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A human factors' approach to Mega yacht concept design

by

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This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

Signed: Tineke Bosma Date: December 2012

'A large modern yacht is without doubt the most complex product ever conceived for personal consumption'
(Schutte, 2010)

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Tineke Bosma

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NOMENCLATURE

ABS	American Bureau of Shipping
BV	Bureau Veritas
DNV	Det Norske Veritas
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration
HoReCa	Hotel, Restaurant, Cafe
IBC	International Building Code
ILO	International labour Organisation
IMO	International Maritime Organisation
LOA	Length Over All
LR	Lloyds Register
LY2	Large Commercial Yacht Code
MARPOL	The International Convention for the Prevention of Pollution from Ships
MCA	Maritime and Coastguard Agency (MCA)
MLC	Maritime Labour Convention
MLO	Maritime Labour Organisation
PYC	Passenger Yacht Code
REG	Red Ensign Group
RINA	The Royal Institution of Naval Architects
SOLAS	Safety Of Life At Sea
VOC	Volatile Organic Compound

ABSTRACT

Surviving in the mega yacht shipbuilding industry as a shipbuilder is notoriously difficult. The yacht owner usually demands a high degree of comfort and luxury without compromise of other complex requirements. In many cases, conflicts arise in the late stages of the building process. There are many shocking examples of costly rework that the shipyards had to do because the ship owner changed his/her mind about the interior design or layout upon inspecting the almost finished ship. In other cases, the ship owner simply ended up with a product that was not as comfortable as initially envisaged. This thesis explores the hypothesis that disappointing interior layout and design is a result of yacht builders primarily acting as ship builders, focussing mainly on exterior design, exterior aesthetics and performance of the yacht. As a consequence, interior design and human comfort considerations are not taken into account until the very final stages of the design process. This means that many compromises have to be taken with these very important issues that determine the experience of owning and being on board the ship.

The aim of this work is to demonstrate that there is an absence of prioritising the importance of implementing the human comfort factors into the preliminary mega yacht design stage in its place of the final design stage. Prioritising human comfort factors contribute to a reduced risk of conflicts between the different domains; yacht owners, naval architects, interior and exterior designers, amongst others. An important part of this demonstration is identifying the comfort factors by researching the design approach to human comfort taken by various sectors. These sectors are transport, aviation, hospitality and merchant ship design. This thesis demonstrates and suggests a new approach to concept mega yacht design by presenting a framework of how these identified human comfort factors can be implemented as early as possible within existing classical process of mega yacht preliminary ship design.

AUTHOR'S FOREWORD

Prior to starting my career as an interior stylist and human factors research assistant at the University, I spent four year as a Maritime Officer where I gained experience in all aspects of ship operation and management of merchant cargo ships. It was, however, my role as a Chief Officer on board a mega yacht that inspired the choice of topic for this research. I remember being very impressed by the beautiful exterior and interior design of this magnificent ship, but also noticed that the interior and layout of this vessel left a lot to be desired in terms of comfort and practicality. This in my opinion could have been prevented through a better cooperation between marine engineers, naval architects and interior designers; having been professionally active in these three different disciplines myself.

After my period at sea I utilised and further developed my experience within the maritime sector supporting ship operations for a mayor global operating container vessel company. From there I took a position as a consultant for a ship electronic systems and equipment provider, providing sales support and training people in using ship tracking and safety equipment. But also wanting to develop my artistic side I embarked on a training to be an Interior Stylist, an area for which I had a passion for from a very early age. I also started my own interior styling Consultancy Company before having been offered a job as a research assistant human factors and safety at sea at Strathclyde University in Glasgow Scotland. During this research I further developed my theory that key to success for any product is awareness of the importance of human factor related aspects. Knowledge of how the design of a product interacts with its' users is crucial to success in anything you create, whatever industry you work in.

Tineke Bosma
23 October 2012, Glasgow, UK

1 INTRODUCTION

1.1 Chapter outline

This chapter briefly presents the general background reasoning for the initiation of this thesis' research work. It concludes by presenting the outline of the layout of the paper to improve its readability.

1.2 General introduction

The success of a private mega yacht lays within the pleasant state of mind of the yacht owner i.e. the connection or type of relationship the owner has with his expensive yacht is of paramount importance to the end result and success of the design. The owners' personal taste and vision on the design of the yacht plays therefore a key role in the concept design processes and should not be taken lightly. Styling and design of the interior and exterior play an important role in the owners state of mind. The quality of the end product and the production costs of a private mega yacht depend therefore not only on a good cooperation between the architect and the designer, but more importantly on a good understanding of the vision and personal taste of the owner of the yacht.

For conventional cargo and passenger ship building the cooperation between different parties involved in the process is already very complex. Design and build of a private mega yacht is even a greater challenge. Private Mega yacht technology and design has to be a constant state-of-the-art process. The owners' personal taste and often excessive requirements influence the design significantly. Not only does poor interpretation of the owners taste and needs reflect in the efficiency of the design process, but more importantly, it directly affects the quality of the end product. In

addition, unlike in the automobile and aviation industry there is no possibility of developing and testing a prototype. When a design fails, a lot of time and money is wasted. Contract engineers and designers all have to work together in a project especially with private mega yachts (Meunier & Fogg, 2009). The building and design of a mega yacht often seems to be an even more painful process, especially because private 'super and mega yachts' are relatively new in the shipbuilding industry and little is known about engineering data and design practise (Nam, Kim, & Lee, 2010). Shipyards get into problems as a result or the end product does not live up to the clients' expectations.

Two main reasons can be identified leading to these problems, private mega yachts in particular:

The first is that the variety of different disciplines involved with the design and building is considerably wider than is generally the case with the design and building of cargo ships. Three aspects playing a very important role in the mega yacht industry, besides the aesthetics and performance of the yacht (Jordan, 1998), (Nemeth, 2004):

1. Usability of the ship,
2. Physical comfort and
3. Psychological comfort

The second and the purpose of this study are difficulties with 'measuring' how successful the yacht genuinely is or can be. Certain parameters can be specified in advance and measured during the trials. These parameters are for instance ship speed, on board noise, vibrations and on board climate and are specified in the rules and regulations of the different classification societies (organization that establishes and maintains technical standards for the construction and operation of ships). However, there are also many parameters related to human elements that contribute to the success of the mega yacht that are not directly measurable such as

psychological comfort, sociological factors and aesthetics etc. These parameters are difficult to measure and therefore not described in the relevant regulations. The mega yacht does not only have to fulfil the same requirements any other ship has to fulfil, but also very importantly has to possess 'the X-Factor'.

It is a complex combination of sometimes conflicting requirements that determines 'the X-Factor' of the ship. The terminology used by naval architects compared with the Product Design Industry about the exact interpretation of comfort design starts already with a conflict. In general the four technical parameters linked to comfort in ship building, as described in the American Bureau of Shipping guide for passenger comfort on ships are: noise, whole body vibrations, indoor climate and lighting (ABS, Passenger comfort on ships, 2002). Slater however, described comfort as a pleasant state of physiological, psychological and physical harmony between a human being and his environment (Slater, 2008). According to Green and Jordan (2001) a more efficient approach to product design is to look at human beings more holistically. That is a person with emotions, fears, hopes, desires etc., rather than approaching the human being just as 'physically, simple and cognitive processors' (Green & Jordan, 2001).

This study aims to contribute to the success of all parties involved in the mega yacht building industry, the owner included, by presenting a new approach to concept design and research the possibilities to merge human elements into the design process. One of the most important outcomes is expected to be an increased inter-disciplinary understanding and enhance the cooperation of these disciplines. This will contribute to a more efficient design process and a product that exceeds the customer's expectations. Not only does poor cooperation reflect in the efficiency of the design process, but more importantly, it directly affects the quality of the end product. In a recent study by Payne and Siohan (2008) about comfortable yacht structures, the key element to success is good team work and a good management design plan early in the design stage.

1.3 Outline of the thesis

After the chapter 'Introduction', 'Aims and Objectives' of this study are presented in chapter 2, followed by chapter 3, 'Critical review'. The first two sections of the Critical review, 3.1 and 3.2, starts with a brief introduction followed by a human orientated approach to general product design. The key elements to human orientated design are analysed and presented, followed by section 3.3, 'human needs and satisfiers'. In section 3.4 the mega yacht industry and its human needs are discussed and the definition of a mega yacht is explained. From these definitions, the function is identified and results are presented. The identified functions are translated into other industries with comparable target groups and compared with the mega yacht industry. In section 3.5 the general shipbuilding design approaches and human factors are presented and critically reviewed. The mega yacht design industry is compared with the general ship design industry; discussed and explained. Section 3.6 elaborates on the design approach of a cruise ship compared to a mega yacht. The rules and regulations for cruise ship comfort design are discussed and analysed. In section 3.7 and onwards the key elements to design and human factors' approach to interior design of hotels, restaurants, cafes, cars, trains and airplanes are researched and analysed and subsequently presented together with the newest trends, gaps and companies economical needs.

Chapter 4 presents the Field Study of this thesis that includes a variety of interviews with the mega yacht designers, builders and naval architects.

Chapter 5 presents the human orientated design framework for mega yachts. After an introduction to the key elements to human orientated design, as was researched in the critical review, a framework is presented which includes the work process of how the mega yacht industry should implement the key factors in the preliminary ship design process.

Chapter 6 presents the implementation process of the human orientated design framework towards the Case Study of this thesis. The implementation process

demonstrates the functionality of the framework to human orientated design as was presented in chapter 5. Accordingly the Case Study is presented in chapter 7, in which this process has been utilized.

Finally chapter 8 presents the Conclusion of this research followed by chapter 9 in which Future Recommendations for the mega yacht industry are discussed.

1.4 Chapter Summary

The chapter Introduction has presented the factors for pursuing this research in general as well as specific terms. It also summarised the layout of the thesis. The next chapter outlines the research question, the aim and the objectives of this research.

2 AIMS AND OBJECTIVES

2.1 Chapter Outline

This chapter presents the research question along with the aims and objectives of this thesis.

2.2 Research Question

The research question of this study may be put together as:

'*Can human elements be integrated into the preliminary design stage of mega yacht ship design, in place of the final stage?* '

2.3 Aims & Objectives

The primary aim of this research work is to analyse if human elements can be integrated into mega yacht design and introduce a new approach to concept mega yacht design that will contribute to a reduced risk of conflicts between the shipbuilders, naval architects, designers and ship owners. The key objectives to this aim are:

I. Critically review the existing concept ship design approaches in order to identify short comings and providing the necessary key elements into the concept ship design.

II. Critically review the approach to design in other industries in order to identify their approach and providing the necessary key elements to design.

III. Develop a general mega yacht design process
    a. Step by step work flow diagram which represent the design process.
    b. Find the key criteria for mega yacht design
    c. Compare the key criteria for mega yacht design with the classical ship building process

IV. Modify and propose improved solutions by presenting a new concept design approach for mega yachts.
    a. Develop a human orientated design framework for mega yachts.
    b. Analyse an existing layout of a mega yacht for gaps in the human orientated interior design and identify the missing key human elements.
    c. Demonstrate how early naval architectural design choices could have made implementing the missing key human elements possible or easier

V. Discuss the findings of the study and suggest future developments for this industry

2.4 Chapter summary

In this chapter, the research question of this thesis has been formulated along with the thesis principal aim and objectives. The next chapter presents the Critical Review carried out on the existing design approaches in the maritime industry as well as in the broader industrial field such as architecture, product development, aviation and automotive industry e.g.

3 CRITICAL REVIEW

3.1 Chapter outline

In this critical review the general design philosophy of product design according to the human needs are critically reviewed. With this philosophy in mind the key factors towards human comfort and needs for the mega yacht interior design industries are identified. Thereafter special focus is on how these human elements in design are applied compared to other industries. This critical review concerns with the human needs and design approaches to mega yacht interior design in the first stage; preliminary design methods.

Subsequently, a theoretical model is created of how to introduce these key elements to human orientated design into the mega yacht design industry. The model is presented in chapter 5.

3.2 General overview

Many conflicts and problems between clients and shipyards are experienced during the building of mega yachts. Many owners are very disappointed with the overall result of the end product caused by inadequate communications and human errors (Haack & Hoogs, 2004-2005). Often refitting takes place after full completion due to misinterpretation and miscommunication of the needs of the owner. A lot of trouble and frustration and even sometimes the bankruptcy of the ship yard are the results of huge claims they get for these refitting and price competitions among yards (Francessetti, 2008) (Howorth M. , 2009). Before investigating the ways to improve cooperation between these disciplines the key elements to the design approaches must be understood. On one hand the yacht designer considers the effect of a design

on perception of comfort from a psychological point of view, whereas the naval architect looks at comfort aspects in physical measurable units like: temperature, climate, noise and vibration levels and light intensities. In a recent interview with naval architect Schutte (2010) on his professional career as an industrial designer and later as a naval architect, he particularly addressed the lack of mutual understanding for each other's profession:

'*The huge difference between creative design and heavy engineering is not just about adding a few calculations*'.

These kinds of attitudes are quite common in the yacht building industry, and cause a lot of miscommunication with the yacht owner as well in the industry itself. Before investigating how the private and commercial shipbuilding industry and its people work together in the first design stage of the yacht, the differences in the design approaches must be understood. Regulation and guidelines concerned with the human factors of passenger ship, private mega yachts and charter yachts are accordingly analysed.

3.3 Human factors' approaches to general product design

Extensive research has been carried out in the past of what effects interior design may have on the state of mind of people. Ulrich's research in 1991 named the positive and negative effects of interior design on the wellbeing of patients in healthcare centres (Ulrich, 1991). In his journal article he elaborates on the general key elements and concerns with deficient interior design and how this may lead to negative stress of the patients. For example lack of windows in a room can cause serious depression. Other stress factors are noise, light and colour, specifically colours that are too intense; red colour in a hospital room will immediately rise your blood temperature (Yoto et al, 2006). The upcoming sections present the different approaches to general product design and are accordingly analysed in order to obtain the key elements for the design.

3.3.1 Approach to product design: Hierarchy of needs and the key elements to design by Maslow (1970):

Identification of the human needs in different industries depend fully on the research of the target group; it is based upon the life style and background of the person or target group of whom the product is designed for. The hierarchy of needs, as identified in a study by Ekins and Max Neef (1992), is about product design according to the needs and satisfaction of human towards the products. If the primary function of the product design stage is fulfilled, more satisfaction is needed to achieve fulfilment (see Fig 1).

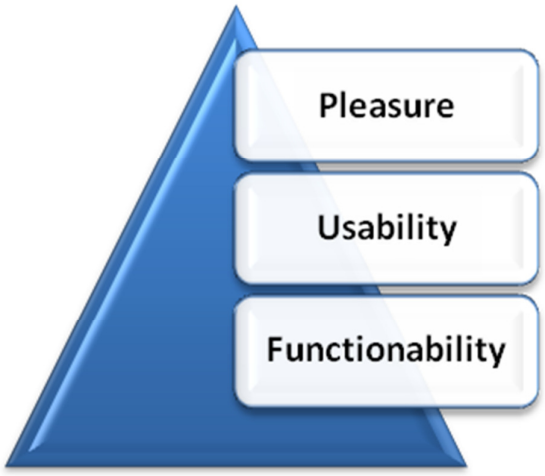


Fig. 1 Hierarchy of needs or design triangle (Maslow, 1970)

The approach to design in this work is that the quality of the design depends on a balance between the three requirements, also mentioned as the design triangle (Maslow, 1970). In the mega yacht industry the requirement of providing pleasure is the most important one, however, in practise it seems that huge compromises are made with regard to functionality and usefulness in favour of aesthetics.

3.3.1.1 Key elements to design: psychological comfort

In general yacht design the focus is strongly on the psychological effects of the design; as a yacht owner you want to be unique and stand out of the crowd. It is the

task of the interior designer to reflect on the personal taste of the owner. The interior designer often gets all the free space to make the owners fantasy happen. The yacht has to breathe the owners' personality (Candy & Candy, 2010).

3.3.1.2 Key elements to design: finding a balance between functionality and aesthetics.

Materials, colours, and textures used in the interior of mega yachts must be perfectly blended to provide a balance that is aesthetically pleasing for the owner and in the same time serve the purpose of its intended function. According to the designer a good design is a challenge and requires thinking beyond the architectural space. The aesthetic goal is to create an interior that combine plain lines and forms and harmonise it with just the right touch of colour to give the space the energy it needs. The aesthetic goal may vary from one designer to another designer.

'The first characteristic a mega yacht owner is looking for in a yacht is that it has to fit their lifestyle. Cost and value is never on the first position'
(Candy & Candy, 2010).

3.3.1.3 Key elements to design: Comfort and ergonomics

'Comfort is a pleasant state of physiological, psychological and physical harmony between a human being and his environment'. On board the yacht it is all about having a good understanding of what the owners desire and the ability to translate personal taste into the best possible design, style and luxury. Even more important is to create comfort on board the yacht in in order to live and work in. Comfort and ergonomics is closely linked to one another. To achieve this state, assessment of good ergonomics in design is of paramount importance. Most of the large yacht regulations describe comfort as a state of physical wellbeing. Factors such as: size, appearance, safety, air quality, temperature control, lighting, noise, vibration levels and sea motion, all influence the state of onboard comfort. Most regulations simply set up technical regulations of these above mentioned factors. Lighting also is

described but very limited and is mostly focussed on safety aspects. Other ergonomic factors like size and appearance are generally not even described.

Extra challenge for the designers is the dynamic behaviour of the yacht and its effect on the human body. Seasickness for example is a common problem on board of yachts (Grech et al, 2008). Favourably more analysis should be carried out in order to analyse how exactly the dynamic motions of a mega yacht affect the comfort levels in the interior design and search for possibilities to mitigate these completely by means of stricter design rules.

3.3.1.4 Key elements to design by Payne and Siohan

Comfort as a measure for good yacht design can be summarised under three areas (Payne and Siohan, 2008):

1. Physical Space
2. Ergonomics
3. Visual Space

The physical space (1) is important for the people on board the yacht in order to move comfortable and freely through the accommodation without claustrophobic or crammed feelings. Good ergonomics (2) determines the physical wellbeing of the passengers and crew living on board. Visual space (3) increases the feeling of comfort; natural daylight and bright colours help in order to increase awareness of space and therefore provide more comfort to the beholder. Payne and Siohan (2008), among other things, discussed conflicts that arise during the design process of the yacht. They researched parameters of ergonomics and comfort of racing yachts against the general slower cruise yachts. While the racing yacht designer focus more on ergonomics of the exterior, cruise yacht designers have a natural tendency to focus more on the psychological and visual side of comfort. Thus both yacht designers approach comfort in a completely different way. To avoid contradictions like this in the design stage the first priority is to focus on the key design parameters. Once all parties agree, the process can commence without conflict.

Although Payne and Siohan (2008) make a good point in their paper by explanation of why the key parameters to design are an important focus point, the actual conflict between the naval architect and the interior designer still remains. The focus is often too much on the aesthetical requirements of the owner and less on the actual human physical needs; ergonomics and comfort can have a huge impact on the human body in the long term. What looks like a good idea at the time, may turn into a complete nightmare in the future once the yacht is finally launched. Interior designers often forget the importance of the effects of the rolling movements of the yachts to the human body, while the naval architects forget the importance of the psychological state of the mind.

'*Design needs to include not just knowledge of physical world, but knowledge of human being as* well. (The Naval Architecture July/August 2009)

3.3.2 Approach to product design: human satisfiers and needs by Manfred Max Neef (1992)

As Sjöberg & Thompson (2010) show in their research concerned with human needs on submarines; Manfred Max Neef (2007) developed a theory about the human basic needs. For his theory he developed a human needs' structure in which he re-arranged the basic human needs and the higher needs in a stringent hierarchy. According to Neef the urge of fulfilling these higher needs, such as sense of belongings and self-esteem etc., can only be experienced after the more basic human needs, such as food and shelter, are fulfilled (see Fig. 2).

Fundamental Human needs	Being (qualities)	Having (things)	Doing (actions)	Interactions (settings)
subsistence	physical and mental health	food, shelter, work	feed, clotherest, work	Living environment, social setting
protection	care, adaptability autonomy	social security, health systemes, work	co-operate, plan, take care of, help	social environment, dwelling
affection	respect, sense of humor, generosity, sensulality	friendships, familiy, relationships with nature	share, take care of, make love, express emotions	privacy, intimate spaces of togetherness
understanding	critical capacity, curiosity, intuition	literature, teachers, policies educational	analyse, study, meditate, investigate	schools, families, universities, communities
participation	receptiveness, dedication, sense of humor	responsibilities , duties, work, rights	coperate, dissent, express opinions	associations, parties, churches, neighbourhoods
leisure	imagination, tanquility, spontaneity	games, parties, piece of mind	day-dream, remember,relax, have fun	landscapes, intimate spaces, places to be alone
creation	imaginiation, boldness, inventiveness, curiosity	abilities, skills, work, techniques	invent, builddesign, work, compose, interpret	spaces for expression, workshops, audiences
identity	sense of belonging, self esteem, consistency	language, religions, work, customs, values, norms	get to know oneself, grow, commit oneself	places one belongs to, every day settings
freedom	autonomy, passion, self-esteem, open-mindedness	equal rights	dissent, choose, run risks, develop awareness	anywhere

Fig. 2 Manfred Max-Neef; hierarchy of human needs (2007)

Fig. 2 shows Manfred Max-Neef's hierarchy of human needs. In the hierarchy Max-Neef classified 9 fundamental human needs namely:

1. Subsistence
2. Protection
3. Affection
4. Understanding
5. Participation
6. Leisure
7. Creation
8. Identity
9. Freedom

In this hierarchy or matrix, Manfred categorised the fundamental needs accordingly: being, having, doing and interacting. Max-Neef explains that in order to fulfil the 'being' or qualities on one level in the matrix you need some things, actions and settings first. The matrix is based on the 9 fundamental human needs and separating them from the satisfiers of those needs. To keep the needs separated from the satisfiers, the easiest way for explanation is to show some examples:

1 Food, shelter, clothing or work aren't needs, they are the satisfiers of the need subsistence
2 Family, friends and emotions are not needs either, these are the satisfiers of the need affection and so forth

This matrix of human fundamental needs and satisfiers can be used for complex design projects such as mega yacht design to find out what the fundamental human needs are for owners and their crew plus accordingly for diagnosis, planning, evaluations of these needs and how they can be fulfilled or satisfied. The overall aim is not only to fulfil the owners and crew fundamental human needs, by presenting better technical solutions or design, but also to meet with their higher needs in order to accomplish the optimum comfort of wellbeing that resembles the lifestyle of owning a mega yacht. The next section elaborates more on these lifestyle choices and how they influenced product design through time.

3.3.3 Approach to product design: The Four Pleasures Theory

There are many theories about how to design a pleasurable or comfortable product. A product that not only is comfortable to use, ergonomically designed but also is aesthetically designed. The presence of comfort means in general the absence of discomfort. Patrick W. Jordan (2000) wrote a book for those involved in products design in which he elaborates about product design according to the four pleasures. The book starts with an example of the hierarchy of needs by Maslow (1970) Fig. 3.

At the base of the pyramid there is the functionality; a product is designed with a primary function in mind, context and environment in which it shall be used etc. After the function of the product is clear, the consumer of the product is interested in the products' usability. Is the product ergonomically built, and according to the design rules of anthropometrics e.g. the next stage is to design a product for pleasure fulfilment as well. The consumer wants a product where they can emotionally relate to, something that reflects on their lifestyle and perhaps even their social status. The last fulfilment of needs is related to human factors.

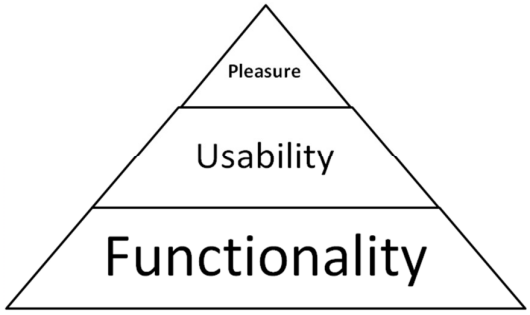


Fig. 3 Hierarchy of Consumer Needs

In the past, product design in terms of the human factors industry was generally all about the usability of the product and less about the pleasure of the product or if it reflected the persons' lifestyle; think about the mobile phone industry and how their focus have shifted from functionality to usability to style icon, if the product is usable, then the pleasure follows isn't it? It isn't; nowadays the focus in product design has shifted. Many studies have proved that product design, a mobile phone, building or even a mega yacht, is more about thinking beyond the usability design and consider the pleasure site of the product as well. Luxury products are more designed to resample a certain life style and social status but product designers seem to focus less on the usability of it; appearance is everything. Pleasure based design is about a combination of needs. Designing according to the four pleasures is based upon the lifestyle and background of the person or target group of whom the product is designed for (see Table 3-1).

Table 3-1Examples of 'The four pleasures theory of design'; Physio- and Socio-pleasure (Jordan, , 2000)

Physio pleasure	Socio pleasure
Physical dimensions of the body: size, weight, length, height, shape e.g.	Social needs, pleasures/social status/authority
Anthropometrics	Relationship with others
Pleasure of the senses: sight (colour), hearing, taste, smell, tough	Product design to help being socially accepted
Temperature	Leisure
Balance and acceleration	Formality
	Avoid design products that contribute to social nuisance; noise, vibration, climate, temperature, visual disturbance
	Desire to avoid stigmatisation
	Design to avoid and discourage theft
	Design to avoid vandalism
	Material status

Table 3-1, shows examples 'The four pleasure theory of design'; Physical and Social pleasure; Jordon shows that Physical pleasure has to do with the Pleasure of the senses; touch, smell, hearing, taste, sight etc. Also the human body size, anthropometrics and ergonomics, will be a form of what he labels as 'Physio pleasure'. An example of Physio pleasure; visual comfort is a research study carried out recently by Dazkir and Read (2011). Dazkir and Read revealed that persons in general are drawn more to the curvilinear shaped furniture than the rectilinear shaped ones. This has to do with their visual perception of comfort: People assume that rounded furniture objects naturally look more comfortable. Although in their research case study the technical comfort qualities of both the curvilinear furniture and the rectilinear ones were the same, people felt more at ease in the room with the curvilinear shaped furniture and had a more calming effect on them.

Social pleasure or Socio-pleasure refers to design of a product that is part of the social feeling or social status of the owner of that product; for example a mega yacht is all about the social status of the owner, the owner who wants to be seen. Every kind of relationship will be part of the Socio pleasure design rule. Mega yachts for example are built in order to meet with a social status and expectations of the owners. Design for Socio pleasure also includes products that contribute to social nuisance like, noise and vibrations. Besides that noise and vibrations are very unpleasant for the human body (physical), they are also very unwelcoming for the

people in the neighbourhood (social). The following Table 3-2 shows the two other pleasures of design: Psychological and Ideological pleasure.

