These principles were derived from our experience in the aircraft passenger cabin domain and general human factors knowledge and know-how. However, affordability, situational awareness, individualisation & customisation, and variability & flexibility are very general concepts that apply to other domains such as train and bus transport, waiting rooms, hospitals etc. The aircraft cabin is an extreme environment; people are confined in it for sometimes very long periods and in close contact with other people from different countries and cultures. Models of comfort can be generalised to other environments, even if they are less demanding or if not all requirements are equally valid. Improving comfort will be

appreciated by users and thus contribute to the productiveness of the service provider. By taking the point of view that comfort is not just a luxury item, but a necessary element of the well-being of humans, designing for comfort may become an innovative process, integrating knowledge from psychology, physiology, sociology and technology, and probably other disciplines.

References