Table 3-2 Three Examples of 'The four pleasures theory of design'; Psycho and Ideo pleasure (Jordan, 2000)

Psycho pleasure	Ideo pleasure
Emotional satisfying products or products that aim to give a satisfied reaction	**Ideological pleasurable designed products that pertains to peoples moral values: taste, personal aspirations, values, upbringing e.g.**
products designed to avoid: stress (noise) frustration, irritation, discomfort e.g.	**Attitude towards the products/ technology/ era etc**
Products designed in order to extend or enhance peoples' cognitive capabilities	**Environmental aspects /eco-living and natural materials, Low carbon emission etc**

Table 3-2 shows the two other pleasures: Psychological and Ideological pleasure. Jordan labelled these as Psycho pleasure and Ideo pleasure. Psycho pleasure refers to emotions of people and to the emotional reaction the product provokes on its surroundings. For example the mega yacht owner might require a yacht that resembles the shape of an old steam cruiser because this evokes a strong emotional reaction on him for whatever reason. But also noise, vibrations and colour can trigger emotions, either positive or negative.

Ideological pleasurable design or Ideo-pleasures are pleasures that relate to people's values: like taste, personal aspiration, values, upbringing, attitude towards the product etc. But also environmental aspects; green shipping and materials, low carbon shipping can relate to ideological pleasures. In the mega yacht industry Ideo-pleasure is more of a trend amongst the mega yacht owners to fulfil their social status rather than a necessity.

What Jordan in fact wants to verify is that in product design you need to take all four pleasures; psychological; ideological, physiological and sociological pleasure into account to facilitate all the needs and pleasures of the consumer. The previous sections have reviewed different approaches towards general product design in order to find the necessary key factors towards human orientated design. The following

section review the human factors and design approach as adopted in the mega yacht industry as to find the gaps in mega yacht design approach.

3.4 Mega yacht design approach and human factors

In this section the definition of a mega yacht is explained. An introduction is given to the general rules and regulations that need to be applied during the building process. The varieties of rules, regulations towards human factors design are even so critically reviewed, as well as the functionality and usability of the design approach.

3.4.1 Functionality and usability

According to the web, a mega yacht is a term used for a very luxury yacht, which refers to a very expensive, privately owned and professionally crewed mega yacht. It is also referred to as a super yacht or giga yacht. Mega yachts are yachts that are generally over 100 feet (30.5 meters) LOA. The classification society ABS refers to mega yachts as large yachts:

'*Large means 24 meters over in load line length and the Code of Practice applies to yachts which are in commercial use for sport or pleasure, do not carry cargo and do not carry more than 12 passengers*' (ABS, Passenger comfort on ships, 2002).

3.4.1.1 Distribution of mega yachts

If mega yachts carry more than 12 passengers', the IMO requires building it as if it were a passenger ship; passenger ships are therefore ships that carry more than 12 passengers. According to the Super Yacht Index that has been published by Camper & Nicholsons every year (Perignon et al, 2009), there are two super yacht categories: first the custom super yachts, these are yachts that are only designed and built once and are therefore truly unique, secondly the semi-custom yachts, these are the yacht that are only designed once, while multiple units are built. The total fleet of super

yacht with length over 24 m exists in the year 2009 out of 5400 yachts, 440 of these yachts were delivered in 2009. Fig. 4 presents the total distribution in 2009 of mega yachts by length in meters as defined by the super yacht index.

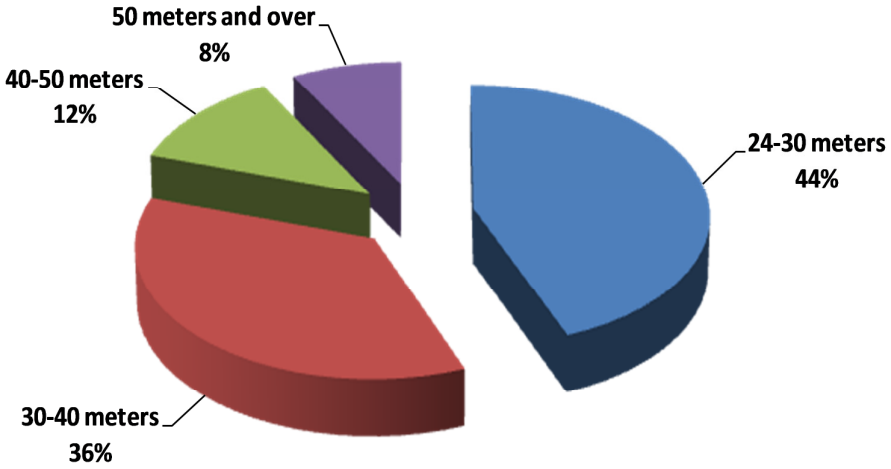


Fig. 4 Distribution of super yacht, 2009, by length (meters) as defined by Camper and Nicolsons (Perignon et al, 2010)

As shown in Fig. 4 the distribution of super yachts, 2009, are shown in length in meters. The distribution of mega yachts with a length of 24-30 meters is 44%, which is the largest group of super yachts. The second largest group is a distribution of 36% of mega yachts with a length of 30-40 meters. 40-50 meters in length is 12% and the smallest group of mega yachts is 8% with a length of 50 meter and over. The amount of super yachts build in 2009 in a length of 30 meter and over is in total 213. Fig. 5 shows the distribution between the custom yachts and the semi-custom yachts.

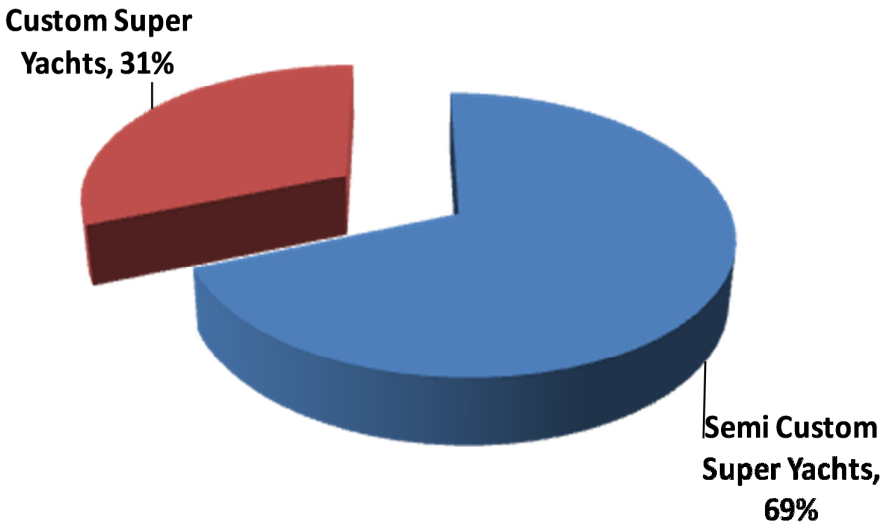


Fig. 5 Distribution of Super Yachts in 2009: Custom Super Yachts and Semi-Custom Super Yachts as defined by Super yacht Index of 2010 (Perignon et al, 2010)

Fig. 5 shows the distribution between the custom yachts and the semi-custom yachts. Out of the 213 super yachts delivered in 2009 in length of 30 meters and over, 31% are custom made yacht, which are built and designed only once and 69% of them are semi-custom yachts.

3.4.1.2 Typical mega yacht layout design

Most mega yachts are 45-to-100 meters in lengths and even onwards. They usually have three or four decks with cabins for up to12 guests. After analysing numerous mega yacht space arrangements, it can be stated that the accommodations and general arrangements for mega yachts have very little differences and variations in the actual layout; in brief for most mega yachts with four decks are standard usually as follows (Fig. 6):

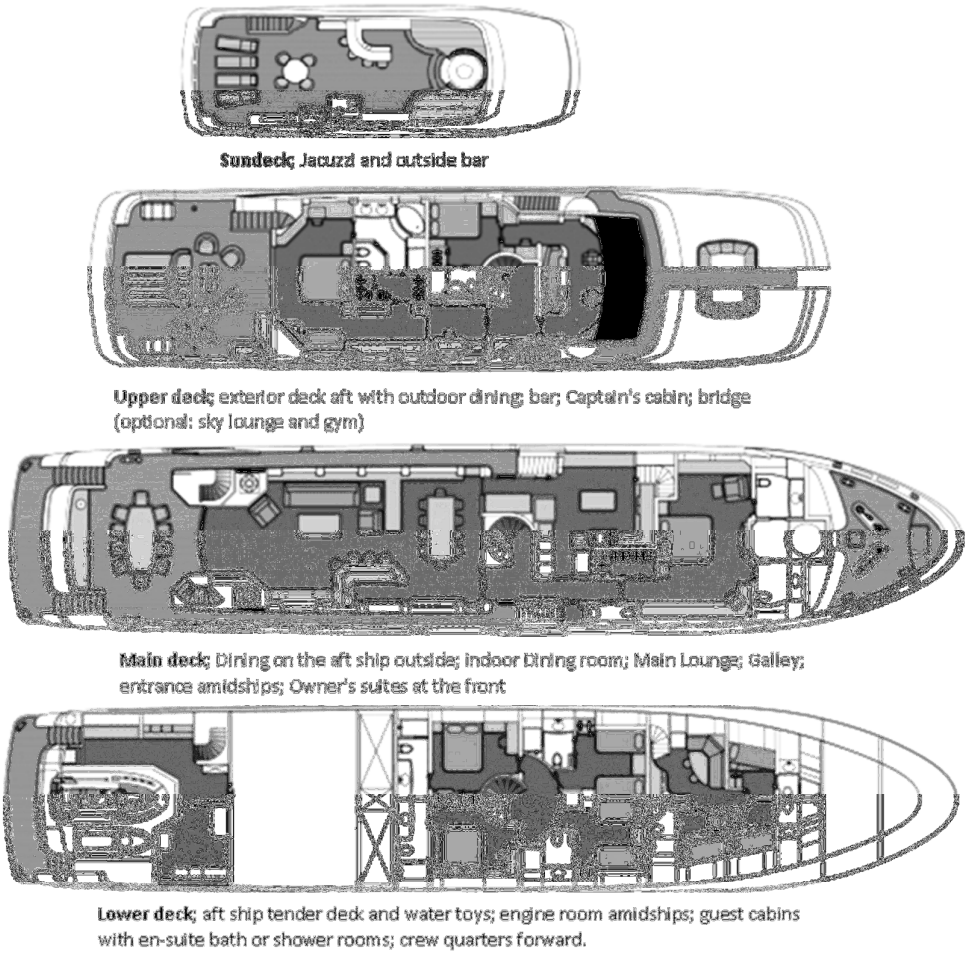


Fig. 6 Typical mega yacht general arrangement

- Lower deck: guest cabins with en-suite bath or shower rooms aft; engine room amidships; crew quarters forward.
- Main deck: dining room; galley; entrance amidships; owner's suites
- Upper deck: exterior deck aft, outdoor dining; sky lounge; bar; gym; Captain's cabin; bridge.
- Sun deck: on the roof of the upper deck, Jacuzzi facilities, bar and outside lounge

According to studies made by Ho et al (2010) the interior design of mega yachts strongly dependent on the purpose the customer has in mind that can be influenced by the customer's personality or culture. It has been investigated that there exists no specified formula in designing the interior spaces. Nam et al (2010) even so stated that an experienced designer designs the interior usually after the length of the mega

yacht is decided. They have explored the concept of preliminary design for mid-size mega yachts and researched current used methods in hull modelling and interior space arrangement. They carried out the interior arrangement to provide a background of the preliminary mega yacht design and developed a computerised design system for hull modelling and interior arrangement on mega yachts (Nam, Kim, & Lee, 2010).

In comparison to research on exterior design of mega yachts; researches on interior design of mega yachts are limited. No specific guidelines on the interior lay out or space arrangement has been developed yet. The space arrangement of mega yachts have merely been analysed on the space arrangements, as it already exists. Therefore, more advanced guidelines to preliminary space arrangements for mega yachts are very much required (Lee & Byun, 2007).

3.4.1.3 Preliminary mega yacht design

The preliminary design stage of the shipbuilding process refers to the stage of the ship where its main parameters and characteristics are set. What type of design approach is used depends largely on ship type and therefore its building and design regulations that go with this specific type of ship. The most important decisions are to be set in the preliminary design stage. In case of a mega yacht, the number of passengers and crew the owner requires to have on board is one of the most crucial focus points. The total number of passengers and crew define not only its main parameters, but also what building and design regulations need to be applied.

Many discussions are taking place amongst mega yacht owners and classification societies all around in order to meet with the needs of mega yacht industry (Architect, 2009). These discussions can be found on the Internet, forums and official blogs (global super yacht forum), but also the classification societies organise regular conferences on this topic (For example the yearly RINA conference in Genoa on Design and Construction of mega yachts). For mega yachts these rules, regulations and guidelines are complicated. For this reason, Manta Maritime (Gradwell, 2008)

developed a plain schema in applicable rules and regulations for large yachts (see Fig. 7).

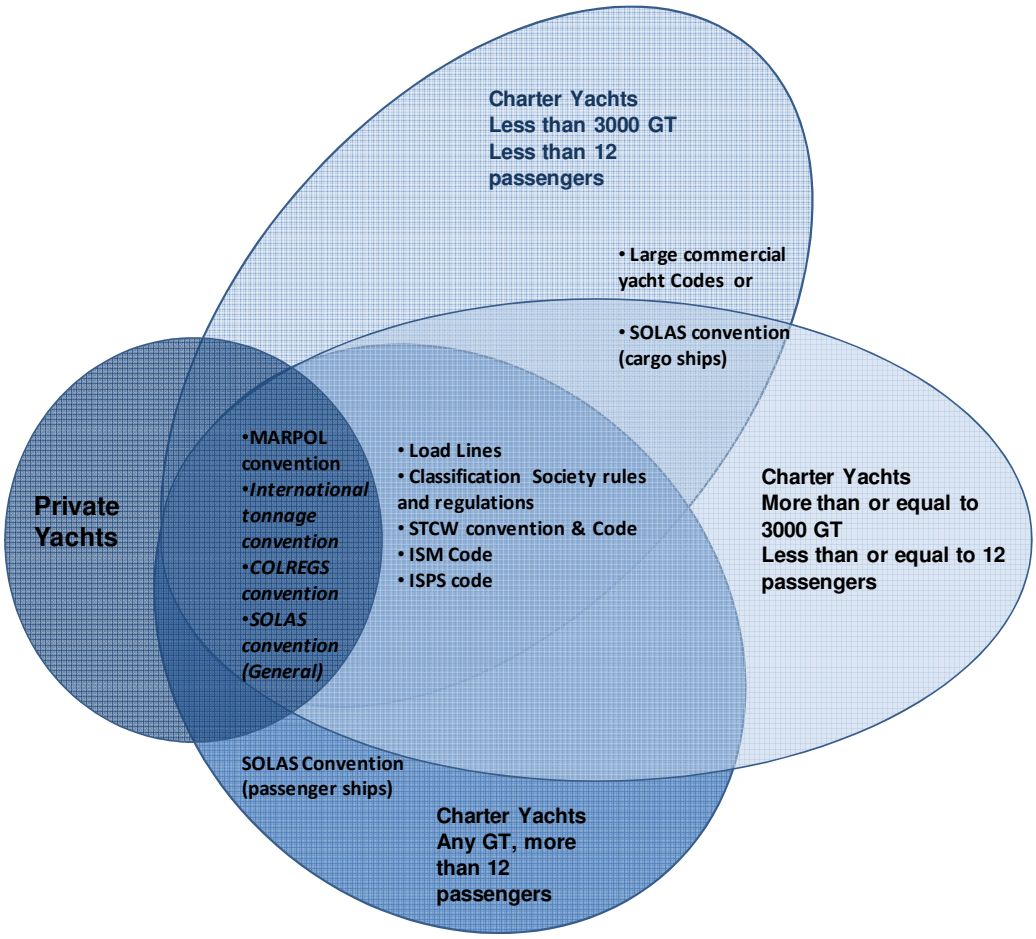


Fig. 7 Manta Maritime's Applicable rules and regulations for large yachts (Gradwell, 2008)

Fig. 7 shows a schema developed by Manta Maritime (Gradwell, 2008) in applicable rules and regulations for large yachts. Crucial point for the design of a private yacht is her weight, amount of passengers and the choice of charter or non-charter; in order to grade the yacht as a mega yacht, passenger vessel or charter yacht and applicable rules and regulations.

3.4.1.4 The 13th passenger

For the mega yacht owner it is a difficult choice to certify the yacht as private or charter and the decision to have 12 passengers or more, as these choices will have

great consequences for what set of rules and regulations need to be applied. There are different requirements for charter or private yachts. Mega yachts comply with the Large Yacht Code II when the yacht does not carry more than 12 guests. For mega yachts in charter that are to carry more than 12 passengers there are two options: The first is with the Cayman Islands Shipping Registry who has published their 13-36-code. This is for yachts with 13 to 36 passengers. The second option is the SOLAS requirements for passenger ships. Furthermore are there consequences attached to the choice of a 13th passenger on board the yacht.

Manta Maritime (2008) stated that probably 95% of all the charter yachts carry 12 or less passengers and thus need to comply with the MCA, LY2 code. That means that only 5% of the mega yachts choose to classify their yacht with more than 13 passengers. Mega yachts with more than 13 passengers are obliged, only when in charter, to certify according to SOLAS passenger ship rules. To make things complicated, when the yacht carries more than 12 passengers and is not engaged in trade, the yacht is free from MCA LY2 rules or SOLAS passenger Ship rules with the exception for SOLAS chapter V; Navigation, and only needs to follow the MARPOL rules.

A private yacht is a yacht not engaged in trade and is not obliged to meet with any of the above mentioned charter yacht rules. However, this may vary from different flag state. Some flag state may require private 13+ yachts to meet with the SOLAS passenger vessel requirements or the owner decides to meet with the SOLAS passenger vessel requirements for the following reasons: (Manta Maritime, 2008):

- It may not be welcomed in the waters of those countries that do have requirements for this type of yacht (Port State Control)
- Registered commercial yachts have tax benefits
- Pros: can be that because there are no safety requirements enforced by a regulatory authority, the designer, builder, owner/manager and crew are given free design space to do whatever they require reign’

The major differences between SOLAS passenger ship (Charter ≥ 12 passengers) or MCA LY 2 rules (Charter ≤ 12 passengers) were briefly described by Manta Maritime (2008) and lay in the following areas:

Item/Area	SOLAS Passenger Yacht (<36 passenger) requirements	LY2 Yacht >500GT (12 passenger) requirements
Subdivision and stability	One or two compartment damage survivability required depending on whether lifeboats are carried or not.	One compartment damage required, two if the provision oflifeboats is to be avoided.
Double bottom	Required unless not practicable.	Not required.
Weathertight integrity	Main deck and above to be weathertight. Windows not permitted on main deck without reasoned technical justification. Internal deadlights required for sidescuttles on main deck. Load Lines to be complied with.	Storm shutters required for windows on main deck or extra thick toughened safety glass. Equivalent requirements to Load Lines permitted, subject to damaged stability requirements being met.
Bilge pumping	At least three pumps required, a fourth independent pump sometimes required.	At least two pumps required.
Emergency source of electrical power	Emergency services to be supplied for 36 hours.	Emergency services to be supplied for 18 hours.
Fire growth potential	Limited amounts of combustible materials (paints, varnishes,veneers, facings, mouldings, decorations, etc) permitted on"A", "B" and "C" class fire divisions in accommodation and service spaces subject to not generating smoke or toxic byproducts of combustion in accordance with the IMO's Fire Test Procedures (FTP) Code. Exposed accommodation bulkheads to have low flamespread characteristics as per the FTP Code.	All "A", "B" and "C" class fire divisions in accommodation and service spaces may be faced with combustible materials. Exposed accommodation bulkheads *need not* have low flamespread characteristics.
Containment of fire	Matrix of "A", "B" and "C" class fire divisions for accommodation, service spaces and control stations.	Matrix of "A", "B" and "C" class fire divisions for accommodation and service spaces and control stations.
Fire fighting	Two independent fire pumps providing at least 0.30 N/mm² at any hydrant.	Two independent fire pumps providing at least 0.20 N/mm² at any hydrant.
Means of escape	Escape routes are to be marked by lighting and photoluminescent strip indicators complying with the Fire Systems Safety (FSS) Code.	Aids for escape to be provided as necessary to ensure accessibility, clear marking and adequate design for emergency situations.
Lifeboats	Under 500GT not required, over 500GT one partially or fully enclosed lifeboat each side or alternative arrangements to be proposed to Flag.	Not required under 85m, one totally enclosed each side for 85m and above unless two compartment sub-division.
Rescue boats	Two SOLAS rescue boats. The lifeboats may be accepted as rescue boats.	SOLAS rescue boat required or Flag-approved equivalent.

Fig. 8 Main differences between the two sets of Requirements (Maritime, 2008)

For exact requirements see SOLAS convention on passenger ships < 36 passengers and the Large Yacht code (LY2). The new Private Yacht Rules and Private Yacht Code particularly are developed to meet with the requirements of the mega yacht industry for yachts larger than 24 meters and more than 12 passengers as to avoid being graded as a Passenger Vessel are accordingly reviewed in the following section.

3.4.1.5 Private yacht rules

A new private yacht code was necessary because earlier yachts that would carry more than 12 passengers on board would be registered as passenger vessels. The complications of this was that the International Conventions for passenger ships are originally designed to meet requirements of "merchant" ships not super yachts, even so yachts have a very different operating pattern and risk profile when compared to

commercial passenger vessels. Managing director of the marine division of RINA explains that the International Regulations do not meet with the requirements of the Super and Mega Yacht Industries (Squire, 2009). The Maritime Coastguard Agency's Large Yacht code for example is for yachts larger than 24 meters, but is restricted to 12 passengers (MCA LY2, 2007). In the Large Yacht code all the safety and technical details of construction of the yacht are described in order to keep yachts construction safe and maintain the passengers/crew safety as well. As a result of the needs from the industry for rules and regulation that were not restricted to the number of passengers or to the size of the yacht, the Passenger Yacht Code was developed (PYC). The PYC was submitted by the UK to IMO as an equivalent standard to the requirements of Load Line, SOLAS, and STCW Conventions.

The PYC is a Code of Practice for Yachts Carrying 13 to 36 Passengers and has been introduced by the Red Ensign Group (REG) during November 2010 (PYC13-36). The Maritime Authority of the Cayman Islands or Cayman Maritime in conjunction with the Red Ensign Group have developed the new Code of Practice which applies to pleasure yachts of any size, in private or engaged in trade, which carry more than 12 but no more than 36 passengers and which do not carry cargo. The Passenger Yacht Code focuses on amongst others: the Safety of Life at Sea international convention standards [SOLAS] (Howorth & Howorth, 2010).

The same time and even so to meet with the mega yacht industry requirements, the United Arabs Emirates (UAE) has developed in 2010 a Code that are specifically measuring up to the privately owned yachts that are larger than 24 meters. The United Arabs Emirates (UAE) developed private yacht rules with the support of Det Norske VERITAS classification bureau (DNV). There was no classification society yet that focussed merely on the private super yacht market segment. The UAE private yacht rules were developed in order to fill in this gap. The UAE private yacht rules are, unlike the PCY, only applicable to privately owned Super yachts larger than 24 metres with absolutely no restriction in the amount of passengers on board and are not intended for the commercial trade.

3.4.1.6 Mega yacht design and human needs

To establish and maintain technical standards for the construction and operation of ships there are classification societies. A classification society is a non-governmental organization that establishes and maintains technical standards for the construction and operation of ships and offshore structures. The society will also validate that construction is according to these standards and carry out regular surveys in service to ensure compliance with the standards. Classification societies set technical rules, confirm that designs and calculations meet these rules. For this research thesis the American Bureau of Shipping rules and regulations were used for analyses.

The main driven idea of all ship regulations is to maintain safety on board and at sea. Most mega yacht design guidelines, rules and regulations limit the freedom in design of the mega yacht. To name a few guidelines on human factors that exist to support the (mega) yacht design industry are amongst others:

- ABS, Comfort - Yacht (COMF(Y)) and Comfort Plus - Yacht (COMF+(Y))
  Published in 2008, last updated in Nov-09-2010
- Bridge Design and Navigational Equipment/Systems
  Published in 2000, last updated in Nov-09-2010
- ILO Maritime Labour Convention, 2006
  Published in 2009, last updated in Oct-13-2010
- Passenger Vessels
  Published in 2001, last updated in Jun-30-2011
- Passenger Comfort on Ships
  Published in 2001, last updated in Dec-01-2003
- Crew Habitability on Ships
  Published in 2001, last updated in Dec-01-2003
- Ergonomic Design of Navigation Bridges
  Published in 2003, last updated in Oct-01-2003

The last one in this list: Ergonomic Design Rules of a Navigation Bridge as described by the American Bureau of Shipping (ABS, Guidance notes on Ergonomic Design of Navigation Bridges, 2003) gives design guidelines on bridge ergonomics in order to keep the safety on board by efficient operation. There are numerous studies about the development and correct position of bridge equipment design. In order to reduce human errors, the ABS regulations set guidance notes on how to design the correct bridge lay out, like alarm colours, labels, ergonomic chair design, window inclination, distances etc., in order to avoid any type of human error. In section 9, Work Environment (ABS, 2003) regulations for prevention vibrations, noise and climate are described. All of the guidance notes in the list above mentioned, comfort of the human being on board are very much approached by means of technical parameters. In section 12 the colour of the bridge is described in order to avoid reflection and glance, more with the safety at sea in mind than the direct comfort of the people on board. In none of the regulations and guidance notes is mentioned neither the psychological comfort of the people on board nor the ideological or social comforts of people are referenced. Ergonomics is only one aspect of the key human elements that are needed on board for peoples' wellbeing and restore safety.

The following statements can be made after research of the many guidelines, rules and regulations on human factors on mega yachts design:

- Comfort of the human being on board are very much approached by means of technical parameters like, ergonomics in order to improve health and safety issues on board and avoid accident and incidents at sea e.g.
- The regulations merely focus on physical and technical comfort factors. Other factors of comfort, like sociological, psychological and ideological comforts (Jordan, 2000), are not mentioned in any of the regulations.

The absence of other human factors related guidelines, besides ergonomics, that are responsible for wellbeing and safety on board, could explain why a lot of mega yacht designs fall short once build and in use. To name a few problems: people on board

complain about the uncomfortable layout and lack of personal space. The main concern with yacht design is actually the minimum required size for the crew cabins and is an on-going debate between the ILO (International Labour Organisation) and the yachting industry. BMT Nigel Gee, a leading independent Naval Architecture and Marine Engineering Design Consultancy based in the UK, carried out an analysis on crew accommodation. The analysis covered the MLC requirements on crew cabins; include officer cabins and mess-rooms for yacht between 40m to 100m LOA, regulated under LY2 and SOLAS passenger ships. Results were amongst others, the LY2 yachts below 65 meters were not meeting with the crew cabin requirements, (Hardy et al, 2010), see Fig. 9. The smaller the yachts, the fewer the crew cabin spaces meet with the actual MLC criteria. More research on comfort factors for crew cabin spaces are needed in the future.

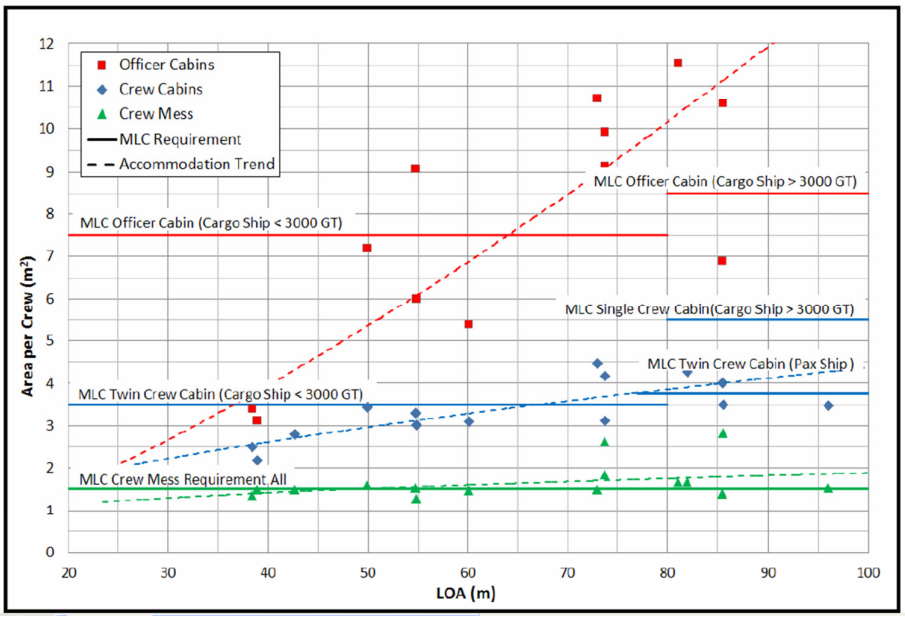


Fig. 9 BMT Nigel Gee crew accommodation study results (Hardy et al, 2010)

The ABS even gives a general definition of Comfort:

ABS, Comfort - Yacht (COMF(Y)) and Comfort Plus - Yacht (COMF+(Y)):

'Comfort: The acceptability of the conditions of a yacht as determined by its vibration and noise qualities according to prevailing research and standards for human comfort.'

The IMO and SOLAS state 'Comfort' (Guide: Accommodation, part 6 Safety. Security and Comfort, chapter 1 general definitions) as:

*'A state of **physical** wellbeing*'

The appearance, size, escape possibilities, air qualities, temperature control, lighting, noise and vibration levels and sea motion are all mentioned factors by the rules that can influence comfort. Not Only the ABS fall short in providing guidelines on human factor design, also the SOLAS and IMO regulations describe comfort on board simply in technical parameters such as noise, vibrations, climate and ergonomics factors etc.

In the following 6 sections of this thesis, comparison is made between the different interior design industries. The sections critically review the functionality and usability of the design approach according to the first two layers of Maslow's' hierarchy of needs triangle (Maslow, 1970), as was discussed in Fig. 1. The sections accordingly elaborate on their design approach towards human factors.

3.5 General shipbuilding design,
3.6 Cruise ship design,
3.7 Hospitality; hotel, restaurant and cafe design
3.8 Interior car design,
3.9 Interior train design and
3.10 Airplane design

3.5 General shipbuilding design approach and human factors

This section critically reviews the functionality and usability of the design approach of cruise ships. Accordingly the human factors approach to ship design is reviewed, followed by a discussion. In this section the trade shipping and commercial leisure ship design industry are evaluated in comparison to the mega yacht design industry and evaluation is made between the differences these industries. Even so is discussed why the mega yacht design industry has a different focus point towards design than the other industries and how this may have an effect on the approach to design. This section also elaborates on marine design, the current existing ship design methodology; the design spiral, and the utilization of human factors in the ship design methodology.

3.5.1 Functionality and usability

In the past numerous researches in human factors of the commercial and private shipping industry have been carried out in order to understand the human element in relation to safety, comfort and human needs. However, there is still insufficient knowledge in relation to the human elements in ship design. The requirements in the shipping industry concerned with trade are fairly straightforward; Types and the function of the ships is to carry the cargo from A to B and in the best economical way in order the save on fuel and to gain profit. In reality saving on money often means: less crew, less cabin space, leading to cramped uncomfortable living quarters and fatigue by working long hours etc.

When it comes to the approach of design methodologies used in the different ship design sectors, the approach to design of cargo ships and that of cruise ships are both the same. Either a ship is designed for the trade, or for the commercial leisure industry, they basically follow up an existing previous design. The technology is updated and the design is slightly improved and maybe some extra features are added. ‘Gaining profit’ is the biggest motivation for both trade and leisure shipping.

The private mega yacht sector, however, is for leisure of a different class; it's for private use and money is not a problem. As the main goal to successful mega yacht design is different than for trade and commercial leisure industries and the aspiration of this industry is not to make a profit but purely to leisure, the approach and methodology to mega yacht design needs to be different as well. This next section analyses and discusses the most frequent used ship design methodology as used in both trade and commercial ship design. Even so the methodology to ship design development is analysed on the use of human factors.

3.5.1.1 The design spiral

In many study books of ship design, the design spiral is explained (Larsson & Eliasson, 2007) Fig. 10

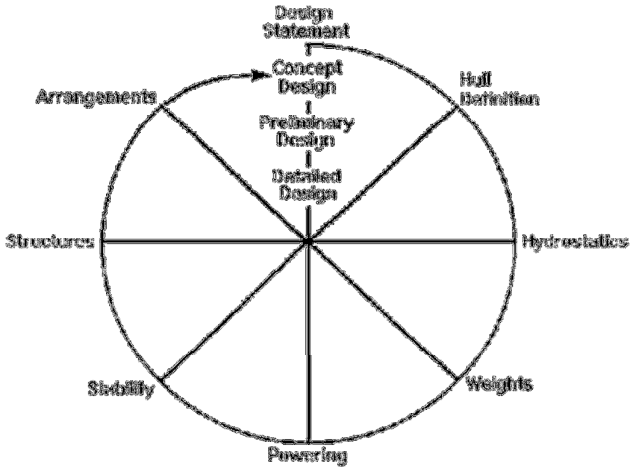


Fig. 10 General used ship design spiral (Evans, 1959)

The ship design spiral was first introduced by Evans to characterize the ship design process (Evans, 1959). Although the design spiral knows many variants on the original spiral, Economic design spiral and time dimension, the basics remain the same (Andrews, 1981), although this methodology to ship design is still used. The spiral focus lays mainly on the technical parameters of the project, like costs, size etc. (Katsoufis, 2006). Mistree et al (1990) researched the limitations of the different design spirals as they are used in the shipping industry. They mention the design

spirals as not useful when it comes to the possibilities of including the complete life cycle of the ship. In addition Mistree (1990) mentions another important limitation of the design spiral, namely, that the design spiral shows the design process of the ship as a sequential process, what is not necessarily the case. Even so the design spirals are merely focussed on the analytical and technical parameters to design.

Young naval architects learn in their primary studies that the approach to ship design begins with the ship design parameters. Their approach to any ship structure is that the ship's hull form is the most important object in the design stage. Stability, bending moments, shear forces etc. In naval architect' study books, the design spiral is pointed out as one of the main used methods to design (Larsson & Eliasson, 2007). The spiral is divided into several segments and when the circle has finished the process starts again and again, like a spiral, which resembles the ship building process. The whole process is described as exclusive mathematical approach to ship design. In addition the classification society's rules and guidelines in ship design require a technical and sequential approach to design. Ship in general design is very much different than any other design industry, like aero industry, car or train industry design. The design of an airplane is far less complex than that from a ship (Andrews, 2006). In the airplane the passengers and crew only spend a few hours, whereas the time passengers spend on board varies from 1 hour to two weeks and the ship's crew even spend months on board the same ship. The ship becomes a second home for the crew, they have to eat, sleep, work and live there for at least 6 months a year. In Therefore the ship designer must take this fact into consideration in their ship design.

The success of a product depends amongst others on how much money is spent on the development of that product. How much money is available depends on both the selling price of that product and the number of products of that type one expects to sell/produce. Considering the effect of the anticipated production of repeats of the same design, the development cost of a car or aeroplane is allowed to exceed the selling price of that car or aeroplane by a large margin. For a ship, however, the development cost cannot exceed its selling price as only one or a very small series

will be built of the same design. Andrews (2006) compares the shipbuilding and its complexity in design therefore with the building project of a bridge or large building. Considering the limited (financial) means for the design of a complex product that a ship is, the pressure on the ship builder in particular is very high. A key element to success of the design here is communication between ship owner, designers, and naval architect and ship builders. In many cases only one ship of that design will be built and the team needs to get it right the first time, as there is no second change.

In the aero and car industry development cost of a new type of airplane may easily exceed the selling price of one airplane/car. Human factors taken into consideration in an early stage of design can, according to Andrews (2006), prevent problems in a later stage. Especially when there is no prototype to be tested, everything must be taken seriously, also in the design spiral process are human factors not addressed, see Fig. 10.

Traditionally the design process of a ship can be shown in three interactive design stages (Smith, 2005): Preliminary design, Contract design and Detailed design, whereas the Preliminary design process consists of two stages: Concept design stage and Feasibility design phase. In the first stage of the design process: Preliminary design, all the requirements of the owner and possibilities are discussed. Main characteristics of the ship include; ship dimensions, tonnage, preliminary arrangements of the machinery and hull, speed requirements are proposed in this design stage before the actual contract of the project is approved and signed. These design stages and how detailed every stage is described, vary from company to company and depends on different factors such as, the experience of the naval architects, the size of the project etc. As previously mentioned; the stages overlap each other constantly and the more detailed the preliminary design stage is described, the less confusion and adjustments will occur in the final stage.

3.5.1.2 Marine ship design process

In Marine design, there are three phases to ship design: preliminary, contract and detail design. The traditional marine design process is reflected in a step-by-step approach (Fig. 11).

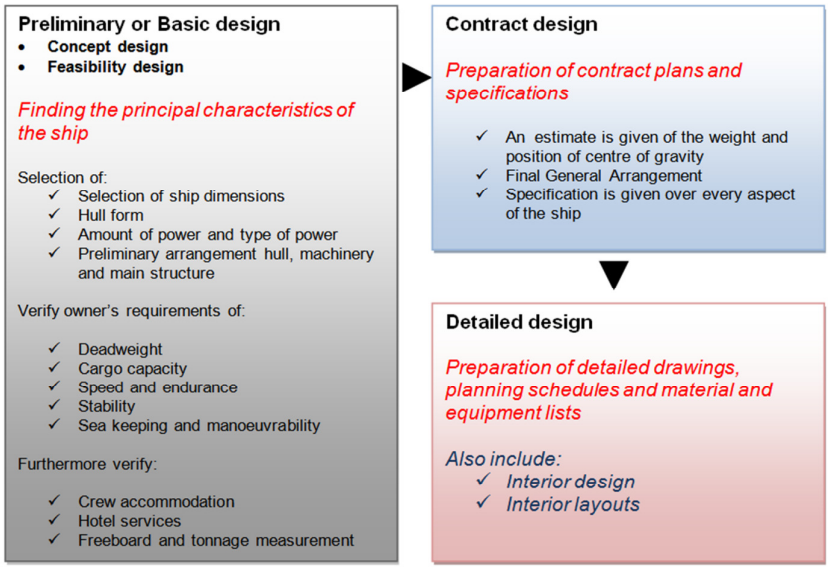


Fig. 11 Marine Ship Design Process

Fig. 11 presents The Marine Ship Design Process in 3 phases (Turan, 2011). The first phase is the Preliminary or Basic Design, which is about finding the principal characteristics of the ship and can be further subdivided into two phases: Concept design and Feasibility design.

The naval architect receives the order specifications of the new build ship. The first part of the preliminary design phase includes all requirements of the owner or company: required performance of the ship, speed, costs, amount of passengers required etc. This phase should also take into account the traditional human factors' requirements like low noise, vibrations, indoor climate etc., because they are very much caused by a combination of the exterior and interior design and engine specifications and lay outs.

Once the owner's requirements are specified, the preliminary overall dimensions, preliminary general arrangements and weight estimates are predetermined. Furthermore the preliminary design sketches are made of the hull and general lay out. Once the naval architect and owner come in to an agreement about the ships main parameters, the contract is signed and the contract design phase can commence.

In the Contract Design phase preparation of contract plans and specification is made. The technical specifications of the ship are designed in detail and the Centre of Gravity calculations are set.

The Detail Design phase follows after the Contract Design Phase. The Final Design phase can only commence if the owner signs the contract. Preparation than is made for the detailed working drawings, planning schedules etc. Even so in the Detail Design phase, the interior layout is designed by either an interior architect working for the same company, or hired from a different company.

To most owners of a mega yacht appearance of the exterior and interior yacht is very important, even more important than Performance, Functionality or Usability (Candy & Candy, 2010). Professor Nagamachi (2002) pointed out in his customers orientated design technique that most customers tend to choose products based on their emotions (Chen & Chang, 2010). The mega yacht is an accessory, an object of pure art and decadence; it's designed to be a reflection of their life style. As shown in Fig. 11, it is only in the traditional shipbuilding's' Detail Design Phase that the interior lay out and other interior designs are planned. The reality may show, although, less strict boundaries and interior lay out details are often already discussed in the Preliminary Design phase and in Contract Design phase. Often it occurs that the actual building of the ship has already started at the beginning or even in the middle of the final design stage rather than at the end. The different design phases overlap each other constantly (ABCD Working Group 2008).

Every detail of the ship interior layout depends on the first design and modelling of the ships' outer lines; general arrangements, weight, hull shape etc. All these

parameters are related and influence one another. If the general arrangement changes, naturally the interior lay out parameters should change as well. Therefore the Preliminary design phase is of paramount importance in order to avoid catastrophic problems in the Detail and Final Design phase. The following section elaborates more about the human factors approach to general ship design.

3.5.2 A human factors approach to general ship design

Frequently re-design and restructure of a ship design are the results of a misunderstanding of human needs between the different stakeholders involved, designers and the customers. Even after the completion of the ship there are unsatisfying elements and construction failures to be noticed. One way to avoid problems after completion of the construction phase of ship design is to integrate human factors directly into the concept design stage of the ship rather than in the Final phase of the design.

3.5.2.1 Absence of human factors in ship design

Riola and Garcia (2006) commend in their research on the absence of human factors in the design methodologies of ships. They particularly address the personal space on board. The person space that is needed on board ships is much bigger than they are needed on land. In bad weather people on board react very differently than people on land, they get irritated much sooner in extreme circumstances and heavy weathers and need therefore more personal space to stay focus. These human factors, such as need of personal space should be taken into consideration in the first approaches to ship design.

Even so Andrews et al (2004) discusses the possibilities of personnel simulation into the initial ship design. Personnel simulation such as stability, strength, sea keeping, crewing and ship operations and other human orientated ship design issues are traditionally relevant in a later design stage and often are the cause of many problems. The research concludes with the possibilities in implementing these human

factors in design in the preliminary design stage rather than in a later stage, to avoid problems afterwards when the ship is already in its last construction face and all sorts of adjustments have to be made. The next section critically reviews the functionality and usability of the design approach of cruise ships and the human factors approach to cruise ship design is reviewed.

3.6 Rules and Guidelines and their approach of human factors for Passenger ship design

When a passenger ship is designed, one of the most important tasks of the designers is to create a perfect comfortable environment, in which the passenger can escape from daily life. In other words: a balanced combination of aesthetics, comfort, pleasure and functionality. In this aspect the shipping company can reconstruct the ship many times. They can use the same structure, hull and parameters, with the only difference; the dream scenario theme can change every time (Atonucci, 2009). The dream scenario theme on every passenger ship is different and adjusted according to the needs, culture, age, etc. of the different target groups. How to design the perfect theme lies in the hands of the creators. This dream theme cruising is unique for the Cruise Industry and by creating different themes over and over again, they can develop over the years together with their customers' needs, and by doing this, the Cruise Industry stays active and competitive.

This section critically reviews the functionality and usability of the design approach of cruise ships, as well as this industries' human factors approach to ship design.

3.6.1 Functionality and usability

Prior to cruise ships and mega yachts there were the ocean liners. The ocean liners were constructed to transport people from A to B; these ships were not designed to be comfortable cruisers. They had a deep draft and high amount of fuel consumption,

which made them unsuitable for cruising. These ships were simply constructed to transport as many passengers as possible. In cruise ship design; safety of the passengers and crew is the designers' first priority. For safety and evacuation of passengers and crew, competitive evacuation methods in design are researched. For evacuation the layout of ships for human factors, special simulation software is used, such as EXODUS (Deere et al, 2008). Safety in relation to comfort and human factors is still very much an unknown area to many researchers. Human factors in comfort do not have any priority other than in the mega yacht industries (Klupfel et al, 2000).

The behaviour of passengers in case of an emergency is a very complex and long process and research mostly focus on evacuation of passengers. In case of evacuating passengers, there are guidelines developed in construction and lay out design (IMO, 2007) and (Andrews et al, 2007). However, still a very much unknown area, more and more real human behaviour in relation to ships movement parameters are simulated in order to guarantee passengers safety on board in case of an emergency evacuation (Klupfel et al, 2000). Existing evacuation models for passenger ships are normally based on the average passenger behaviours in average sailing condition: limited stress, limited trim, average weather circumstances, limited heeling etc. New software has been developed to improve the existing passenger evacuation models with the use of real human behaviour under stressed circumstances.

Evacuation design is very different for a ship than for a hotel. In a hotel there are no extreme sea keeping conditions, no rolling no pitching, noise of engines etc., therefore the design of a commercial or private ship is far more complex, as a passengers safety at sea is priority and must be guaranteed. Naval architects therefore need to follow the rules and regulations on general arrangement and evacuation design. However, research has been carried out in order to meet with the rules and regulation on general arrangement and evacuation design on board, this industry nevertheless is challenged with problems. Humans tend to react very differently in case of emergencies. The evacuation behaviour of passengers on board the ship also

depends on country, religion and physical wellbeing (Riola & Garcia de Arboleya, 2006).

Again for passenger ships the safety is priority and the budget for safety is available. In case of the development of a mega yacht, the budget is focussing mostly on the aesthetics of the yacht; more money is being spent on the appearance, speed and performance of the yacht, than on safety. The success of the safety and comfort of the passenger industries lies in the research carried out over the years in safety and comfort, based on years of experience and the already build and existing passenger ship models.

The next section reviews the human factors' approach to ship design.

3.6.2 An human factors' approach to ship design

Comfort is of paramount importance on board cruise ship. A cruise ships' primary function isn't transportation, but a fairy-tale holiday of a week that the industry sells to their customer: 'A dream scenario' (Antonucci, 2009). He speaks in an article about the creation of a dream scenario theme holiday on a cruise ship (like Disney Cruises); the line between the original purposes of a ship, transportation and the comfortable cruising of today's industry has faded away. In this section all the key factors that contribute to the psychological factors of wellbeing and comfort feeling of passengers are analysed and discussed.

The first section elaborates on the different habitability guidelines and researches what comfort means to the classification agency ABS, directly followed by a discussion on the importance of good ergonomics on board the ship and how the guidelines implement these in the design stage. Accordingly the hydrothermal comfort and comfort by means of personal space and personal space in extreme sea keeping condition is analysed. Even so the positive influences of indoor colour choices on motion sickness are discussed.

3.6.2.1 Comfort and the habitability guidelines

In this section the key factors contributing to the wellbeing of passengers are analysed and compared to the regulations. When the Comfort and Habitability Guidelines of ABS Guidelines on Passenger Comfort on Ships (December 2001) are analysed, comfort of passenger ships is described as follows:

'*The acceptability of the conditions of a vessel as determined by its vibration, noise, thermal, indoor climate and lighting qualities as well as its physical and spatial characteristics, according to prevailing research and standards for human comfort'* (ABS, Passenger comfort on ships, 2002)*'*.

Although the ABS guide makes use of different references such as the 'Human Handbook for Ergonomics and Design' (Sanders & Mc Cormick, 1993) and 'Handbook of Human Factors and Ergonomic' (Salvendy, 1997), there are no comfort rules of human psychological factors, such as personal space or choice of colour. The ABS guide describes the comfort of people in a diversity of chapters with guidelines concerned with: noise, body vibrations, lights, temperature and indoor climates. Little is said about ergonomics: although the maximum and minimum measurements are described for furniture and lay out spaces for every area of the ship, nothing is mentioned about what effect ship dynamics have on the human body and how this should change the design of the furniture and accommodation spaces.

Accommodation criteria such as light, noise, indoor climate and whole body vibration levels, for other crew on passenger ships as well as on merchant vessels, can be found in the ABS guide 'Crew Habitability on Ships' (ABS, 2002). However, the guidelines mention that painted wall surfaces and deck heads must be light in colour, the ABS guide don't provide guidelines to improve on aesthetical and psychological factors of comfort.

The accommodations criteria in the appendix (ABS, 2002), section passenger ferry seating, gives guidelines on the interior of seats that should be equipped with

cushions or padding. Nonetheless, nothing is mentioned about the effects of the hydrothermal comfort of the seating, as mentioned in a study by Brattgard and Severinsson (1978). Hydrothermal comfort concerns the temperature and humidity of the seating surfaces. A rise in temperature while the seat is in use; the contact area is generally associated with sweating and a high local relative humidity. As with temperature; the effect depends both on the nature of the support surface as well as on the environmental conditions. Humidity controlled seating is already available in luxury car interiors to increase comfort of the driver.

In the guidelines for passenger cabins, the minimum space requirements are described as well as the type of furniture acquired for each cabin, but little is said about visual comfort and psychological comfort, like colours and illumination. Colour for example is merely mentioned from a safety point of view; walls and surfaces should be light in colour and does not have a glare (ABS, Passenger comfort on ships, 2002). For lighting criteria's, illuminations levels are described for all areas on the ship, however, the ABS guidelines for passenger comfort on ships mention only that the psychological and aesthetic effects of lighting and colours should be taken into consideration, no specific guidelines are provided. In a study by Knez was stated that there is a non-visual psychological effect of colour and light on the human psychological processes (Knez, 2001). Extra guidelines in psychological comfort factors on board ships should be taken into consideration.

3.6.2.2 Relation between visual comfort and Lighting quality

'Lighting quality is much more than just providing an appropriate quantity of light. Other factors that are potential contributors to lighting quality include e.g. illuminance uniformity, luminance distributions, light colour characteristics and glare' (Veitch & Newsham, 1998)

Primarily the quality of lighting is important in order to carry out the visual task in the specific room when there is lack of daylight. The visibility is defined by the ability of people to detect the objects or signs of given dimensions at given distances and with given contrasts with the background (CIE, 1978). Secondly the quality of

lighting is important to feel comfortable in the room. It is as Boyce (2003) and Veitch (2001) mention: ‘there are many physical and physiological factors that can influence the perception of lighting quality. Lighting quality cannot be expressed simply in terms of photometric measures nor can there be a single universally applicable recipe for good quality lighting.

Although the visual performance is primarily the focus point to quality lighting, on board mega yachts accommodation areas the visual comfort of the persons using the rooms is equally important. Special visual performance models are designed to assist between the visual task performance, visual target size and contrast, observer age and luminance levels, see (CIE, 2002). When the focus is on creation of visual comfort with the right kind of quality lighting it can be said that simply bad quality lighting caused discomfort, although the right kind of visual lighting in order to perform the task doesn’t automatically guarantee visual comfort. The indoor lighting recommendations for a start give ranges of illuminance values for different types of rooms and activities. Even so there are guidelines the designer can use for the light distribution in a room, the limitation of glare or the characteristics to the right colour of light (EN12464-1, 2002), (CIBSE, 1994: additions and corrections 1997, 1997). However, these guidelines may only prevent the room from visual discomfort. In order to create visual comfort the designer needs to pay attention the psychological side of the lighting in the room and designer and customer need to converse regularly. Visual comfort is to be achieved by finding the right balance between all of the above. Fig. 12 shows a human performance and luminous environment model by (Gligor, 2004).

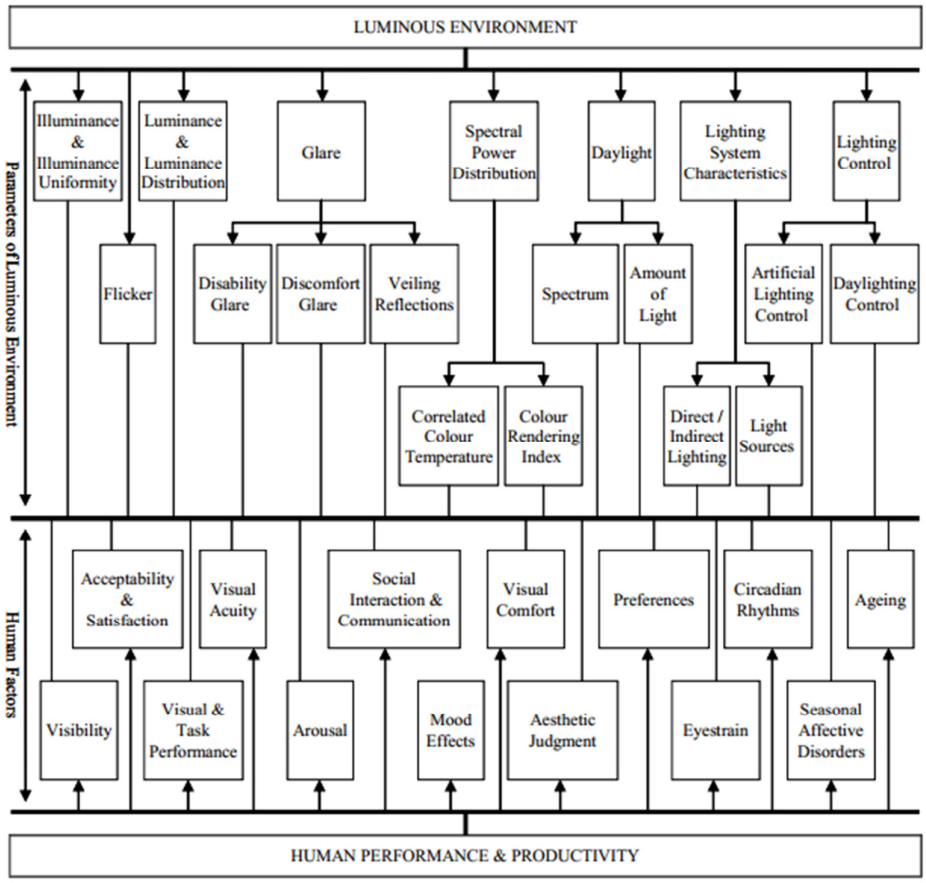


Fig. 12 Luminous environment and human performance (Gligor, 2004)

The model in Fig. 12 presents the human factors that influence productivity: visibility, visual & task performance, arousal, mood effects, aesthetic judgements, eyestrain and seasonal affective disorders. The model also shows the parameters to luminous environment such as: glare, daylight, luminance, luminance distribution and illuminance, illuminance uniformity, spectral power distribution, lighting control and characteristics of the lighting system itself. The models present how the factors of performance are related to these parameters of luminous environments.

Out of this section can be concluded that the human behaviour, comfort and human performance are unmistakably related to the quality of light and the luminous of the environment. The quality of the lighting should therefore be taken seriously and are in need to be discussed with the customers of the yacht in an early design stage in

order to be able to anticipate on the factors as described in the model of Fig. 12, such as amount of daylight that is needed for the crew to perform well and for the passengers to offer them optimum comfort.

3.6.2.3 Luminance and individual well being

Luminance is often used to characterize emission or reflection from flat, diffuse surfaces. The luminance indicates how much luminous power will actually be detected by an eye of a person looking at the surface from a particular angle of view; luminance is thus an indicator of how bright the surface will appear. According to Casey (2003) the reason why we humans are tend to respond more intense to the sharp changes in luminance than the luminance power itself is because our eyes are in continual movement, Casey explains: '*Each eye has a field of view of about 160 degrees with overlapping fields of view. The two eyes work together to provide stereoscopic vision. The small ocular vibration set the retinal image in oscillation and the neural network is tuned to detect the important local changes in luminance'*. (Luminance: the intensity per visible unit area of the surface of the actual light source).

Amount of natural daylight that comes in the room is one of the most important parameters to illuminance or light level, artificial light is the other parameter. Artificial light also determines the overall comfort and wellbeing of the people in the room when there is lack of daylight. Veitch (2001) reported that the preferred illuminance levels by people are higher that the recommended illuminance levels ,See also recommended illuminance levels in Appendix B/ 2.3, Table 4 and Table 5. Also see Fig. 9 of the Appendix B that demonstrates a conceptual framework setting out the routes by which lighting can influence human performance (Boyce and Rea, 2001).

The lighting quality inside a room depends on not only the economics of the room, such as installation or maintenance issues, but also on the architectural factors such as style and code and standards. Individual wellbeing is equally responsible for the quality of lighting as he shows in Fig. 13.

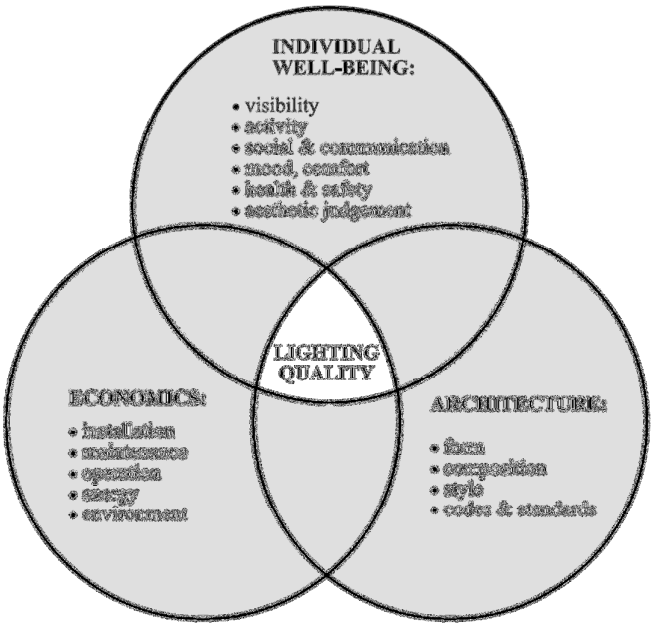


Fig. 13 lighting quality, the integration of individual wellbeing, architecture and economics (Veitch, 2001)

Fig. 13 shows the model by Veitch (2001), in which the circles represent lighting quality; the integration of individual wellbeing, architecture and economics. The quality of lighting in the room depends on these 3 main factors and their key influencers. Also mentioned that it is impossible to report on the exact preferences of people in illumination as the influencers and psychological factors of individuals are so variable. The key influencer to keep in mind when the room design is considered is the 'aesthetical judgement', as part of the individual wellbeing factors in Fig. 13, as this is the most influenced factor and the most difficult one to consider. Before the preliminary design stage of the mega yacht commences it is of the utmost importance to get familiarised with the owners' taste, needs and aesthetic requirements.

Besides the standard safety regulations on lighting in buildings, numerous studies have been carried out on light, daylight and the effect on humans' preference, comfort and wellbeing in different areas. Many regulations have summarised the most important factors of light and human comfort and wellbeing like the Chartered Institution of Building Services Engineers' Interior lighting Code UK (CIBSE, 1994) or the Energy code from ASHRAE in the USA (ASHRAE, 2010). These codes give

allowances in the interior lighting power in different areas or space types. The CIBSE's Interior lighting code for example has target ranges of installed power density for different lamp types and room index to be used with recommended lux levels.

Specials surveys are carried out in order to report if the particular space meets with the required standards for the people who make use of that space. Most often the designers and habitants or employers of the space require a special survey to check the accurate light levels of the area. Actual allowance levels vary between the different codes and different countries (Field and Super, 2000).

3.6.2.4 Ergonomics on board

Seafarers are used to less satisfactory circumstances and therefore their tolerance towards comfort and ergonomics is higher compared to other professions. Seafarers are very flexible and are highly praised for their adjustment skills towards rough living conditions at sea, such as bad weather or long periods away from home. According to Silltoe et al (2009) this should change and the human factors should be implemented into the concept stage of the shipbuilding project as well. Safety and health regulations should be improved for seafarers.

Mery and Mc Gregor (2009) underline the importance of good safety and health regulations such as good ergonomics. They underline the importance of using the guidelines on ergonomic principles in the design stage of the shipbuilding project in order to retain maximum impact. Every detail of the bridge and engine room equipment has been studied with regards to ergonomic and human factors usability levels. If it comes down to effective working environments many studies have been carried out; anthropometrics is a very well-studied area for industries like the aviation. Human factors and the effects of ergonomics in relation to human comfort in all day life on board the ships, has been poorly covered compared to other commercial transportation industries.

Projects and publications such as ALERT by Lloyds register are meant to raise awareness of the urge to improve the human living conditions on ships and not only implement the human factors in the early design stage of the ship, but also throughout its complete lifecycle (lloyd's Register, 2003 and onward). In the next section the comfort on board for passengers and crew in relation to personal space is reviewed.

3.6.2.5 Comfort on board and personal space

Personal space has been numerously mentioned in studies in all fields and has been widely recognized as a contributing factor to the overall wellbeing and comfort feeling of persons working and living in all areas. According to a study by Riola & Garcia de Arboleya (2006), there are 4 main areas to define for personal distances see Table 3-3.

Table 3-3 Defined areas of personal distances (Riola & Garcia de Arboleya, 2006)

Intimate (for closest friends)	30-45 cm
Personal conversation	45-120 cm
Social distance (commercial transactions)	120-210 cm
Public distance (low formal meetings and public speeches)	3 meters and more

As shown in Table 3-3, there are 4 main areas defined. The first area is the closest possible distances as seen by good friends and relationships which can be defined between 30 and 45 cm, the second closest distance is for general personal conversation, which is between 45 cm and 120 cm, accordingly the distance for social conversations, like commercial transactions etc. is between 120 cm and 210 cm and the largest possible personal distance is the public distance, like low formal speeches etc. and can be defined as 3 meters or more.

When the ABS guidelines for passenger comfort on board passenger ships are reviewed, recommendation is made for amongst others the width of passenger walkways; walkways should be at least 91, 5 cm in width, considered for normal traffic, whereas corridors and passage ways that serves as an exit should be at least

110 cm in width (ABS, Passenger comfort on ships, 2002). According to Table 3-3: 91, 5 to 110 cm wide corridors and passenger walkways can be categorised in the section: Personal distance (45-120 cm), this is the distance where normal conversation among friends would take place. In the walkways and corridors of passenger ships people would pass each other and greet other passengers and are not necessarily friends or acquainted, the personal distance, according to Table 3-3, should be therefore between the 120 cm and 210 cm, in order to feel comfortable when passing other persons in the corridors.

There are more examples like the previous one, but the aim of this example is to raise awareness of the fact that wellbeing and comfort of passengers and crew lies not only in creating a safe environment but also in paying attention to the human soft factors such as personal space. Ideal would be if the classification agencies could pay more attention to the benefits of personal space in order to increase the wellbeing and comfort on board. The next section elaborates on the importance of increasing personal space in extreme sea keeping conditions.

3.6.2.6 Personal space in extreme sea conditions

Many studies have achieved results about the human behaviour in extreme sea conditions. Results show that when feeling seasick the need for more personal space increases. Gerin-Lajoie et al (2008) tested the relationship on people's behaviour concerning their personal space with regards to their walking speed in different environments; it was found that there is no relationship between persons' need in personal space and the difference in environment and walking speed. Personal space was maintained during different walking speeds and environments; however, the age of people seems to make a difference. It can be said that young people need less personal space than older people. Also culture makes a difference in the need of personal space (Hall, 1966) and (Evans, 1973). Study of Evans showed amongst others that people from the United Arabic Emirates need more personal space than Americans. Americans seems to have a bigger personal space tolerance than people from the Arabic Emirates.

Considering the sea keeping behaviour of a mega yacht, personal space is something for the designers to keep in mind. People tend to feel more cramped in the same space under worsened dynamic sea keeping behaviours (ABS, Crew habitability on ships, 2002) and (Garcia de Arboleya & Riola, 2006). Most mega yachts have relatively low ceilings, compared to for example hotel rooms, because of the limited space available on board. This has a huge influence on the people's perception of crowdedness (Ryu & Han, 2011). However, designers can trick the mind to think they have more space in crammed rooms, for example to heighten the ceilings or by using light colours on the walls that reflect sunlight also into the dark corners. In general all ships have lower ceilings compared to buildings, as well as fewer windows etc. All this factors contribute to a higher perception of crowdedness and personal space invasion.

As a possible compromise for the limited spaces on board the ship Sjöberg and Thomson (2010) suggest that privacy on board the ship can be approached by concentrating more on the psychological factors, rather than trying to create extra space on board a ship that is naturally very crammed and crowded, what is often an impossible task. On a ship there is nowhere to go other than the spaces on board; you cannot just leave the 'room' to have a walk outside. So in order to raise comfort on privacy and personal space levels on board the ship, implementation of psychological factors like, colour, choice of fabric etc. should be taken in consideration very early in the design stage.

The next section discusses a variety of studies that have researched that there exists a necessity of choosing the right colour in a room in order to improve on overall wellbeing.

3.6.2.7 Effect of colour and human wellbeing on board

Although many studies have been carried out on the negative influences of noise on the human comfort and emotion, little is known of the negative side effects of colour on the human psychological behaviour. With regards to motion sickness and colour, a few papers have been published, relating colour to seasickness (Richard & Yuen,

2007). Numerous research have been carried out in order to find seasickness remedies, and to understand the effect of colour on humans and seasickness (Bonato et al, 2004). Seasickness is a serious problem for the people on board. Seasickness is a form of motion sickness. It occurs when the brain receives signals from the inner ear and eyes telling the body that it is in motion. When these signals do not match, the person starts to feel nauseas, and can start to vomit. The Department of Psychology, Saint Peter's College in Jersey City has researched of how certain colours have an effect on the symptoms of motion sickness (Bono et al, 2004). The test was carried out using different patterns, colours and stripes with different luminance, in order to test the effect of chromaticity and motion sickness. The results of the test revealed that chromaticity increases the symptoms of motion sickness; chromaticity may increase the disparity between visual and vestibular inputs, a factor thought by many to contribute to motion sickness. However, soft grey colours with a low luminance value may have a positive effect on the symptoms of motion sickness; other studies on the effect of colour on motion sickness have found similar results.

In the ABS guidelines for passenger comfort on board ships and the ABS Crew habitability on ships (ABS, 2002), insufficient guidelines are given to improve on human soft factors; there are no guidelines for the actual psychological effects of colours, illumination, hydrothermal and limited personal space on board the ship. The effects of colour on the state of wellbeing of persons on board is merely mentioned from a safety point of view and the psychological effects are taken into consideration; nonetheless, there are no guidelines of how to improve the comfort and well-being of passengers and crew in extreme sea conditions. Mery and McGregor (2009) underline the importance good safety and health regulations such as good ergonomics. They underline the importance of using the guidelines on ergonomic principles in the design stage of the shipbuilding project in order to retain maximum impact. According to Sillitoe et al (2009) this should change and the human factors should be implemented and considered directly from the concept stage of the shipbuilding project. All this human soft factors and the effects of ergonomics in relation to human comfort in all day life on board the ships, has been poorly covered compared to other commercial industries like the HoReCa (Hotel,

Restaurants and Café industry), automotive, train and aviation industry. The next section critically reviews the functionality and usability of the design approach in the hospitality industry and their approach to human factors.

3.7 Design approach to design of the hospitality industry and human factors

This section critically reviews the functionality and usability of the design approach of public spaces such as restaurants and hotels Accordingly the human factors approach to design of this sector of the hospitality industry is reviewed.

3.7.1 Functionality and usability

Horeca is an abbreviation used to define the **Ho**tel, **Re**staurant, and **Ca**fé industry. The Horeca is a segment of the industry of hospitality. This branch has become more and more important over the years. Unlike in the ship design industry, where the exterior design takes precedence over interior design, in the HoReCa interior design is often more important than the exterior design. For the HoReCa sector, choice of interior design depends very much on its environment; culture and location. Their priority lies with creation of a pleasant atmosphere, offer good service and optimum comfort for their guests and customers alike. From an economical point of view creation of a pleasant and comfort atmosphere is of paramount importance in order to satisfy the customers and make them visit regularly.

Recent studies on human factor comfort in the hospitality industry have revealed the positive outcomes and importance of good ergonomic interior design for hotel rooms for all type of guests, either families or business travels (Mohn, 2010). As the human comfort factor remains the same, these studies can be of use in the mega yacht industry as well. It might be of paramount importance to consider the human comfort factors for all types of guests.

Just like in cruise ship design, Horeca design needs to consider a wide spectrum of customers with special needs; young children, elderly or disabled people. Many research in Interior design for care homes for example has been done to raise awareness for the need of extra care for this group of people with special needs in order to increase safety and prevent accidents (Ford et al, 1995). According to the governmental department of health and safety in the U.K., most accidents which occur in private homes are down to the construction failures; 4000 people die each year due to construction failures of which 543 children in 1992 (Avery & Jackson, 2008), (Department of Health, 1992). Even if particular buildings have implemented all the health and safety regulations and restriction to the design, failures still occur (Burge, 2004). At the work place for example, many studies have been carried out for health and safety reasons. The number of sick people cost companies a lot of money each year. Many health and safety issues therefore have been researched amongst employees and found out that the air quality is of paramount importance in a working environment (Redlich et al, 1997). Sick building syndrome for example is a very serious illness that occurs in older buildings that have poor ventilation systems. Symptoms are among others: sore throat, headaches, fatigue etc.

Not only poor ventilation but also the outgassing of some types of building materials (volatile organic compounds, VOC) can cause sick building syndrome (Redlich et al, 1997). The most frequently occurred accident for example in the Hospitality industry; restaurants and hotels, are amongst others: Food poisoning, burns or electric shocks from faulty equipment, trips and falls due to wet or greasy floors, injuries caused by faulty furniture such as faulty beds and chairs, poor ergonomics; lay out, furniture etc. To avoid problems and accidents in the hospitality industry, like the above, there are many rules and regulations known, one of them is the 'Body of Law' that relate to the food service and lodging industry, namely: Hospitality law. While hospitality law covers many different entities, hotels and restaurants are the two most common hospitality businesses.

All of the above examples underline the importance that more legislative restriction on health and safety issues in public space is needed. It is the responsibility of the

designer not only to consider the aesthetics of the interior, but equally important the health and safety and ergonomics of the design for all types of people in order to prevent accidents. The next section analyses the human factors approaches to Horeca interior design and gives key elements to the human factors approach of this industry.

3.7.2 An human factors' approach to Horeca design

Studying a person's perception of personal space in a restaurant environment is very different than from an individual's perception of personal space when walking through a shopping mall, or walking on the street while passing strangers commuting to work. Ryu and Han (2011) of the college of hospitality and tourism management at the department of food services management studied customers' perception of discomfort in restaurants and their loyalty towards the restaurant in order to come back (Ryu & Han, 2011). In this section an inventory is made to the key elements of human factors' approach to interior design as applied in public spaces such as in the Horeca. The following key topics in relation to the human factors to comfort and wellbeing in the Horeca are discussed:

- Aesthetics and satisfaction
- Perception of crowdedness
- Meeting with the needs of the target audience
- Human comfort and colour
- Illumination levels horeca versus passenger ships

The first section elaborates on the importance of aesthetics in interior design of restaurants.

3.7.2.1 Aesthetics and satisfaction

Factors that influence behaviour and satisfaction of persons the most when in a restaurant are aesthetical factors like: illumination, lay out, service/staff, music, odour, décor, interior design, colours and table settings. Aesthetic factors and atmosphere are of the utmost importance. When it comes to illumination in a restaurant, it was researched that with low levels of lights, customers in restaurants tend to feel more comfortable (Baron, 1990). It was found out that when customers enter a restaurant, their first impression of the facility aesthetics like colours, lights and décor, are the ones that count as most important. When the first impression of the customers is positive, technical details, such as; table setting and comfortable chairs, are of secondary importance (Ryu & Han, 2011). When dinning out, people do not want to feel 'at home', they want to feel more special than that; something they will remember.

Resembling the interior of a restaurant or hotel with the comfort of home would be a mistake; and is often made by designers. Passenger ships, private and mega yachts, all are meant to be special, therefore the designer have to keep in mind when designing the interior of a mega yacht; this is not a home, it is should be more special than a home. Extra attention therefore is needed to the satisfaction of the aesthetic factors. The second section discusses comfort and wellbeing in relation to the perception of crowdedness in public spaces such as restaurants.

3.7.2.2 Perception of crowdedness

Yildirim and Akalin (2007) of the Gazi University in Turkey researched the perceived crowding in restaurants with different seating areas and how a positive attitude was created with a moderate seating density rather than a high seating density. It was researched how people perceive crowding. In shopping malls a more positive feeling is achieved, when a positive atmosphere is created (Baker et al. 1994). Less density or average density is created with less furniture in a room. This means that less crowdedness can give a more positive attitude towards customers and as a positive result they spend more money and stay longer. Also gender seems to

make a difference. Male and female have different perception towards crowding. Male in general are more flexible towards overcrowding than female. Women, however, are more sensitive for tidiness and other aesthetic factors when entering a room for the first time (Yildirim et al, 2007). Factors contributing to the perception of crowdedness are among others: amount of available space in the room, visual exposure, structural depth, openness, brightness and view. All of these mentioned factors have a huge influence on the human behaviour and should therefore be considered before an interior design plan is created.

The following section elaborates more on the influence of the difference in target groups in the designer choice of interior.

3.7.2.3 Meeting with the needs of the target audience

In a study from Yavas and Babakus (2005) it was stated that leisure travellers' choice of hotels, compared to business travellers' choice of hotels, are very different. Apparently the needs for people on holiday are very different then for people on a business trip. When on holiday people seek comfortable, clean hotel rooms on a very easy distance from for example the city centre, whereas business travels first priority is Internet and computer access in the room, express check in, quietness and convenient location. Both leisure and business travellers find cleanliness and location top priority when it comes to find a proper hotel (Knutson, 1988). Same conclusion can be stated for hotel design as for restaurant or café design, customers' first impression of a room is determinative for a customers' comfortable feeling and depends therefore very much on the quality of aesthetic factors.

Similar to a hotel designer, the designers of mega yachts should take the importance of the differences in design approach, for different target groups, into consideration too (Avery & Jackson, 2008). Questions may vary from: 'Is the yacht privately owned' or; 'is the yacht meant for charter?' and 'is the owner going to use the yacht for pleasure or business?' etc. The target group needs determine the features of the interior design, layout and other key factors. The first impression of the customers lies within the satisfaction of the aesthetics in the design. The next section elaborates

more on the importance of aesthetics as key factor to comfort and wellbeing. In this section 'colour' is discussed in relation to behaviour changes and emotions.

3.7.2.4 Human comfort and colour

Little research is done on one of the most used and important aesthetic key factors: colour, and the effect of colour on the human emotional behaviour, for example when entering a room in a café, restaurant or store (Yildirim et al, 2007) and (Yildirim & Akalin-Baskaya, 2007). This is in contrast with the numerous testing that has been carried out in other ambient factors like: type of music, lighting and design factors like the layout of the restaurant/store and the effect on the human emotional behaviour (Kotler, 1973). This section reviews studies in effects of human emotions and behavioural changes as a result of different room colour used. The section concludes on review of a study concerned with the effects of colour.

In a recent study of Yildirim et al (2007), the effect of indoor colour use and the human emotion were shown. The relationship of colour in combination with the gender type and age were showed to make a difference in shopping and spending behaviour of customers in the restaurant or store. The study researched different relationships between colour and other objects in the room. His results showed amongst others that the colour violet seems to have a more positive and calming effect on customers' behaviour in a café in Istanbul than the colour yellow, other researchers, however, have concluded that the colour yellow has a remarkable positive effect on customers in a library for example. The relation of colour and its environment therefore can be concluded depend on many different factors, like location, amount of natural sunlight and target group etc.

A lot of confusion is created by researching colour on the effect on human emotions because of the many different results. Colours are often associated with memories; a particular period in your life or in history or colours can have a positive effect on the healing process of patients etc. The colour yellow for example causes quite a stir: yellow is often associated with suicidal patients, for example in paintings like van Gogh (Yildirim et al, 2007 and Porter, 1997). However, according to a study by

Jennings (2010) who wrote an article on the positive effects of the yellow colour on seasickness. Jennings (2010) used the advice of a colour therapist and explained the psychological effects of different colours in the interior and believes in the positive effects of yellow colours in order to prevent nausea and seasickness rather than using pills or other drugs to prevent getting sick. His research, however, is not sufficient; the positive use of colour in a room depends on many other factors like, countries climate, culture, target group, age gender, but also the colour yellow for instance has many spectrums, variation can occur from almost orange to bright white-yellow colours etc. (Dube & Morgan, 1996). The colour used in one space, can be of negative influence in another due to many different factors.

In other studies the effects of colour has been tested on humans' performance, motivation, mood, satisfaction and the urge to buy products. It was found out that in general it can be said that cold blue colours have a calming effect on people, where as warm red colours have the opposite effect and can even trigger claustrophobic feelings as red colours seems to make the walls come closer and make the blood temperature raise (Stone, 2003), even so can be said that colours in the blue spectrum create a more spacious effect than colours in the red spectrum (Canter, 1974).

When researching the use of colour in a room and its effect on the human emotion and comfort, many different results were shown. The effects of colour in a room need therefore be considered individually in every case because of its individual nature. The next section critically reviews the functionality and usability of the design approach in the car design industry and their approach to human factors.

3.7.2.5 Illumination levels for hotels, housing and passenger ships

This section analyses the recommended illumination levels for both hotel and housing areas compared to the recommended illumination levels for on board passenger ships. The highest level of illumination possible: sunlight is for example about 100.000 lux on a bright day. Inside the building, in the area closest to windows, the light level may be reduced to approximately 1,000 lux. In the middle area it's may be as low as 25-50 lux. Additional lighting equipment is often

necessary to compensate the low levels. The level of ambient light in which we are feeling comfortable depends mainly on the activity carried out in the room. For example for general office work the luminance comfort level is about 500 lux while the luminance comfort level for a bedroom and a living room is about 50-100 lux. In a comfortable visual environment, users' physiological and psychological needs should be considered. The needs for visual comfort are given as recommended values for illumination levels and luminance. The recommended Illuminance levels for hotels and housings by the CIBSE are compared to the recommended lighting criteria for onboard passenger ships by the ABS (see Table 3-4 and Table 3-5).

Table 3-4 Recommended values for Illumination levels by the CIBSE (1994)

Recommended values for Illumination levels by the CIBSE (1994)		
	Space type	**lux**
Housing	Living room	50-150
	Bedroom	50-100
	Kitchen	150-300
	Bathroom	150
	WC	100
Hotel	Entrance Hall	100
	Reception	300
	Bedrooms	50-100
	Bathrooms	100

Table 3-5 Recommended luminance levels by the ABS passenger comfort on ships (2001)

Recommended values for illumination levels by the ABS passenger comfort on ships (2001)		
	Space type	lux
Accommodation: passenger	Living room general area	300
	Dining room	300
	Fine Dining	100
	Staircases, interior walkways	110 (215)
	Corridors, Access ways	110 (215)
	Guest cabins	Min 150, var 150-540
	Living spaces in the guest cabins	150
	WC	150
	Bathroom	325
	Cinema	1-100 lux
	Embarkation area	200

It is remarkable that most levels for the passenger areas on board ships are significantly higher than for Hotel and Housing areas:

- Living spaces on board 300 lux and living spaces for housings 50-150 lux
- Bathroom on board 325 lux and bathroom in hotels 100 lux, bathroom for housing 150 lux
- Toilet on board 150 lux and toilet housing 100 lux

Lux levels for on board passenger areas are almost 3 times as high as lux levels at home or in hotels. The reason for these differences, between the horeca and passenger ship illuminance levels, is unknown, although they could be explained by the higher safety requirements necessary on board passenger ships. More research is needed on comfort in use for crew and passengers on board ships as lux levels on board could have a huge effect on the visual perception and thus comfort of the people on board.

3.8 Interior Car design approach and human factors

'On a vehicle, a seat and often controls (more or less related to hand tools) are found among other elements that influence comfort, such as view, climate, noise and vibration. This complicates the decision on how to improve the comfort in a vehicle interior. The theory of comfort and discomfort in seating and using hand tools does not give enough support to make a decision on how an ideal comfortable interior should be designed' (Vink & de Looze, 2008).

Ergonomics is one of most studied and researched areas in the car design industry. However, when studying ergonomics, good ergonomic designed seating and car cabin interiors do not automatically mean they are comfortable. According to Vink and de Looze (2008), comfortable seating involves more factors than just ergonomics. More analysis is needed to discover what comfort in vehicle design actually mean. According to Slater (1985) comfort is a '*pleasant state of physiological, psychological and physical harmony between a human being and his environment*'. He describes the meaning of the word comfort as a harmony between not only technical factors but also harmony between human factors, such as the

ergonomics and aesthetics. In order to feel comfort, all factors must be equally balanced.

This section critically reviews the functionality, usability and human factors approach to design as used in the car design industry.

3.8.1 Functionality and usability

In the car design industry many research studies have been done over the past in searching for the perfect balance between customers' satisfaction, good ergonomics and the technical aspects and functionality of a car (Jindo & Hirasago, 1997). In the car design industry, the functionality of the car seemed rather more important than the human factors, such as good ergonomics and aesthetics. Once the functionality of the car seems fulfilled, the customer seeks after good ergonomics and aesthetics (You et al, 2006). However, the focus of interest seems to have shifted over the years. In the car design industry the following satisfactory factors are being assessed: shininess, slipperiness, softness, brightness, saturation, hue, embossing etc. The materials of the individual parts in the interior of the car are of equal importance: steering wheel, gearbox, chairs etc. Most car customers tend to judge the interior of a car based on its very comfortable settings and simplified readable speedometers (Jindo & Hirasago, 1997). Not only have they stated that most car customers have a propensity to choose a luxury interior over performance, Ryu et al (2003) even so researched that most car customers now have a tendency to choose luxury and comfort over performance and even over functionality.

Not only luxury appearance of the car interior matters, but also the correct material is important. The type of material seems to be a very important buying factor for the customer. Specially developed 'material models' show two important factors for the customer to consider when choosing the correct material for the interior of their car;

1. The visual comfort factor; comfort of the eye that meets with something the client desires,
2. The tactile comfort factor; which means comfort of touch (for example soft and smooth surfaces or fabrics) (Ryu et al, 2003)

This section elaborated on the fact that not just only in the mega yacht design industry luxury is often chosen as key element towards comfort above performance and functionality, also in the Car Design Industry, luxury seems to be the most important buying factor. This section reviewed several studies that demonstrated the importance of good cooperation between designer and architect in order to meet with the needs of their target audience. The studies illustrated that in order to satisfy the customers, the designers should not just focus on the functionality and usability of an interior but moreover treat all the key factors to comfort in design as equally important: functionality, usability and aesthetics are all key factors to comfort in design. Different human orientated design approaches to interior car design is reviewed in the following.

3.8.2 An Human factors' approach to car design

At a human physical comfort conference in Leeds University it was addressed that; however, comfort is immeasurable, isolating small section of comfort and investigate these, can bring solution. For example comfortable seating in cars can be tested by research in the parameters of the type of textile used (Institute, 1983), namely seating comfort and type of fabric used are very much related to each other. The fabric used for car seats need to offer certain parameters like; thermal comfort and tactile comfort. Thermal comfort contributes to comfortable seating; prevent the seat from heating up too much by the body temperature or sunlight, even so can be said that tactile comfort relates to mechanical comfort; examples that can be given are steering wheels and gearboxes and other equipment used in car cabins. In order to understand the human emotion on these comfort factors, the best thing to do is to analyse these factors independently from one another (Slater,1985).

Previous examples show that a more human factors and customer's orientated approach to car development has proven to be successful. Many successful industrial designers from the automotive industries in Japan like: Toyota and Honda already use a human orientated design approach for their design industries. One popular human orientated design approach is called; 'Kansei' ergonomics, Kansei is a Japanese term for expressing customers' psychological feelings, needs and desires (Nagamachi, 2002). Kansai engineering is human orientated computer software invented in 1970 by Mitsuo Nagamachi that can translate humans' desires and psychological feelings for a product into technological parameters. This helps the design process of a product. Human orientated approach to product design is of paramount importance to the designer on the long term. When developing a new product, the company's main aim is to focus on the psychological needs and desires of the customer, before the technical department researches the possibilities of this design. The Japanese use human orientated design in most of their product design services like: landscape design, in house design etc., and has been proven highly successful (Nagamachi, 2002) and (Yoshimura & Papalambros, 2004).

Another good example of successful human orientated design is the 'concept centred process for product development' by Kelley and Littman (2001). This concept is based on the costumers needs, instead of the technology approach to product design development, like Kansei engineering. Kelly's process does not make use of an existing product. This approach does not work for the mass produced industries, as most mass products are a derivative of an already existing product (Carson & Steller, 2000).

This section has demonstrated that a human orientated design approach in interior car design is successful and adopted worldwide by other product design industries. The next section reviews the human factors methods in the interior train design industry.

3.9 Human factors and interior design of train approach

In this section the primary function of trains are discussed in order to find the correct key elements to design. The functionality and usability of the design approach in interior design of trains, as well as the human factors approach, are reviewed. Train companies have to deal with great antagonisms; on one hand the train needs to carry as much passengers as possible, which costs a lot space, and on the other hand in order to let the passengers return on public transport, personal space requirements need to be applied.

3.9.1 Functionality and usability

The primary function of a train is to transport passengers from A to B, comparable to other commercial transportation industries like; ferries and airplanes. Train companies, however, are also economically driven; they want the passengers to come back and choose the train above not only other commercial transportation industries but importantly: above cars. In order to make the passengers choose for public transport they need to satisfy the passenger on the short trips as well as on the longer trips by increasing the pleasure and comfort factors. While the comfort and pleasure factors are important for the train passengers; safety design is the first priority to fulfil. Design of interiors of trains depends on many factors like, destination, route, time to destination etc.

A lot of research have been carried out on interior design on trains for safety purposes as well as increase for comfort levels of passengers (Ilkaer & Lind, 2001). Adjusting train interior design such as, headrests at seats, adjusting table design and adjusting the heights of the luggage compartments etc. can mitigate injuries occurring on trains. Most train companies deal with the two big contradictory issues: space and economics. On one hand the train needs to carry as much passengers as possible in order to make profit, and on the other hand they need to secure the safety and comfort of the passengers during their train journey. However, in order to feel

comfortable and safe on long journeys, enough personal space is required, which seems to be impossible on trains during rush hours. Studies have showed that discomfort on trains is more likely to be caused by lack of personal space than ergonomically well designed train seating (Evans & Wener, 2007).

3.9.2 An human factors' approach to interior train design

The most researched area in human orientated train design is on comfort of train passengers in relation to personal space. Personal space or personal distance stands for the flexibility and safety zone that is maintained around the human body. Personal distance in public areas has an enormous impact on the behaviour of people (Garcia de Arboleya & Riola, 2006). Comfort in personal space depends on factors like: location, walking speed, personality, gender etc. (Gerin-Lajoie et al, 2008). The 4 types of personal space distances were previously presented in 3.6.2.5; comfort on board and personal space. Recent studies have carried out by Cornell University in New York, (Evans & Wener, 2007), concerned with personal space invasion on trains; It was found that even in brand new trains, with bigger seats, passengers still did not feel comfortable, due to personal space invasion; the seats in the middle were kept empty (Mc Greeham, 2005). Other research studies in seating comfort of passengers on high-speed trains found out that 90% of the passengers have a strong preference facing the same moving direction of the train, which complicates the interior design seating plans (Han, et al, 1998), (Jung et al, 1998). The difficulties, namely, for all commercial passenger transport design is; the combination of the companies' economical interest to optimise the transport of passengers and transport as much passengers as possible, and at the same time provide enough comfort space to the passengers. These two conflicting needs challenge the interior design of trains.

The aim of the train design industry is to persuade passengers to choose for public transport, the train design companies need to satisfy the passenger on the short trips as well as on the long trips by increasing the most important comfort factor for this

industry; personal space. The next section reviews the interior design industry of airplanes and their human factor approach to interior design.

3.10 Interior airplane design and human factors

An aircraft interior is designed not only to meet the requirements of the Federal Aviation Administration/European Safety Agencies (FAA/ EASA), but also to meet the requirements of the manufacturers, passengers and crew. This section critically reviews the functionality, usability and human factors approach toward design as used in the interior airplane design industry.

3.10.1 Functionality and usability

As well as in the train design industry, the industrial designer of airplane cabins struggle with huge contradictions; the problem is to increase the amount of passengers on board without reducing the comfort. The general comfort of passengers on board depends on dynamic factors, physical environment, psychological factors and design, and gender. The design of airplane cabins is very much restricted and limited by technical factors, economics, space, weight and standard aviation (Hadibroto, 1992). The designers of interiors of airplanes face a challenge to create personal space while meeting other requirements such as the ergonomic and safety on aircraft chair design, ventilation, light and air, the layout as well as various visual aspects. Human comfort problems on airplanes that interior designers and architects face are amongst others: pressure in your ears when taking off and landing, stiffness, tight chairs with little leg room and problems with your blood circulation. One of the key factors towards human comfort design in the airplane interior design industry lies within the seating design. The challenge is to bring the seating weight to a minimum; considering the constantly rising fuel prices, airliners need to reduce their weight of the interior to be able to reduce carbon consumption.

The challenge is to reduce the seating weight and at the same time optimize seat ergonomics and increase their carrying capacity while meeting with legal restrictions. Create maximum passenger comfort with minimum space available. It might happen that a flight last up to 24 hours. This is a relatively long flight time considered that most passengers are not able to leave the cabin. Same as for the train industry, the main objective of any airline is to transport as many people as possible to their destinations in one single flight. In the meantime airlines need to focus on one of the most essential key factors of air travel, and that is to guarantee passenger safety and comfort.

The comforts of ergonomics of airplane seats have been studied numerously. Most general comfort problems not only depend on the type of flight as well as on flight time and factors like cultural differences, direct physical factors; leg space, cropped feeling, stiff neck etc. (Vink & de Looze, 2008), (Hadibroto, 1992). The seating comforts of passenger seat on airplanes are tested on both static level and dynamic level. Static levels are levels when the person in the chair is sitting still and where the physical parameters of the seat interact with the person in the seat. Dynamic level is the level when the person moves in the seat in order to carry out some tasks, likes; eating, drinking or grab something. Static factors but also, dynamic factors of the flight, like acceleration, pitch need to be taken into consideration in the interior design. Compared to the shipping industry, dynamic factors are more related to location and the actual time passengers and crew spend on board that it is in the airplane industry. Seating comfort on a dynamic level on board a ship depends very much on the sea conditions at the very moment in combination with the location; river, canals, ocean, tide, swell, squat etc. In the same time it can be said that passengers and crew spend more time on board a ship than on an airplane. Dynamic factors, both for the aero industry as for the shipping industry, however, are not always predictable and this should be taken into account before the interior design is created. A more human orientated approach is needed.

3.10.2 An human factors' approach to airplane design

Soizick and Christian Bastien (2008) have developed a methodology to explicit dimension of comfort. Their methodology approach towards product design is based upon measurements, analysis and test towards comfort. According to them there are 11 dimensions in comfort (Fig. 14), namely:

1. Dimensional comfort
2. Comfort of use,
3. Tactile comfort (perceived comfort in terms contact pressure; contact between an object and the body.)
4. Postural dimensions,
5. Comfort in the interactions,
6. Eco design
7. Choice of materials,
8. Sensory comfort
9. Vibratory comfort,
10. Hydrothermal (concerns with the temperature and the humidity that the seat sends back), but also,
11. Physical ambient comfort

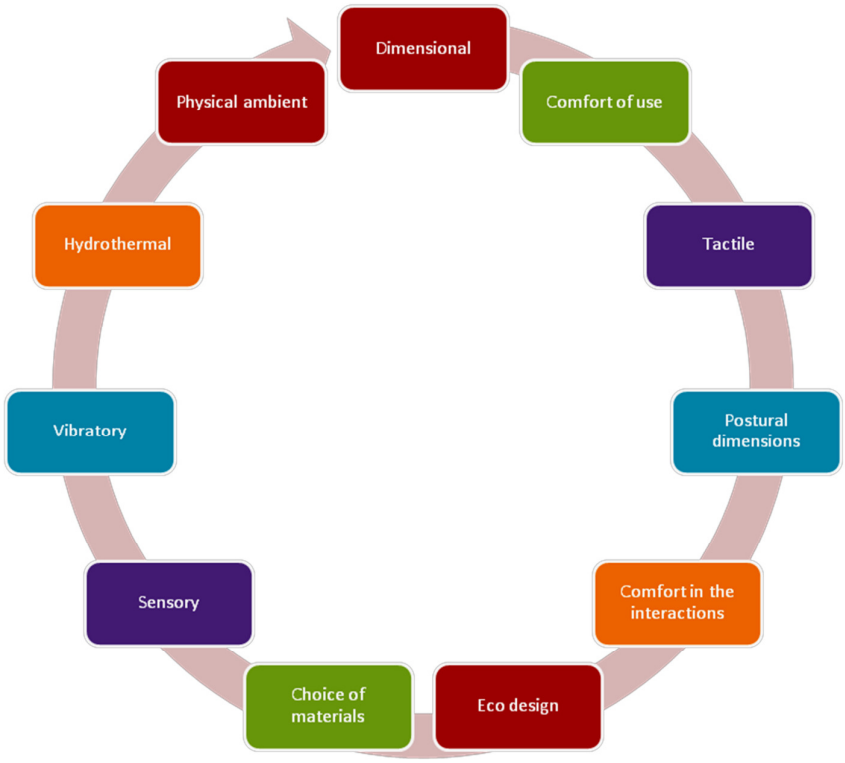


Fig. 14 Comfort dimensions (Soizick & Christian Bastien, 2008);

Fig. 14 shows the wheel of comfort dimensions (Soizick & Christian Bastien, 2008), as used for testing comfort levels in product design. They explain that the first comfort dimension; dimensional comfort, is one of the most important comfort dimensions, namely; comfort starts with freedom in movement and dimensions. Dimensional comfort has changed throughout history as the anthropometric of the human body changes. Ergonomic and anthropometrical parameters create the foundation of dimensional comfort. The second dimension is comfort of use, which means the usability of the room or product, task and use analysis. Tactile comfort is the third dimensions; the perceived comfort in terms of contact pressure; contact between an object and the body that only can be measured by means of pressure sensors or either by interviews from the users themselves. The fourth dimension is postural dimensions that focus on the anthropometric and ergonomic guidelines for comfort in body posture. The fifth dimension; comfort of interaction has to do with how the product interacts with the person and if this is comfortable enough, understandable and simplicity in use etc.

The sixth dimension is concerned with ergonomics but from the product point of view; ecological design, concentrates on sustainability of the product whereas material comfort, the seventh dimension, concentrates on the type of fabric or product material. For example: comfort in material use in order to avoid allergic reactions, anti-bacterial, easy maintenance etc. The eighth and ninth dimension are sensory and vibratory comfort, of which sensory comfort is comfort of the senses including visual comfort, comfort of sounds, body temperature, climate, smell, touch etc. The tenth dimension concentrates on hydrothermal comfort; the humidity and temperature used products send back. Finally the last dimension is the dimension of the physical ambient that concentrates on the environment; temperature, climate, daylight, artificial light etc. All 11-comfort dimensions idealistically should be in harmony with each other.

Several tests pointed out that *postural comfort* is one of the most important types of comfort when it comes to passenger comfort in airplane seats. Their aim in this test was to develop an ergonomic guide for passenger seats on airplanes to provide more comfort. However, postural comfort was tested as one of the most important types of comfort; other studies demonstrate that the psychological assessment of comfort is more important than the technical assessment towards comfort (Kleeman, 1983). Several tests showed two exact identical designed chairs, the difference between the two chairs was choice of fabric and colour. When the passengers were asked to name their favourite chair, they stated that the chair with the bright colour and the soft feeling fabric was more comfortable than the other chair. It can be said that; Peoples first impression influences the feeling of comfort. Most people are very sensitive for style and colour used. Aesthetics wins choice above all other parameters to comfort, like ergonomics and practicality (Kleeman, 1983). Emotion and pleasure are both pleasurable parameters and seems to satisfy the customers 'needs'. Comfort must be tested for both sociological and psychological factors (Jordan, 1998). However, chair design needs to be both technically as aesthetically comfortable in order to meet up with the expectations and needs of the passengers.

In this section it was reviewed that *discomfort* does not automatically mean *comfort*. People are in a state of discomfort when there are in direct physical pains and aches, caused for example by long periods of seating or postural discomfort. Comfort is a state of overall wellbeing and comfort means that all types of comfort are being achieved; technically, aesthetically and physically (Helander & Zhang, 1997) and (Zang et al, 1996).

3.11 Chapter Summary

In this chapter, the Critical Review of this MPhil thesis has been shown. This section summarises the Critical Review. The primary aim of this study is to analyse if human elements can be merged into the approach of mega yacht concept design. The general design philosophy, as used in the product design industry, was adopted and the key factors towards human orientated interior design have been identified. Thereafter it is analysed how these key elements towards human orientated design are applied within other interior design industries, namely; general ship building, cruise ship, horeca, automotive, train and in the aero industry in order to identify their approach to design and providing the necessary key elements to design. The Critical Review is concerned with the human needs and design approaches to mega yacht interior design in the first concept design stage; preliminary design methods. The above is performed in order to obtain a clear insight of the key elements toward human orientated design so as to identify the gaps in the preliminary mega yacht design industry and as to develop, modify and propose improved solutions by presenting a new concept design approach for mega yachts.

4 FIELD STUDY

4.1 Chapter outline

In this chapter a Field Study to human orientated mega yacht design was carried out and the results of the interviews with professional naval architects, shipbuilders and interior designers who are involved in the Mega Yacht Industry are presented. This Field Study serves as background research before the thesis 'strategy can commence, in addition to answer the research question: '*Can human elements be merged into the concept design stage of mega yacht design, in place of the final stage?'*

4.2 The interviews

Not only does poor cooperation between naval architects, interior designer and the customer reflect in the efficiency of the design process, but also more importantly, it directly affects the quality of the end product. In numerous studies the human element is addressed as one of the key elements to ship design. In a study by Lloyds register, Walker (2011) mentioned that the triple S defines the traditional approach to shipbuilding, namely: Speed, Stability and Strength. However, Payne and Siohan (2008) also addressed the importance of comfortable yacht structures, as well as the key element to success is good team work and a good management to have design plan early in the design stage. Not only the emotional state of humans can be influenced by the change of the key elements to design, as has been analysed in the Critical Review, but more over key human elements to design can change your state of wellbeing.

To evaluate if the implementation of human elements into ship concept design is effective, experienced naval architects and designers were interviewed both one to

one as to test the possibilities to the human centred mega yacht design approach. As this thesis aims to research the possibility of implementing the human factors elements into the basic mega yacht ship design phase, the outcomes of the interviews presented in this chapter helps to gain understanding and knowledge required to design a framework that shows how to implement human elements in an early design stage

In this section different experts who are involved in the industry of mega yacht design and yacht building were asked several questions in one to one interviews about their experiences in their field with human orientated design. The below presents a list with key questions that were asked in the interviews (Fig. 15):

I. *Could human factor related problems be avoided by implementing the human elements into an early stage of design instead of in the final phase?*

II. *Are there problems with the communication of the interior designer and naval architect?*
   - *Do you have experienced any problems concerning this subject?*
   - *Please can you tell me if there are more problems that the industry can focus on in future research?*

Field study			
Company name	**Type of company**	**Research question: 'Can human elements be implemented in the preliminary mega yacht design stage?'**	**Are there problems between the Naval Architect and the Interior Designer?**
Lloyds Register	Classification Agency mega yacht expert	yes	yes
Hyun Seok Kim	(Yacht) Designer	yes	yes
Francis Design	Naval Architect	yes	yes
Vripack	Yacht design	yes	yes

Fig. 15 Overview of the two key questions asked in the interviews with the four different companies as part of the Field Study

4.2.1 Interview with a classification society

This section presents a summary with a mega yacht expert of Lloyds register. In an online interview with the mega yacht expert from Lloyds in October 2011, who manages the classifications for mega yachts owners, the main question was asked if the industry could possibly avoid these problems presented above by implementing the human elements into an early stage of design instead of in the final phase. Lloyd register explained that most of these problems, due to the missing human elements, are caused by the fact that aesthetics are prioritised above the quality of human elements. Most owners want their ship to be beautiful in order to boost their ego, rather that functionality or usability of the yachts and its interior. Lloyd's expert in mega yacht classification confirms this and explains that they try to avoid such problems by having regular meetings during the basic design stage of the Mega yacht-building project. In this way the classification societies, who are experienced in the do and don'ts of the mega yacht industry, can guide their customers to the right direction in order to avoid problems in the future. For the full interview, see the Appendices.

'Have Kick off meetings during the pre-contract design stage with all parties involved' (Lloyds, 2011).

4.2.2 Interview with a mega yacht designer

This section presents a summary of interview with Hyun Seok Kim. Hyun Seok Kim is a yacht and car designer from South Korea and was trained as a mechanical engineer and studied product management and research. Kim won the Millennium Yacht Design Award 2011 - Section B: Dream Boat (Kim, 2011). In an interview with Kim following with his design theory on his mega yacht Voronoi (see case study chapter, interior lay out); Kim explained that comfort means something totally different for the naval architect than for the designer. The naval architects out the

technical parameters of comfort whereas a designer tend to focus on psychological comfort, however, sometimes they argue each other to reach different goals.

Kim's key elements to human orientated design:

- Ideal is to have the exterior designer, interior designer and naval architect be the one and the same person; in this case more creativity is researched and less limitations are restricted with no conflicts
- Design should stimulate the owner's dream: dreams-can-come-true
- Engineers need to open their mind more on the possibilities of unique new designs, and should overcome their fears with classic designs and try to reach less to the old and easy, already proven designs
- When there are unlimited financial resources available in the mega yacht design, engineers do have the means to investigate new possibilities:
  'Pioneering always takes more money for verification'
- Mega yacht and cruise ships could consider less crew and an equal number of less guests on board (as to avoid decrease in service), as a solution to the crammed small spaces as seen in design lay outs today. Kim points out to the mega yacht X' lay out, from the case study. Alternatively the layout need more space per person onboard to avoid a decrease in service by cutting crew members.
- Technology currently supports so many areas; less crews, compact engines, alternative energy; there is a possibility for a better deck lay out as well

For the full interview with yacht designer Hyun-Seok Kim, see Appendices A.

4.2.3 Interview with a shipbuilder

This section presents the summary of the interview with a small Shipyard and Shipbuilder in the Netherlands; Woudsend B.V.

In a short interview with Mr Durk H Douma, an experienced employee of the company Kuipers Woudsend B.V. and Ship Yard and Shipbuilder Woudsend B.V. Douma (Douma, 2011) points out the problems the yachting industry faces with regards to the high demands of the owner. Many small shipyards go bankrupt due to high claims after the delivery stage of the yacht. This can occur when owners are not completely satisfied with the results and are not willing to pay for the adjustments. The shipbuilders tend to give the customers what they want because of all the bills they still need to pay. He underlines the importance for the shipbuilders and designers that tend to do whatever the customer wants them to do:

'*It is of absolute paramount importance that you do not relinquish the control of the design to the customer. A lot of problems occur due to the fact that the builder and the owner are not equals in partners; the owner is much more fortunate than the builder.'*

Most owners want something unique and that's the reason that a lot of small shipyards go bankrupt, as they did not have had any chance to eliminate small problems like the large shipyards as Oceanco have faced many years ago. The large shipyards have developed a successful series production in charter yachts or private yacht and working this way most problems have already been recognised and dealt with during the first series.

Due to the enormous amount of money involved in the mega yacht industry, it is appealing to many shipyards and designers to give it a try, unfortunately many will fail and underestimate the challenges and uniqueness of the yacht. One of Douma's experiences with a large sail yacht designer was that he pointed out to him that although he was very experienced with the high demands of customers, he was still surprised about the strange requirements they tried to ask him. He concludes with the phrase:

'The Mega yacht ship design industry is an extremely difficult market where only a few are successful'

4.2.4 Interview with a naval architect

This section presents a summary of the interview with Martin Francis. Martin Francis is highly regarded and a very experienced naval architect and interior yacht designer, who was trained as a naval architect: (Francis, 2011). On the 16th of March 2009 I had the privilege of a telephone interview with Martin Francis. Francis is the owner of the company Francis Design and has a great record of cruise ships and mega yachts designs on his name including the Oasis of the Royal Caribbean, and Special Mega yacht 'A', as will be discussed in the case study later in this thesis. Philippe Starck and Martin Francis designed Mega yacht A. Phillipe Starck is a product designer, interior designer and architect. Mega yacht A is owned by a Russian billionaire named Andrei Melnichenko. In this interview I asked Martin Francis about his experience in cooperation with product designer Phillipe Starck during this special project and what problems they faced as a result of their different backgrounds and approach to interior design. Martin Francis explained to me that a product designer is not aware of the extreme sea keeping conditions the ship has to survive in and that their difference in design approach causes somewhat of a problem. As Martin Francis is a naval architect and yacht designer at the same time, he believes that when the exterior, interior and hull designer are within the same company, or even better are one and the same person, this has enormous benefits for the overall design. Problems can be solved immediately and the designers within the different expertise groups understand the limitations of the yacht.

As of Francis' experience in both cruise ship design and mega yacht design, I asked him to explain if there were any major differences in the design approach between those two.

According Francis the key differences between cruise ship design and mega yacht design are:

- **Limitation, Rules and Aesthetics**: A mega yacht is built with aesthetics as her main priority. Rules and regulations for more than 12 passengers, when the yacht

needs to be regulated, as a Passenger ship is therefore a problem. For example the lifeboat rules and regulation are not in line with the aesthetics the owner wants to create. More aesthetics problems do occur during the follow up these regulations

- **Limitations on accommodation space:** On a mega yacht there is more accommodation space per person available than on a cruise ship and when the rules and regulations are followed up for a yacht that has 12 persons or less, there are fewer limitations than when designing a cruise Ship

- **More Budget**: There is more budget available when building and designing a mega yacht

As Francis underlines that the aesthetics of the yacht interior is more important than anything else, as far as the owner is concerned this is in agreement with the interview with the classification agency Lloyds Agency and mega yacht expert answers from the previous sections. Lloyds explained their problematic experience due to lack of human elements. Most problems occur as a result of misplaced priorities such as aesthetics before functionality and usability. Lloyds try to solve this problem by having this discussed in their kick off meetings, even so they lead a special project named 'Alert' in order to restore human factors and implement these in the rules and regulations in the future to avoid problems (Lloyds, 2003). Also Francis believes prioritising the aesthetics can lead to problems, and these can be solved by having the design lead by one and the same person. This means exterior hull designer is the interior designer at the same time. A full interview can be read in the Appendix A.

4.2.5 Interview with a mega yacht design company

This section summarizes the interview with Vripack; an experienced and large yacht Design Company from the Netherlands. A teleconference meeting was held with the naval architect and yacht designer Mr Bouwhuis on the 2nd of December 2011, concerning the key elements to human orientated design. Mr Bouwhuis is a

professional yacht designer, engineer, naval architect and broker working for Vripack, a yacht design company located in Sneek, The Netherlands and in New York, USA. I asked what according to him is important towards human orientated interior design.

Key elements to human orientated interior design:

- Don't underestimate the importance of good service routing on board the yacht. The layout design of the yacht is therefore of the utmost importance and should be considered and analysed carefully during the basic ship design stage

- Take the importance of maintenance into account already in the basic yacht design stage as expensive modern shiny surfaces or heavenly 3D-patterned decor can lead to impossible maintenance problems for the crew during the life of the yacht

- Raise awareness to the importance of human orientated design to both the customers as to the naval architects as this is just a topic that most designers are not familiar with at all

- Favourably the naval architect and the designers should work for the same company as to avoid important errors and speed up communication and the overall understanding of the design, as internal and external design, technical and human factors cannot be seen as a separate task or project

For the full interview with Vripack, see Appendix A.

4.3 Results and conclusions of the field study

This section presents the conclusion of the outcome of the interviews. The need arises of addressing the human elements in an early stage of the ships life cycle in

order to avoid possible risks for guest, owners and crew on board when the ship is in full service and was confirmed during these interviews. The aim of this study is to contribute to the awareness of the importance of addressing and implementing the human elements in mega yacht ship design, by presenting a framework that shows the key elements to human orientated design and how to implement these human elements into the basic design stage of the yacht. By presenting the possibilities to finding a new way to approach concept design of mega yachts and research the possibilities to merge human elements into mega yacht design, one of the most important outcomes is expected to be an increased inter-discipline understanding and enhance the cooperation of these disciplines. This will contribute to a more efficient design process and a product that exceeds the customer's expectations.

In this chapter, summaries were presented of the interviews with different mega yacht design experts concerning the absence of human elements in mega yacht ship design. Analysing the answers that came of these interviews is that there is a gap in knowledge and more importantly awareness in the importance of addressing human elements in yacht design. They all recognised the human failures in design and the difficulties of this extremely high demanding market. The most important discussion that came out of these interviews is that they all agreed on the fact that is ideal to have both exterior and interior designer, favourably the naval architect, be one and the same person, in this case more creativity is reached and less problems occur.

Other key elements that were addressed during the interviews:

- Design the yacht layout prior to set its dimensions
- Importance of service routing
- Importance of design for easy maintenance
- Keep in mind that the owner and the designers are not equal; the owners are always very fortunate and rich people, who can come away with a gamble; the yards and the designers, however, do not have these luxuries. One mistake and they probably will end up bankrupt. Therefore never relinquish the control of the design to the costumer.

- Have a Kick off meetings in advance with all the parties involved to avoid problems in communication and disappointments in the contract and final design stage of the ship, regards to human factors

- Engineers should make use of the large budget of the owner to research the possibilities in unique designs of mega yachts, instead of aiming for successful series productions

The main conclusion that came out of these interviews is that there is a huge gap in knowledge and awareness to human orientated mega yacht design; this can be confirmed by Walker (2010). Naval architects, designers and Classification Societies need more training in order to recognise the absence of human elements in an early stage and so they can reach out to a human factors' specialist in time.

The next chapter presents a human orientated design framework for mega yachts.

‘*Human behaviour is complex,*

We all experience the environment individually,

each with different experiences, meanings, and values’

(William T. Eberhard, Oliver Design Group, Cleveland)

5 HUMAN ORIENTATED DESIGN FRAMEWORK FOR MEGA YACHTS

5.1 Chapter outline

In the previous chapter, the existing preliminary design approaches as used in various sectors has been researched and critically reviewed. This research has been carried out with the main focus on interior design and human elements and the approach toward human orientated design in order to analyse if they can be integrated into the preliminary design stage of ship design, instead of the final one. The aim to this research is to avoid conflicts in a rather advance stage of the design process. This chapter presents the human orientated design framework for mega yachts. A methodology is presented to achieve the aims and objectives of this research study. An answer is presented to the question why the human elements need to be implemented in the preliminary ship design process followed by a brief summary of the in the critical review identified key elements to human orientated design as they will be the fundamentals of the framework. A strategy framework is accordingly presented in which the process is described.

5.2 Why the human elements need to be implemented in the preliminary mega yacht design process.

What this study analysed is that the many difficulties the mega yacht industry deals with, is not so much situated in the area of expertise of the designers and naval architects and neither with the high demands of its owners, it is more acceptable that the problems occur due to the absence of adopted human elements in the design process, as was demonstrated in the Critical Review. Many believe that by implementing human elements into the earliest design process, most problems can be

avoided in a crucial building stage of the yacht. The adopted preliminary design process of mega yachts is still the same as with merchant ships whereby the interior layout often is designed in the final detailed design process. The first step towards a successful mega yacht interior design process is the acknowledgement that these yachts need a different approach towards ship design than merchant ships, because of its huge difference in eventual purpose: pleasure instead of trade.

Every detail of the ship interior layout depends on the first design and modelling of the ships' outer lines; general arrangements, weight and hull shape etc. All these parameters are related and influence one another. If the general arrangement changes, naturally the interior lay out parameters should change as well. Therefore the preliminary design stage is of paramount importance in order to avoid catastrophic problems in the mega yachts' detail design stage or during the building process. In order to justify why it is necessary to implement the human elements towards the design of the interior lay out in the preliminary mega yacht design stage, a different approach towards the traditional mega yacht design philosophy must be explained.

Most design industries, including the traditional ship design industry, work with Maslow's (1970) philosophy towards design, presented in Fig. 16, where functionality and usability comes before pleasure. However, latest studies demonstrated that Pleasure in the more upper class design industries, like the mega yacht industry, is often chosen over functionality and even usability. Pleasure comes when functionality and usability are addressed together with the aesthetics. This demonstrates that the approach towards preliminary design for these upper class mega yacht industry, need to change as well.

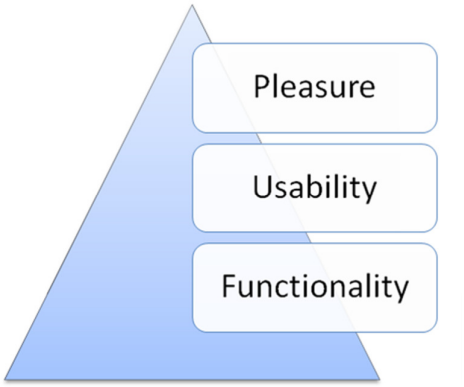


Fig. 16 Hierarchy of needs or design triangle (Maslow, 1970)

As discussed in the Critical Review; the design triangle of Maslow (1970) in Fig. 16 demonstrates that pleasure cannot exist without the product being firstly functional and secondly usable. However, in the mega yacht design industry, the function of the yacht is pleasure and in the same time usability refers to pleasure as well. Therefore it proposed by the author of this thesis that the best way to approach the Maslow's design triangle for the mega yacht industry is to fuse functionality, usability and pleasure together as equally important. This has been demonstrated in Fig. 17; pleasure, functionality and usability are all equally essential to mega yacht design.

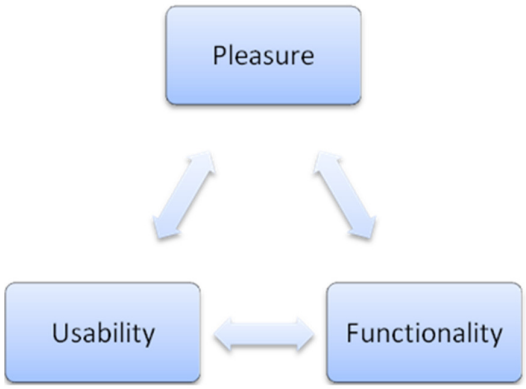


Fig. 17 New proposed mega yacht design triangle of human needs

When demonstrated that pleasure is the main aim for mega yacht owners and therefore equally important to functionality and usability towards interior design, a more human orientated design approach is needed in which the human elements are the base towards a more pleasurable design in which comfort means; not only

functional and usable, but even so pleasurable. The next section presents a short summary of the key elements necessary to human orientated design as previously confirmed in the critical review.

5.3 The identified key elements to human orientated design

A new approach to mega yacht concept design is developed in order to contribute to reduced risk of conflicts between all parties that initially are involved in the design and building process of private mega yachts. The key objective to this aim; to critically review the active ship concept design approaches, in order to identify shortcomings, and provide the necessary key human elements to interior mega yacht design. The human elements, as came out of the Critical Review are accordingly presented in Fig. 18.

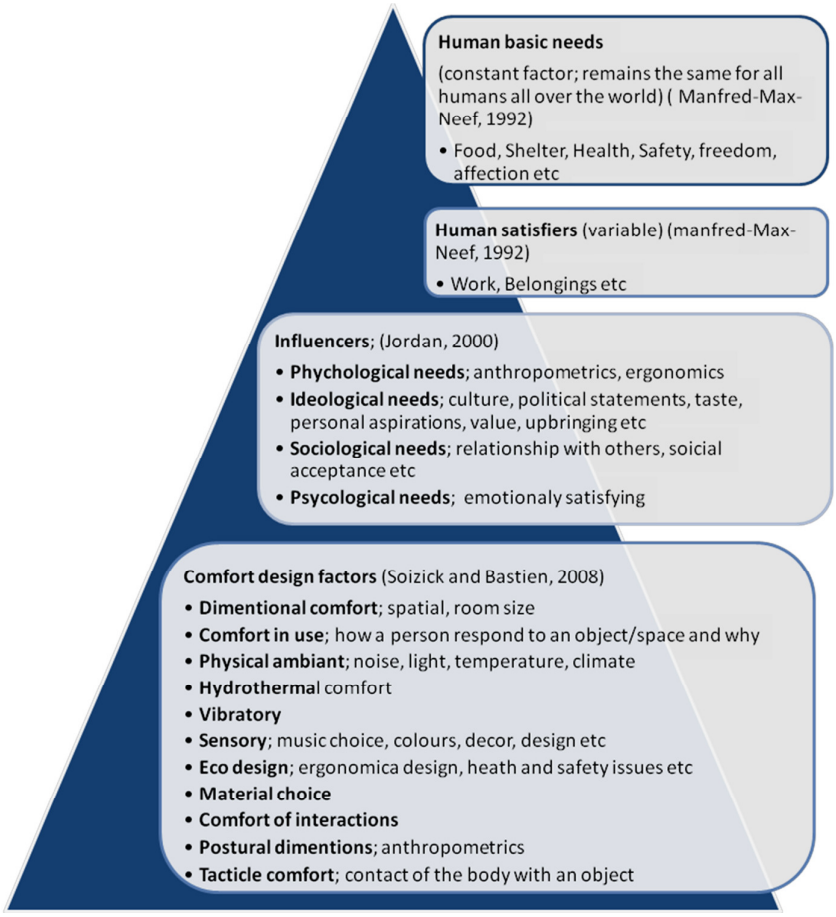


Fig. 18 Pyramid of key factors necessary for Human orientated design

Fig. 18 presents the pyramid of the key elements to human orientated design and its influencers, as was analysed in the critical review. Not only the emotional state of humans can be influenced by the change of the key elements to design but additionally, as reviewed in the previous chapters, these key elements can change your state of wellbeing. In Fig. 18 the top of the pyramid are the human fundamental needs like health and safety. Manfred-Max-Neef (1992) concluded that design is about understanding these human basic needs, which are the same for every person. A good design should primarily accomplish the basic human needs before it can comply with other functions like pleasurable design or status symbol in order to serve its ultimate purpose. Once the basic fundamental needs are satisfied, the human satisfiers come in; more luxury, leisure, belongings etc., as shown in the pyramid underneath the basic needs.

Maslow (1970), described in his study concerned with human orientated design that functionality comes before pleasure, this is not entirely the case, for the reason that according to other researchers such as Jordan (2000), one cannot exist without the other. Functionality does not necessarily create a pleasurable product; neither does comfort (Ekins & Max-Neef, 1992). Jordan developed in his study for product design the four pleasures theory; design of a product is not only about the art of anthropometrics but also about understanding the human social needs and what emotionally satisfies them.

'*A design of a pleasurable product is about implementation of all key factors and understand them really well' (Jordan, 2000)*

In Fig. 18 the four pleasure theory from Jordan comes as third from the top: Influencers to human comfort. Jordan believes that a successful comfortable product depends on not only the person itself, but also on their political statement, upbringing, friends and social status, their health, good ergonomics and psychological wellbeing. All of these factors influence each other and are essential in order to create a successful and comfortable product. To create a successful product the necessity exists to utilize all the key elements of design; one cannot exist without

the other. Soizick and Christian Bastien (2008) developed a methodology in which comfort can be analysed according to 11 dimensions. These 11 dimensions to analyse comfort are adopted in this study. They are significant for the development of a new approach to implement human elements into concept ship design where constant dynamic factors and lateral forces affect the comfortable feeling of passengers and crew on board. The next section demonstrates in a framework how these human elements can be implemented into the mega yacht preliminary design process.

5.4 The framework

Having the above gaps, field study and identified key elements to human orientated design in mind, a framework is presented of how these elements can be implemented into the existing process of mega yacht preliminary design (See Fig. 20). Initially the human orientated design elements need to be considered in the preliminary design process; therefore Fig. 19 presents an adjusted marine ship design spiral for the preliminary design stage of mega yachts, with implementation of the owners' requirements and human orientated interior design.

The overall framework as shown in Fig. 20 of the proposed human orientated design strategy can be employed in the mega yacht design industry and is described and presented in this section, from Fig. 19 and onwards.

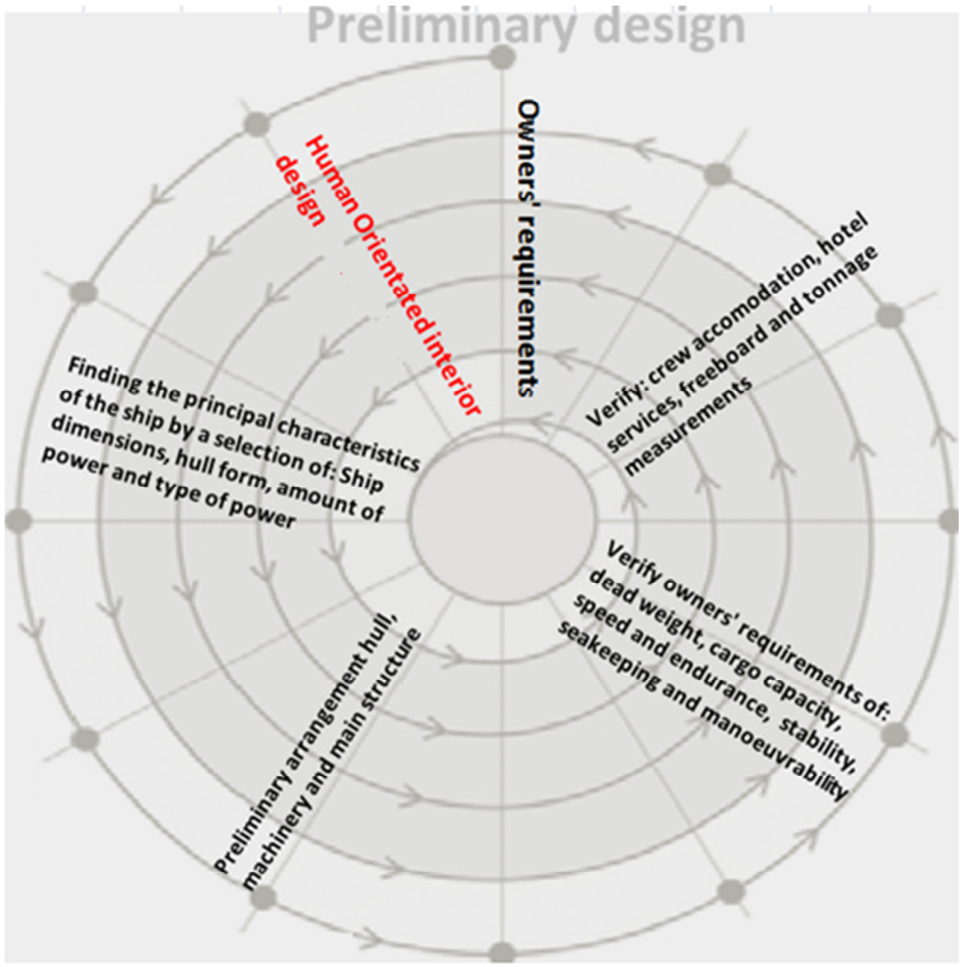


Fig. 19Adjusted marine design spiral showing the preliminary mega yacht design stage, with implemented process of human orientated interior design [See Fig. 20, Framework human orientated design], and owners' requirements [Table 5-2]

5.4.1 The adjusted naval architects ships design spiral

Fig. 19 presents an adjusted version of the marine ship design spiral for the mega yacht design industry. The design spiral adopted for this thesis demonstrates merely the preliminary design stage, with the difference that the process of human orientated interior design is implemented into the preliminary ship design process.

The preliminary design stage for a mega yacht starts with the owners' requirements; ideas of ships 'power, type of ship, lengths, hull form etc. Accordingly, anti-clockwise, the human orientated interior design framework (presented in Fig. 20) is adopted in the preliminary design process. These needs to occur before the overall characteristics of the ship are being finalised, in order to create space for adjustments or suggestions when the customized human orientated design principles for the yacht are analysed. Once the human orientated interior design framework is successfully implemented in the process, the ships' characteristics can be selected; hull form, dimensions, amount and type of ships' power needed. The selections of ships characteristics are followed up by the preliminary arrangement of the hull, machinery and main structure. Accordingly the requirements of the owner with regards to the deadweight, cargo capacity, speed and endurance are verified. The ships stability, sea keeping and manoeuvrability are verified with the owner of the yacht.

After the verification of the sea keeping of the yacht, the crew accommodation, hotel services, freeboard and tonnage measurements are confirmed before the process can commence again with the overall verification of the owners' requirements and Human orientated Interior design in order to make adjustments when necessary.

The main aim of the presented adjusted preliminary design spiral, Fig. 19, is to demonstrate where the human orientated interior design process is implemented into the mega yacht ship design process. The next section presents the actual framework of how to implement the human orientated interior design into the preliminary design stage of the mega yachts ship design process.

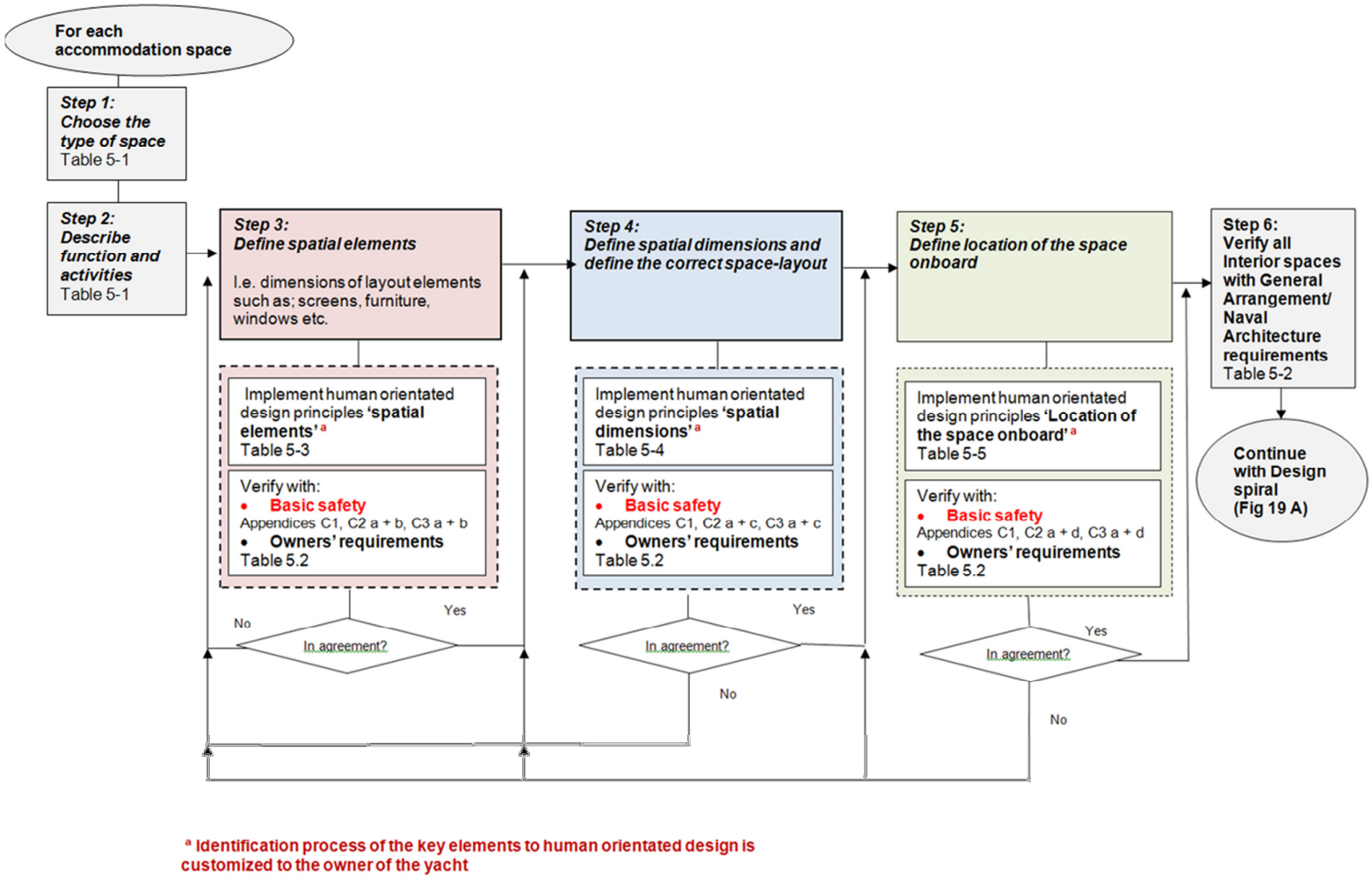


Fig. 20 Framework to human orientated interior design; for implementation into the preliminary mega yacht ships design process (see Fig. 19)

Table 5-1 Example list of the most common passenger accommodation spaces and its related function and activities, on board mega yachts (Step 1 and step 2 of Fig. 20).

Type of space	Function of the space	Related activities
En suite cabins (Time spend varies between: 6-9 hours per day)	Private room for sleeping or resting	Sleeping, bathing , dressing, watching TV, minor work on laptop, small talk and conversation, reading, make telephone calls etc
Living room (Time spend varies between: 0-14 hours per day)	Leisure, lounge room for relaxing and socializing	Relaxing, watch TV/Radio, music, reading, eating/drinking small refreshments, partying, entertaining, making conversations etc
Dining room (Time spend varies between: 1.5-6 hours per day)	Leisure, room for consuming food	Eating, drinking, making conversation, serving guests, etc
Office (Time spend varies between: 1-8 hours at the time)	Work	Manage the administrative activities , organise and store business documents, provide an area for customers, to store equipment, Ships staff-meetings etc
Passenger Corridors and staircases	Purpose: provide access to other rooms onboard the ship and or functions as an emergency exit	Walking from A to B
Cinema (Time spend varies between: 1-3 hours at the time)	Leisure	Leisure: watch a movie, eating/drinking snacks, making small conversations
Spa (Time spend varies between: 1-2 hours at the time)	Leisure	Could facilitate a diversity of Spa treatments: hairdresser, massages, marnicure, sauna, steamroom, jacuzi, facial treatments etc
Gym (Time spend varies between 0.5-1 hours at the time)	Leisure	Variety of GYM activities like: Cardiovascular exercise, body conditioning, weight lifting but also the GYM needs shower facilities , dressingrooms and a place to have a drink and to relax

Table 5-2 Naval architects' (bottom) and owners' requirements (top) to the human orientated design framework

Owners requirements
• Ships' performance requirements: speed, power etc
• Ship's overall dimensions
• Ship's hull form and external aesthetics
• Number of passengers required
• Ships' layout choices and type of spaces required
• Human elements, customized interior design choices

*The naval architect can only review and comment on the human orientated design framework, once all its results are revealed and completed for the whole of the accommodation. The naval architect needs to analyse the ship as a whole in order to verify the below mentioned requirements (also see Fig. 19, naval architects' design spiral with integration of human orientated interior design)

Verify framework human orientated design with the Naval architect's requirements on the following *:
• Ships' hull form and resistance; required propulsion power
• Required machinery space
• Ships' hull form and ships' length (main dimensions)
• Ships' hull form , draft and stability
• Ships' weight distribution and stability
• The in the framework analysed accommodation spaces and the required air- conditioning power
• Ships' hull form and seagoing behaviour
• Ships' hull form and external aesthetics

Note: For both Tables also consider the fire-zones and watertight sub-divisions etc. (See Appendix C: basic safety requirements to preliminary mega yacht design).

Table 5-3 Key human elements and principles for the **spatial elements** (Fig. 20/Step 3) [Parameters for this Table can be found in Appendix B1.1-1.4]

Key human elements for: **Spatial elements**: Interior room layout (layout and dimensions of layout elements such as furniture, windows etc.)		**Principles** Principles to consider when the Interior layout plan of the space is determined, as preparation of the space dimension and layout design and location in relation to the ships layout (Parameters of these principles can be found in the Appendix B1: 1.1-1.4).
1.1 Spatial comfort: comfort in the use of room layout elements in relation to the spatial dimensions of the room and visual comfort	**I. Dimensional:** **Avoid conflict with structure/roominess** **II. Optical:** **a. Visual comfort: Lighting, and daylight needed** **b. Visual balance** **[Creation of balance or harmony] by** 1. Symmetry balance or alignment 2. Asymmetrical balance 3. (Radial) balance: Make use of a central focus point 4. Colour harmony 5. Scale ratio and Visual weight	**I. Dimensional:** - Interactive Furniture layout Using Interior Design Guidelines (Merrell, Schkufza, li, Agrawala, & Koltun, 2011), - Interior graphic standards, (Binggeli, 2012) **II. Optical:** - Physiological and psychological effect of illumination and colour in the Interior environment (Küller, 1986) - Colour in the interior environment (Inui, 1969) - Relationship between colour and emotion: a study of college students (Kaya & Epps, 2004) - Colour emotion associations; Past experience and personal preference (Kaya & Epps, 2004) - Existing theories of colour harmony: (Munsell, 1969); (Nemcsics, 1993) - Evaluation of Visual balance for automated layout (Lok, Feiner, & Ngai, 2004) - Interactive Furniture layout using interior design guidelines (Merrell, Schkufza, li, Agrawala, & Koltun, 2011) - Down size scale for smaller spaces, use the Golden ratio-law: the ratio of the smaller section to the larger section should be the same as that of the larger section to the whole. A universally pleasing proportion in a rectangle is to have the length 1.618 times the width (Berger, 1998) - (Panacentriclimited, 2001-2007), (Ching & Binggeli, 2012)
1.2 Comfort in use	**I.** Traffic patterns **II.** Anthropometrics and ergonomic use; height and usability of equipment's and furniture	**I/II.** - Interior design, visual presentation (Mitton, 2012) - Interior graphic standards, (Binggeli, 2012)
1.3 Sensory comfort	**I.** Noise and vibration	**I.** - Resonance/ furniture related and adjacent walls (location of piano for example) (Acoustics.com, 2004) - Interior graphic standards (Binggeli, 2012) - IMO Noise levels on board ships (IMO, IMO Noise levels onboard ships, 1981)
1.4 Comfort of Interactions	**I.** Personal space /interaction with others, traffic patterns, communication distances	**I.** - Interior graphic standards (Binggeli, 2012)

Table 5-4 Key human elements and principles for the determination of the size and dimensions of the space itself (Fig. 20/Step 4) [Parameters for this Table can be found in Appendix B2.1-2.5]

Key human elements for: Dimension/ layout of the space itself		**Principles** Principles to consider when the space dimensions and layout design is determined in preparation to the choice of the space's location on board (Parameters of these principles can be found in the Appendix B2: 2.1-2.5).
2.1 Personalised space	I. Age II. Gender III. Number of persons IV. Time spend in that space V. Activities carried out in that space	Key elements in order to find the required dimensions of the layout. Personalise space together with ergonomics related principles determine the necessary movements in that space, communication distances needed, circulation paths etc. These principles form the foundation of an activity and space relationship analysis that is necessary to determine the eventual dimension of the space. I-V. - Interior design illustrated (Ching & Binggeli, 2012) - The Universal design File: Designing for people of all ages and abilities (Story, Mueller, & Mace, 1998)
2.2 Ergonomics	I. Postural dimensions of the persons using the space and disabilities	I. - Interior design illustrated (Ching & Binggeli, 2012) - Interior graphic standards (Binggeli, 2012)
2.3 Dimensional or Spatial comfort	I. Ceiling height/personal space II. Amount of daylight/artificial light III. Number and size of windows IV. Floor space needed V. Personal space/walking space/interaction with others	I-V. - Surface lightness influences perceived room height (Oberfeld & Hecht, Surface lightness influences perceived room height , 2010) - Fashion versus Perception The Impact of Surface Lightness on the Perceived dimensions of Interior Space (Oberfeld & Hecht, Fashion Versus Perception The Impact of Surface Lightness on the Perceived Dimensions of Interior Space, 2011) - Thermal comfort and window size (Ravikumar & Prakask, 2009) - The effect of window views' openness and naturalness on the perception of room spaciousness and brightness: A visual preference study (Ozdemir, 2010)
2.4 Amount of daylight needed	I. Relation between daylight/function of space and required activity/performance II. Relation between perception of comfort and performance and daylight amount (Lux)	I-II. - Human factors in ship design: preventing and reducing shipboard operator fatigue (Calhoun, 2006) - The Universal design File: Designing for people of all ages and abilities (Story, Mueller, & Mace, 1998)
2.5 Noise and vibration	I. Noise reflection and sound absorption	**I**. In order to avoid noise/vibrations and resonance, space needs supportive structure and stiffness of walls in relation with windows, as well sound absorbing materials (Binggeli, 2012), sound reduction index , ISO 140 (parts 1-14), (Acoustics.com, 2004)

Table 5-5 Key human elements and principles for the location of the space on board (Fig. 20/Step 5) [Parameters for this Table can be found in Appendix B3.1-3.4]

Key human elements for: Location of space on board related to the ships layout		**Principles** Principles to consider once the space location in relation to the ships layout is determined (Parameters of these principles can be found in the Appendix B3: 3.1-3.4).
3.1 Motion sickness	I. Ships acceleration	- Choose for the key locations on board, spaces with a low acceleration level: Duration during which the passenger is subjected to the acceleration by (Khalid, 2010) - Relation of adjacent rooms: Preventing and reducing shipboard operator fatigue, (Calhoun, 2006) , (Turan, A rational approach for reduction of motion sickness & improvement of passenger comfort and safety in sea transportation, 2006) - International Organisation for Standardization (1985). Evaluation of Human - Exposure to Whole-Body Vibration, (ISO, Evaluation of Human Exposure to Whole-Body Vibration, Part 3, 1985) - International Organisation for Standardization (1997). Mechanical Vibration and - Shock: Evaluation of Human Exposure to Whole-Body Vibration, (ISO, Mechanical Vibration and Shock; Evaluation of Human Exposure to Whole Body Vibration, 1997)
	II. Availability and amount of daylight	- Natural light and the view of an horizon have a positive impact by (Khalid, 2010) - Fatigue design as a reaction to motion sickness (Lamb, 2006) - Relation of adjacent rooms: Calhaun, 2006; Preventing and reducing shipboard operator fatigue Gender and age (Khalid 2011; Bos et al 2007)
3.2 Noise and vibrations	I. Adjacent rooms a. Noise generated by machinery b. Human activity generated noise	- Machinery spaces: example: Engine room, Propellers, Engines, Air-conditioning and ventilation units (HVAC-units). Conversation noise areas: example: Bar, dining room, living spaces, (Kurt, Turan, Arslan, Khalid, Clelland, & Gut, 2010) - Preventing and reducing shipboard operator fatigue (Calhoun, 2006)
	II. Sound transmission through the ship	- STC ratings; STC is a general rating of sound isolation. This site aligns with general goals of promoting the importance of acoustics and acoustic-related issues across a variety of related industries (Acoustics.com, 2004)
3.3 Interaction of adjacent rooms	I. Function in relation to activities carried out in adjacent rooms	- Adjacency matrix and Functional diagrams to analyse relationships between rooms (Mitton, 2012) - On board logistics (Mitton, 2012) - Thermal comfort and adjacent rooms: (Ravikumar & Prakask, 2009) - Comfort standards as set by the classification societies: Lloyds, ABS, and RINA DNV etc. - (ABS, ABS Comfort - Yacht (COMF(Y)) and Comfort Plus - Yacht (COMF+(Y)) , 2008) (ABS, Crew habitability on ships, 2002)
3.4 Amount of daylight needed	I. Relation between function of space and required activity/performance and construction possibilities	- CISB code for Interior lighting, (CISB, 1985)

5.5 The Human orientated interior design framework

Fig. 20 presented the human orientated interior design framework, together with the Table 5-1 to Table 5-5. The framework represents the human elements implementation process that has the intension to be adopted by the mega yacht design industry. The framework demonstrates in 6 steps how to implement the key human elements to interior design into the mega yacht design process. For all spaces on board the yacht count the following process:

Step 1. Choose the type of space (See Table 5-1)

Step 2. Describe the function and related activities carried out in that space (See Table 5-1), in preparation to step 3

Step 3. Prior to the verification of the spatial and layout dimensions (step 4), determine the spatial elements and rough interior design layout and required furniture, for the choice of space (Table 5-3 and Appendix B1)

Step 4. Choose suitable spatial dimensions for the space and determine the required layout in preparation to the verification of the space's location (step 5) in relation to the ships general layout (Table 5-4 and Appendix B2).

Step 5. Choose the location of the space on board (Table 5-5 and Appendix B3)

Step 6. Verify all interior spaces with General Arrangement and Naval Architectural requirements (see Table 5.2)

Step 4 verifies the spatial elements of the specific space for the purpose of finding the most comfortable spatial dimensions (step 5). Fixed equipment and furniture, such as lounge chairs, piano's, large TV sets etc., should be chosen in advance in order to be able to anticipate on not only on the persons' spatial comfort but also their comfort in using the space, sensory comfort and their comfort of interactions with each other. Therefore the type of the space (Step 1 and Table 5-1) and the function in relation with its activities (Step 2 and Table 5-1) needs to be defined first. These chosen key human elements to spatial elemental design dominate and determine the characteristics of the eventual space.

Table 5-3 (as part of step 3) presents the key human elements and principles for step 4, necessary to consider when the interior layout of the space is defined and as preparation of the space dimensions and layout design and choice of location in relation to the ships general layout. The parameters to these principles are described and can be found in the Appendix B1.

Table 5-4, (as part of step 4) presents the key human elements and principles necessary for the selection of the spatial dimensions of the space itself. These principles need to be taken into account as preparation to the selection of the space's general location on board. The parameters to these principles can be found in Appendix B2.

Table 5-5 (as part of step 5) presents the key human elements and principles necessary for the selection of the space's location on board in relation to the general layout. The parameters to these principles can be found in the Appendix B3.

After the key human elements and principles to human orientated design are identified, the basic safety requirements need to be consulted for each step individually (Appendix C1-C3). Adjustments to the steps need to be made when necessary. If any of the steps and implemented human key factors and their comfort design principles, as described in Appendix B, is not in agreement to the owner or the basic safety regulations, the process need to start again, and again, coming back to the step that needs to be redefined, until all parties are in complete agreement with each other.

Only when all 5 steps are completed the results can be verified with the naval architects' technical requirements (step 6 and Table 5-2), as the naval architect can only analyse the ship as a whole in order to verify with the ships main characteristics, sea keeping and stability etc. (See Fig. 19 and Table 5-2).

Once all of the interior design spaces are verified with the comfort to design principles, owner's' requirements, basic safety rules and regulations and the naval architects requirements, the design spiral as shown in Fig. 19 can commence.

5.6 Chapter Summary

This chapter presented a framework in which the implementation process, of how to implement human elements into the mega yacht concept design stage, was demonstrated.

6 IMPLEMENTATION OF THE HUMAN ORIENTATED FRAMEWORK TO THE CASE STUDY

6.1 Chapter outline

This chapter presents the implementation process of the human orientated design framework towards the Case Study.

6.2 Approach implementation process

Many problems occur in the mega yacht industry in the cooperation between naval architect and interior designers. Research in this work has pointed out that many of these problems are a result of involving the interior designer only at the final stages of the naval architectural design process. As a consequence, the interior designer is forced to work under very stringent boundary conditions. This makes it very hard, or even impossible, to implement the key factors to human orientated design that are necessary for the ultimate experience of luxury and comfort a yacht owner is paying for (chapter 3; Critical Review and chapter 4; Field Study).

Following these observations, an integral ship design spiral has been proposed integrating the work of the interior designer with the classical naval architectural design spiral right from the beginning of the preliminary design process (chapter 5).

In the case study that follows, the benefits are demonstrated of this design approach in two steps:

1. Analysing an existing layout of a mega yacht, by means of spot checks, for gaps in the human orientated interior design by identifying the missing key human elements. The key human elements are ranked in the comfort design dimensions, as was presented in chapter 3; Critical review, Fig. 14 (See for parameters to the key human elements Appendix B).
2. Demonstrate how early naval architectural design choices could have made the implementation process of the missing key human elements possible or easier.

Presenting the results of the review of the mega yacht's interior design on the presence of the identified human oriented design key elements, the Table in Fig. 21 has been designed. As the author does not know all details of the interior design of the mega yacht in question, not all comfort design elements could be analysed, and could therefore not be listed in the Table. Some of these design elements that could not be analysed are eco design, tactile comfort, material comfort, and hydrothermal comfort. The last three factors are only measurable with the use of sensory equipment. The factors sensory - hearing and vibratory comfort are also in need for sensory-measurement, but are still added as to include the opinion of a professional naval architect, of which evaluating the design comfort factors from experience.

Analysis Human key element			
Space type analysed	**Missing known Comfort design factors**	**Appendices where the principles can be found**	**Suggested solutions**
Bottom deck - Crew mess **Lower deck** Crew cabins **Main deck** - Living room area - Dining room area - Crew galley - Corridors - Guest cabins (2 cabins stern) (2 cabins front) **Upper deck** - Guest cabin	**D**imensional comfort	B1.1-I-2.3	
	Comfort of use	B1.2-2.2-3.3	
	Postural dimensions	B2.1-2.2-2.3	
	Comfort in the interactions	B1.4-3.3	
	Physical ambient comfort:	B3.1	
	Artificial light/Daylight	B1.1-2.4-3.4	
	Sensory comfort:	B1.1-1.3	
	Visual	B2.3-2.4-3.4	
	Hearing	**B2.5**	
	Vibratory comfort	**B1.3-2.5-3.2**	

Fig. 21 Analysis human key factors; Table example for rating the missing comfort design factors in the Case study

6.3 Chapter Summary

This chapter has briefly presented the implementation process of the human orientated design framework towards the Case Study of chapter 7. Accordingly, chapter 7 presents the Case Study in which this presented implementation process is utilized.

7 THE CASE STUDY

7.1 Chapter outline

This chapter presents the Case Study with the framework presented in chapter 5. Mega yacht X is used to demonstrate how the naval architectural design choices influence the interior design. This is done by relating the absence of certain key factors to human orientated design on board mega yacht X, to that of the design decisions made by the naval architect. The implementation process of the human orientated design framework towards the Case Study has been applied. This chapter is structured into sections of which each one represents a deck.

This chapter starts with an introduction of mega yacht X and presents the background of the ship and its general properties. The sections that follow present the relation between the absences of human design orientated key factors and the naval architectural design choices considering the following:

- How the proposed integrated design spiral (Fig. 19) could improve the general layout related to comfort on board considering the following:
    - Adjacent spaces influencing each other's level of comfort (noise radiation, temperature etc.).
    - Logistics related to operations on board (routing)
    - Analyse the gaps in the human orientated layout of the main living spaces for the bottom to the main deck
    - Propose solutions in order to demonstrate how early naval architectural design choices could have made the implementation process, of the identified missing human key element into the preliminary design stage, possible or easier.

- Naval architectural comments: verify the possibilities in design in the preliminary ship design stage.

7.2 Introduction to the Case Study; mega yacht X

This section is an introduction to the Case Studies 'chosen mega yacht X. This mega yacht will be analysed for gaps with regards to the human orientated interior design by identifying the missing key human elements, as presented in the implementation process. The Case Study uses the existing layout of a mega yacht 'X'. The layout and photographs, as used in this thesis as an example, are for the purpose of this research only.

Mega yacht 'X' (Fig. 22) was built in 2008 by a Dutch yacht builder for private use. The yacht has been designed for a very famous political figure, a family man, married and has two daughters. In 2010 she was prepared and made ready for the charter business but came up for sale in late 2012.

Fig. 22 Mega yacht 'X' (Oceanco.com)

7.2.1 General technical data

In this section an overview is presented of the main parameters necessary for the review of the lay out. The mega yacht has space for a maximum of 12 guests and 20 crewmembers. X contains the following parameters (Table 7-1):

Table 7-2 Main Parameter of mega yacht X

Dimensions	**Performance**	**Construction**	**Equipment**
LOA: 248'/ 75.5 m	Cruise speed: 14 knots	Materials: Steel and Aluminium	Main engines: 2x MTU 4000 V16 720 KW/3648hp at 2100rpm
Beam: 43'/13.4 m	Max speed: 18 knots	Luxury yacht Build: 2008	Propellers: Wartsila 5_blade_ fixed
Draft: 14'6"	Range: 4,100 n,@14 knots		Stabilization: Quantum 4-fin, Zero Speed
Displacement: 1,680 tons	2200 Gross tonnage	100 kw bow thrusters	Auxiliary power: 3 x Caterpillar C18 @ 360 kW / 1 x Caterpillar C9 @ 150 kW

7.2.2 Introduction to the Classification, rules and regulations for mega yacht X

Mega yacht 'X' is surveyed by the Maritime Coastguard Agency (MCA).The MCA Large Commercial Yacht Code (LY2) applies to UK-flagged yachts only, but can also be applied to foreign vessels. If a yacht passes a LY2 survey its owners are given either a Certificate of Compliance for a Large Commercial Yacht or a Letter of compliance. Letters of Compliance issued to foreign-flagged vessels may not have legal status, but do indicate that the vessel meets the code's standards. The LY2 applies to yachts with the following criteria:

Commercial yachts used for sport or pleasure, are at least 24 metres in load line length (or 150 tons or over if built before 21 July 1968) and under 3,000 gross tons (GT), Carry 12 or less passengers and no cargo.

A yacht cannot be certified under LY2 until its hull and equipment has been approved by a classification society recognised by the MCA (see also Appendix C for more information to the private and charter yacht rules).

7.2.3 General Arrangement

In this section the general information about the mega yacht X and her classification is presented (Fig. 23). Most mega yachts have the same lay out. The 6 decks symmetric accommodation, of which the passenger, guests and owners spaces are located on the lower, main and upper decks, this yacht is as follows:

Bottom Deck: Engine room and control room are located amidships, while the crew mess, galley and crew lounge are situated in front of the ship.
Lower deck: Exterior swimming platform is located at the stern together with the space for storage of the water toys, while the crew quarters are situated in the front of the ship, The ten seated cinema is located amidships followed by 2 crew cabins with double beds and 8 crew cabins with bunk beds who are also located in the front of the ship. All together this deck has space for 20 crew members.
Main Deck: A sheltered exterior deck aft is leading into the saloon, dining room, crew's serving area and main galley. Furthermore on this deck can be found; 2 ensuite guest cabins and 2 VIP cabins in the front.
Upper deck: The exterior aft deck, often used for outdoor dining, is leading into the second saloon, game room and a crews' serving area, while a third VIP cabin is located on starboard amidships. Furthermore this deck contains the owners' offices situated amidships and the masters' suite with balcony and office work spaces are located in the front of the ship directly followed by the ships bridge.
Sun deck and owners' deck: In between the upper and sun deck is the owners' double bedded cabin with private balcony. The sun deck features a Jacuzzi, gym and large outdoor sun lounge space.

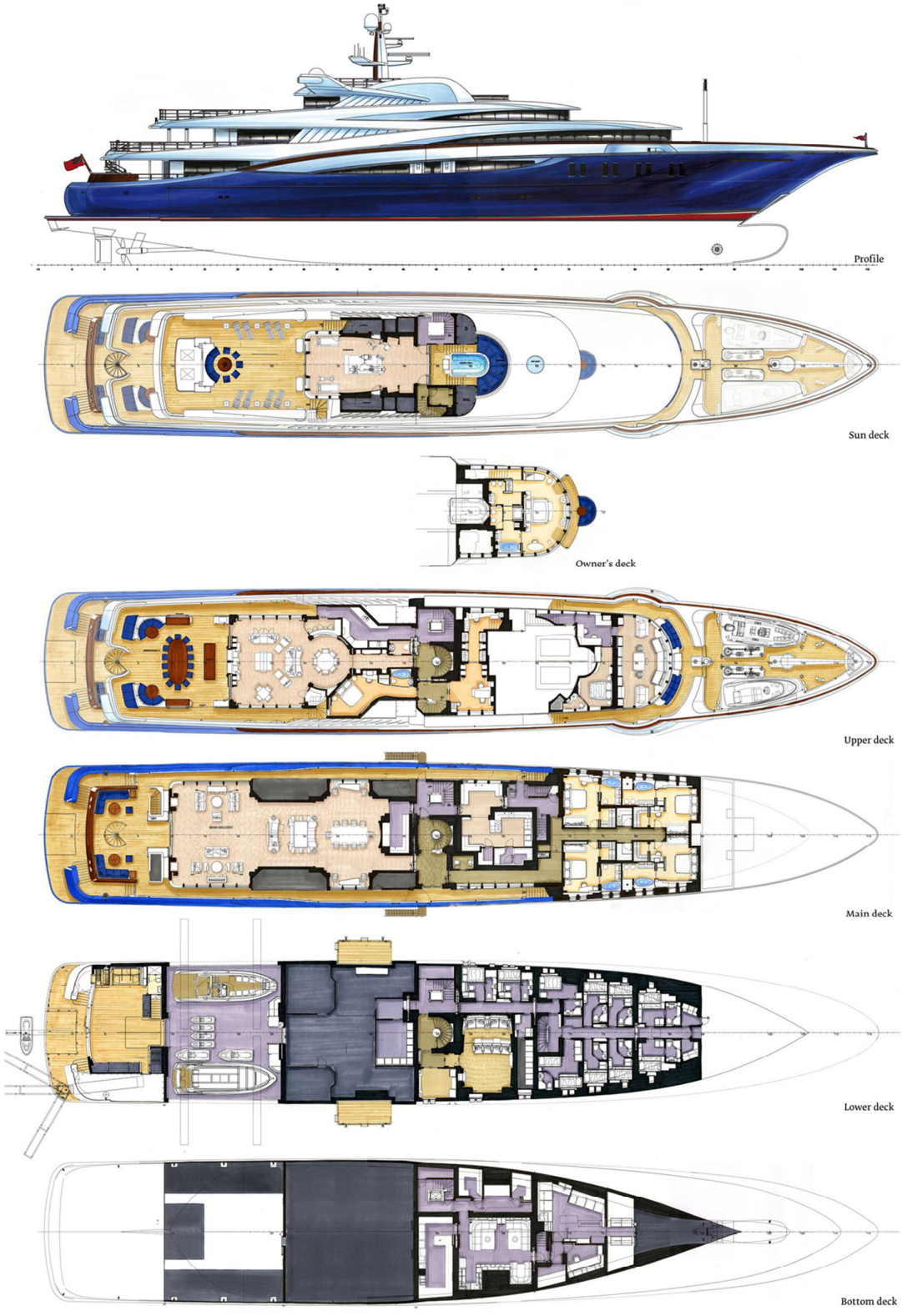


Fig. 23Mega yacht X General Arrangement

7.3 General layout and interior design of mega yacht X

This section demonstrates how the proposed integrated design spiral, as presented in the chapter 5, could improve the general layout of mega yacht X, considering the relevant interior comfort factors. Setting up a general layout is one of the first steps in the design of a mega yacht. This is already a very important step from an interior designer‘s point of view, as through the general layout, the important psychological comfort of traffic patterns are addressed and will reflect the owners’ wishes and comfort requirements (section 7.3.1). Also the layout should be setup in such a way that spaces do not affect each other’s comfort key factors in a negative way (section 7.3.2.).

The setup of a mega yacht layout in general cannot only be based on comfort factors alone. As there are many stringent technical requirements the naval architect has to deal with, which are also closely related to the general layout, it is very important that close cooperation already takes place with the interior designer (Section 7.3.3.) Some of these requirements are:

- Safety (fire, evacuation)
- Stability
- Weight distribution
- Location machinery spaces
- Interaction by means of basic safety, crowdedness, fire zones and escape routes. In SOLAS Chapter II-2, Regulation 27 can be found the Fire Integrity of bulkheads and decks for ships carrying not more than 36 passengers. Table 27.1-2 of SOLAS shall apply respectively to the bulkheads and decks separating adjacent spaces (see Appendix C2.c or C3.b).

The interior of mega yachts in general are most often modelled to previous layouts that have been successfully designed. Newer techniques, like genetic algorithm logistics, are available to calculate the complex space arrangements on board. The

genetic algorithm technique is adopted to generate the space arrangement formulated as an optimization problem that contains multiple objectives and has been proven more successful than previous techniques. This technique, however, does not include the psychological comfort factors of people in order to optimize the traffic flow on board.

7.3.1 General layout and routing of mega yacht X

As Appendix B, 1.2 describes; interior traffic patterns are of paramount importance to the people on board. Both comfort and safety play a big role in the design of traffic patterns within the interior layout. There are traffic patterns on two levels; the first level is the traffic pattern for the overall ship layout, where people would move from space to space and from deck to deck. This level needs its own implementation of human orientated design principles and is concerned with its own complexity in design, such as separation of crew and passenger areas. The second level is traffic patterns within the room itself, which is analysed per room in the upcoming sections.

For both traffic flow between different rooms and areas and traffic flow within an area or room (cabin), the same principles to human orientated design as described in Appendix B1.2, 1.4 and 2.1., need to be observed. It is the task of the naval architect and interior designer to create a safe, functional and comfortable traffic flow for the layout of the rooms and adjacent rooms in order to meet the human orientated design standards as researched in this thesis.

The different class societies have both rules and guidelines regarding the subdivision of different areas, related to the purpose of the areas (activities), the general layout of the vessel and the routing. In this section the guidelines, addressing traffic flows onboard mega yacht X and comfort of use, are examined. The rules regarding safety are considered the concern of naval architect in this work that forms the boundary conditions around which the interior designer should apply the necessary comfort key factors. In this case study, the interior comfort design factors are measured and

related to the guidelines setup by ABS (American Bureau of Shipping). Guidelines of interest in this case can be found in the guidelines formulated in the: Comfort-Yacht and Comfort Plus-Yacht (ABS, 2008), the 'Crew Habitability on Ships' (ABS, 2001) and for passengers: 'Passenger Comfort on Ships (ABS, 2001) guidelines.

According to the ABS Guidelines, there are two type of spaces: either 'accommodation spaces', for the passengers or 'ambient environments', the space where crew live and work in, such as the mess room, leisure facilities or the bridge etc. (ABS, 2002). Study of the general layout of the mega yacht X shows that the spaces are all much grouped according to one of these two categories. Crew accommodation and working areas are grouped so that no crew has to travel through the passenger areas in order to do their job. Also the different spaces seem to be very well grouped according to activities. Mess rooms, galleys and dining rooms for instance are grouped so that routes of food going from the galleys to the mess rooms are as short as possible (see general layout Fig 24 and 25)

Although no faults can be identified with regard to the general layout and routing of activities of mega yacht X, it is still important to note that setting up a general layout for all ships is one of the most important points where naval architects and interior designers have to cooperate, a point that is elaborated on in section 7.3.3.

7.3.2 Adjacent spaces on board mega yacht X; influencing each other's' level of comfort

This section demonstrates how the proposed integrated design spiral, as presented in chapter 5 (Fig. 19), could improve the general layout related to the fact that rooms in each other's vicinities may affect each other's level of comfort. In Appendix B3, the different adjacencies analyses are briefly explained in theory as used in the interior design industries.

As shown in Fig. 23, mega yacht X consist of 6 decks of which the 6th deck is the owners' private sun deck, whereas the first deck is the bottom deck and used for crew only. The human orientated design factors need to be implemented and considered before the final design stage of the yacht takes place, therefore the designers and naval architects should first reflect on the activity plan for each room. Accordingly Table 7-3 has been set up to organise the activities per space. The following present an example of how an activity list could look like for mega yacht X.

Table 7-3 Activities / Space passengers and crew

Deck	**Bottom deck**	**Lower deck**	**Lower deck**	**Main deck**
Space	**Messroom**	**Cinema**	**Crew cabins**	**Main Living**
Activities	*Leisure*	*relaxation*	*relaxation*	*Relaxation*
	Relaxation	*leisure*	*Some writing/desk*	*Disco/ Dance/Drinking*
	Dining		*Sleeping*	*Watch TV*
	Watch TV			

Main Deck	**Main deck**	**Upper deck**	**Upper deck**	**Sundeck**
Main Dining	**4 Cabins en suite**	**Saloon**	**Office**	**Sundeck and jacuzzi**
Dining	*Sleeping*	*Entertaining*	*Work, meetings*	*Sunbathing*
Conversation	*Bathing/Shower etc*	*Games*		*leisure*
Relaxing	*Little work*	*Relaxation*		
	Watch TV			

In Figure 24 and 25 an example is shown of an activity plan for the living areas on the Bottom, lower, Main and Upper deck. The remaining Sun deck can be organised with a similar activity plan.

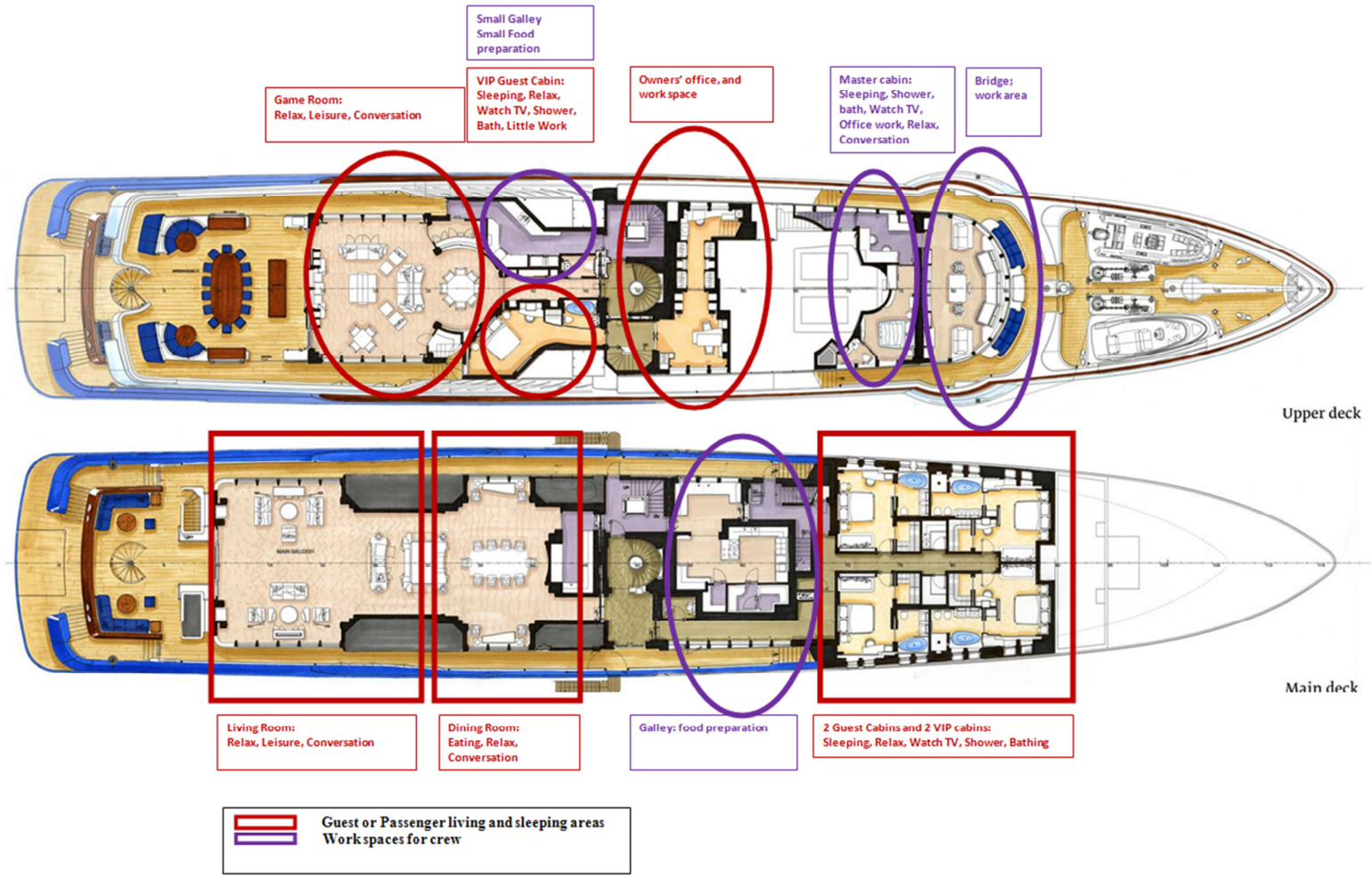


Fig. 24 Example of an activity plan of the general arrangement mega yacht X and activities carried out per interior space on the main and upper Deck

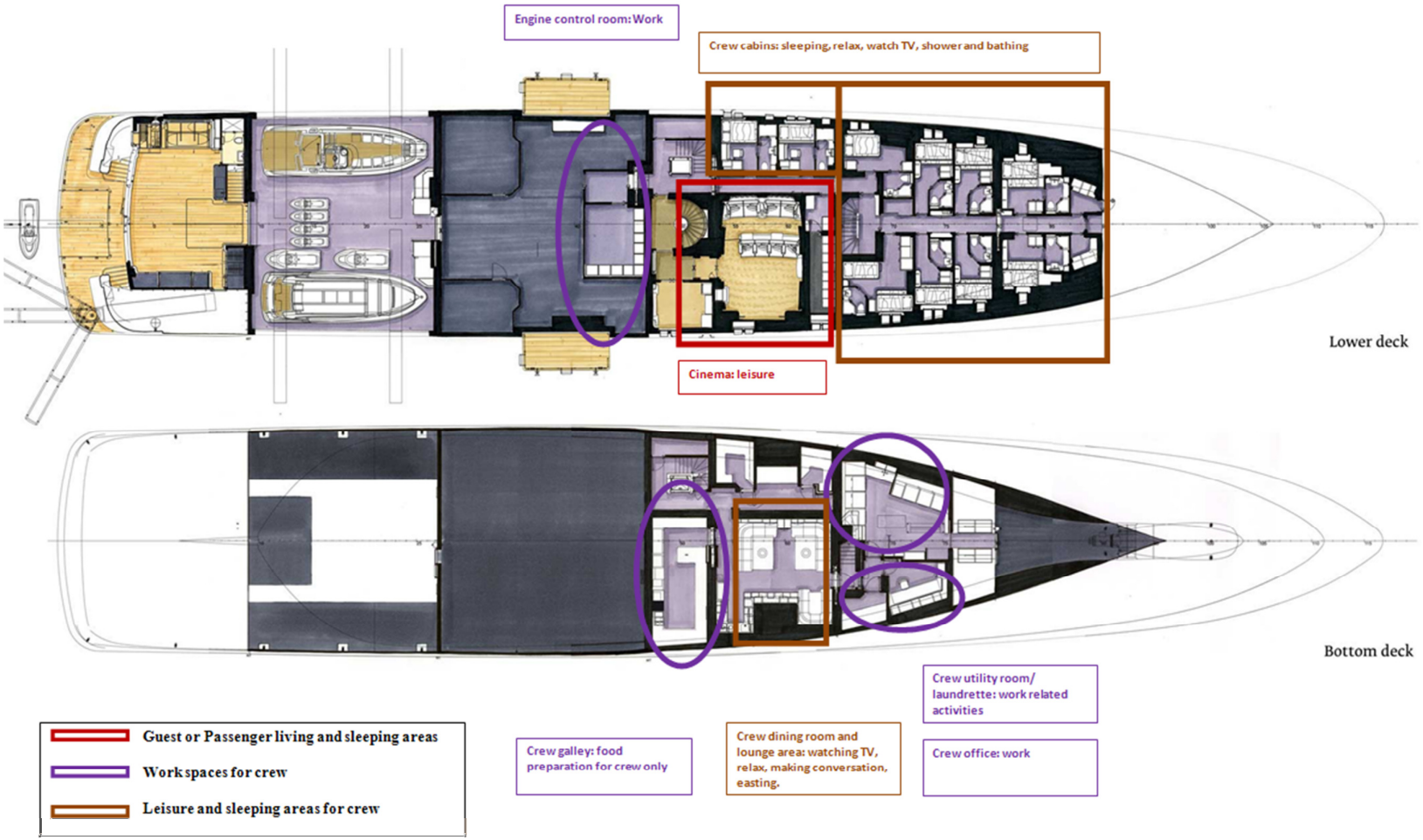


Fig. 25 Example of an activity plan of the general arrangement mega yacht X and activities carried out per interior space on the Bottom and Lower Deck

As shown in Fig. 24 and Fig. 25 activities on the bottom and lower deck are separated between work and leisure for mostly crew. Exception is the guests' cinema located on the lower deck. Leisure activities on the bottom decks' crew dining room and lounge area can be described as: relaxing, watching TV, making conversation and reading. Activities on the lower decks' crew cabins are; relaxing, conversation and sleeping.

The main deck of mega yacht X is primarily used as living accommodation space for the guest and passengers. Activities in the main living room can be described as: relaxing, watching TV, making conversation and reading. Furthermore the main decks' living room can also be converted to part disco-space by moving the furniture aside. When the main living space is used as a disco the activities are; dancing, drinking and making loud conversations. Secondly the main dining area is also located on the main deck, and activities include: dining, making conversation and relaxing. Finally on the main deck are the VIP cabins and the guests' cabins. Activities carried out in the cabin areas are: sleeping, watching TV, little work as there are writing desks in every cabin, relaxing, and furthermore: bathing and showering.

The upper decks' function is mainly to create leisure time with other guests: entertaining and playing games.

In this stage the space location in relation to the general arrangements are reflect upon. The activities need to be described for each room on board in order to find the perfect location of this space in relation to the general arrangements. For example; the living rooms and game room on the upper deck are unlikely to be positioned adjacent to the sleeping quarters due to contradiction in activities: leisure versus rest. In order to analyse relationships between functions of the different spaces on board; staircases, crew and passenger areas, corridors, deck spaces, space arrangements plans, logistics and adjacency analysis all need to be well defined first (principles to routing and mapping, please see Appendix B1.1).

7.3.2.1 Analysed incorrect adjacency and routing factors onboard mega yacht X

Analysis regarding interior design key factor related to the adjacency and routing of activities of mega yacht X, haven't brought many points of criticism, apart from the location of the VIP room located on the upper deck.

As shown in the general layout of mega yacht X (Fig. 23) and close-up in 3D Fig. 26 and Fig. 27, Upper deck, there is one guestroom; VIP cabin. This cabin is located in the game room area, which can cause human activity generated noise problems as the bedroom within the VIP cabin is considered as a noise sensitive area. The adjacent rooms on the deck directly below the VIP cabin (Fig. 26); main dining room and the crews' serving galley, can cause disturbance for the sleeping guests in the morning when the crew prepares breakfast to serve the guests early morning first thing.

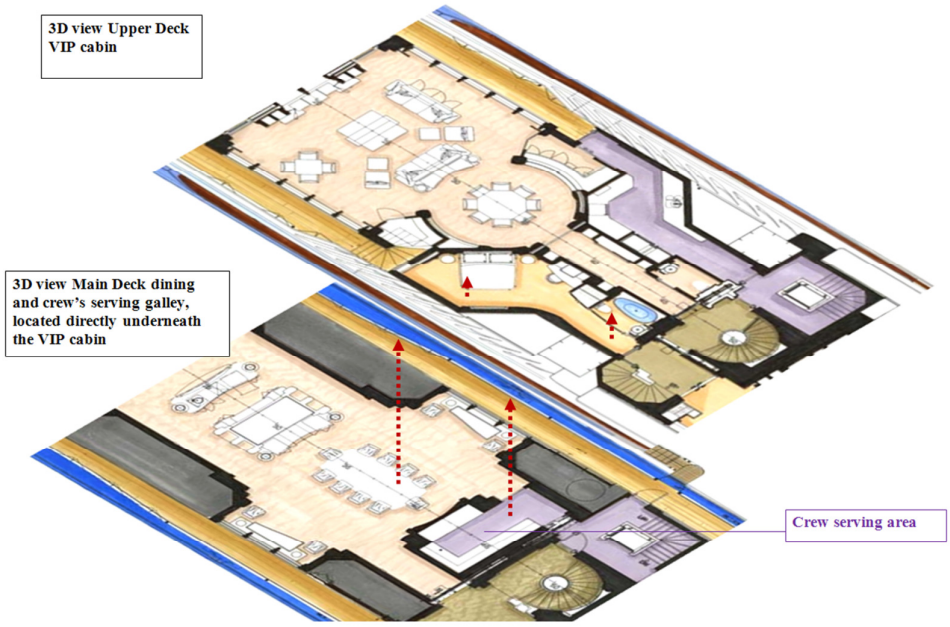


Fig. 26 mega yacht X: 3D overview of the upper deck and main deck. The two red arrows demonstrate sensory discomfort of hearing in the VIP cabin on the upper deck, generated by the human activity on the adjacent Main decks' crew serving galley and dining room located directly below the VIP cabin.

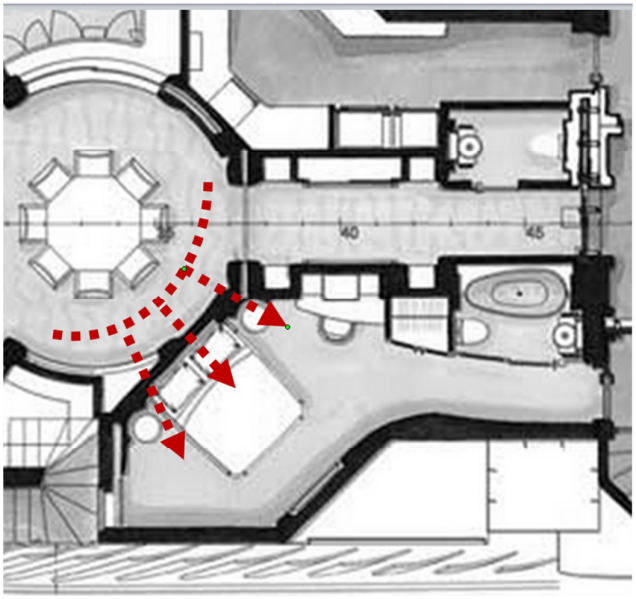


Fig. 27 VIP cabin located on the upper deck; the three red arrows demonstrate the human generated noise coming from the adjacent poker room.

The adjacent room on the upper deck; the poker room can cause discomfort to the sleeping or resting guests inside the VIP cabin as well (Fig. 27). When the poker room is in use and guests are entertaining themselves while the VIP cabin is used for resting and sleeping at the same time, this can cause disturbance. The head of the double bed is located directly against the wall of the adjacent poker room and is in this case an unfortunate choice. The human generated noise can conduct directly through the wall and the bed to the sleeping guests. Human activity generated noise annoyance is a very important psychological key element.

7.3.2.2 Possible solutions to adjacency and routing problems as to implement in the preliminary design stage

In order to avoid problems stated above, adjacency analysis needs to be carried out before the design of the general layout is determined. Human generated noise cannot only be mitigated by isolating the walls, but also by rearrangement of the general ship layout and careful consideration of the cabin internal layout. The following spatial elements could be revised in order to increase comfort in the VIP cabin:

- Change general layout: consider relocation of the Upper decks' VIP cabin to the Main deck where the other VIP cabins are situated
- Within the routing of the cabin: the bed head in the cabin should not be adjacent to the game table, but could be positioned in another corner of the room
- Routing: consider extra service corridor in-between the cabin and the game room can function as isolation space to avoid irritation coming from human generated noise in the adjacent rooms.

7.3.3 Relation between the missing human factor key elements and naval architectural considerations: the benefits of the integrated design spiral.

In this section the absence of the key factors to human orientated interior design is related to the naval architectural considerations in order to demonstrate the need for the integrated design spiral.

7.3.3.1 Routing

Although no real errors in the setup of the general arrangement in relation to routing and activities of mega yacht X have been found, it is still worth emphasising the importance of the integrated design spiral with regard to this point. Apart from the in the Appendix B1.1 mentioned key factors to comfort of routing, also SOLAS requirements need to be implemented where basic safety, crowdedness, fire zones and escape routes have to be considered. In SOLAS Chapter II-2, Regulation 27 can be found the Fire integrity of bulkheads and decks for ships carrying not more than 36 passengers. Table 27.1-2 of SOLAS shall apply respectively to the bulkheads and decks separating adjacent spaces (see Appendix C2.c or C3.b).

Especially when relocation of spaces is considered in favour of routing, it may hugely affect some of the main important main parameters of the ship like weight

distribution and stability. As the decision of where to put a certain space or cabin in the ship affects both the naval architectural design parameters and the comfort of the ship the importance of the integrated design spiral has been demonstrated.

7.3.3.2 Interaction between spaces

One of the interior design solutions suggested to in section 7.3.2.2 described incorrect analysed adjacency and routing factors is the rearrangement of the interior cabin layout. The root of the problem, however, lies in the location of the cabin. As described above, when relocation of spaces is considered, this time in favour of interaction between spaces, and this may hugely affect some of the important main parameters of the ship, such as weight distribution and stability. In the same way as above it has to be noted that the decision of where to put a certain space or cabin in the ship affects both the naval architectural design parameters and the comfort of the ship. Again the importance of the integrated design spiral has been demonstrated.

7.4 Bottom deck

The main living space on the bottom deck of mega yacht X is the crew mess. Providing a comfortable space for crew to work and relax is very important for their working performance. Not only for the fact that it is harder to do a job in a uncomfortable space, but also for the fact that discomfort leads to crew fatigue, through which the working performance is also affected.

The crew's working performance not only directly impacts the safety and wellbeing of people on board, but also affects the experience of luxury and comfort of the yacht owner or charterer and the passengers sailing with her.

In the next section the crews' mess is analysed for gaps in human orientated interior design. This is done by identifying the missing key human elements with the use of the principles as presented in Appendix B. Also it is demonstrated how early naval architectural design choices could have made implementation of the missing key

human elements easier, in order to prove the importance of the integrated design spiral.

7.4.1 Crew-mess

The Table 7-4 below presents an overview of the analysis to comfort design for the crew mess and the proposed solutions to avoid this in the future, together with the naval architectural comments. The Table is accordingly discussed in this section.

Table 7-4 overview of the analysis to comfort design for the bottom deck crew mess

Bottom deck				
Spaces type analysed	**Analysed missing comfort design factors**		**Appendices to the comfort design principles**	**Suggested solutions**
Crew mess	Dimensional comfort	X	B1.1-I-2.3	**R**earrange room layout and implement mapping elements **A**pply principles to Human comfort design factors (Appendix B)
	Comfort in use			
	Postural dimensions	X	B2.1-2.2-2.3	
	Comfort of interactions	X	B1.4-3.3	
	Physical ambient	X	B3.1 B1.1-2.4-3.4	
	Sensory comfort:	Unknown	B1.1-1.3	**R**earrange the room-layout **A**pply priciples
	Visual	Unknown	B2.3-2.4-3.4	
	Hearing	Unknown	**B2.5**	**R**un questionniares amongst Passengers/crew and measure noise and vibration levels. **R**elocate areas in order to avoid noise and vibrations disturbance from adjecency rooms **P**lace Isolation between rooms/decks
	Vibratory comfort		**B1.3-2.5-3.2**	

As shown in Table 7-4, this section will demonstrate that 4 out of the 5 analysed human comfort design factors are missing for the mega yachts' crew mess area (used for dining and leisure).

7.4.1.1 Dimensional / Postural comfort and comfort of interactions

Fig. 28 below shows the layout of the bottom deck on board mega yacht X.

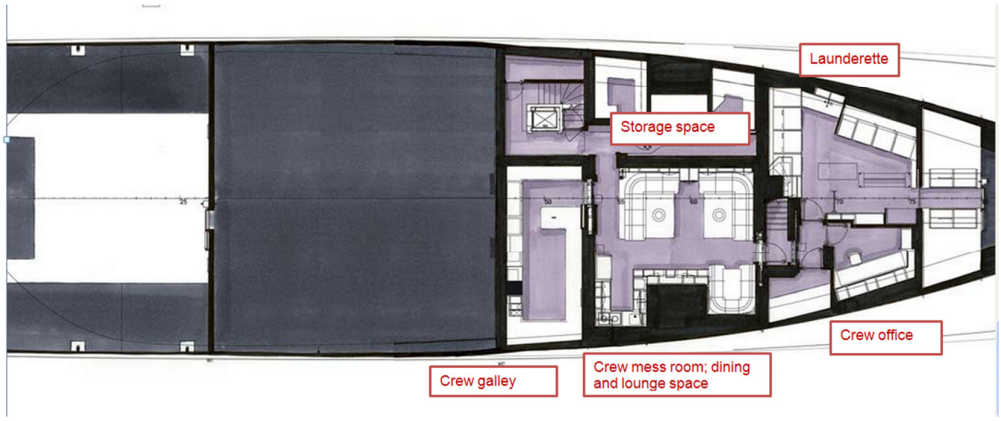


Fig. 28 Mega yacht X-Bottom deck front; crew galley with storage spaces, mess room, office and launderette

On mega yacht X there is room for 20 crew members; Captain, Chief Officer, Chief Engineer, Hotel and Deck Staff. All of them enjoy their meals together in the mess room shown in Fig. 28 Shows three sitting islands designed for 6-7 persons. In this section the dimensional, postural comforts for the persons using the crew mess as well as comfort of interactions are analysed.

7.4.1.1.1 Identified gaps

Roughly the dimensions of mega yacht X crew mess can be estimated on 6.5 x 7 meters or in-between 36 to 49 square meters. The average space per crewmember (20 in total) is 1.8 to 2.5 square meters per person when the crew mess is in its full occupancy (See principles Appendix B). This is assuming that all 20 crewmembers will have their meal together at the same time, which occurs when there is no cruise to be made).

The crew mess makes use of booth and banquette seating areas, grouped into three corners for 6 to 7 crewmembers each. Booth and banquette seating is used in the hospitality industry as well, because it provides comfortable and flexible seating arrangements. On board ships booth and banquette seating is used because its effective use of valuable corner space. The building design standards (Binggeli,

2011) set standards for spacious seating, average and compact seating: (See Principles to Design pg 392; Binggeli, 2011 or Appendix B 1.4)

- Spacious seating has a seating space of 1.3 square meters per person,
- Compact seating is around 0.9 square meters

Fig. 29 show the three crowded corner seating booths in the crew mess of mega yacht X.; each purple circle represent an average man anthropometrics' width while seated in meters.

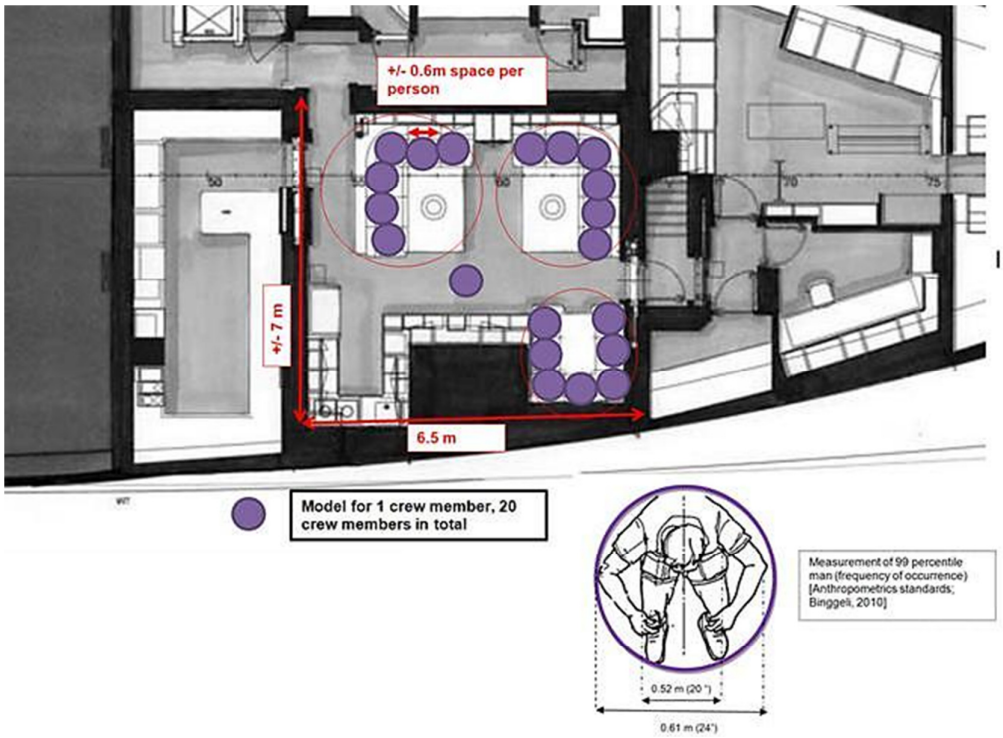


Fig. 29Bottom deck crew mess room mega yacht X showing the three crowded corner seating booths

In total all 20 crewmembers are shown in the Fig. 29. Analysing the left corner booth, the average space per person is measured roughly at 0.4 square meters (0.6 m x 0.7 m); this is about 50% below the building comfort standard for the hospitality industry. The total space to eat comfortably for the crew, meaning; postural and dimensional freedom of movement, is estimates between 0.9 and 1.3 square meters. Ideal situation would be that each booth in Fig. 30, holds up 3 to 4 crew members

only instead of 6 to 7. In other words: the mess room as it is designed, would hold up to 123 crewmembers when the hospitality design standards are implemented. Although these standards are maybe unrealistic for onboard a ship, the fact is that freedom of body movement remains a crucial key human comfort factor. Conclusion that follows from the above is that both dimensional, as well as the postural comfort design criteria are not met for the crew members' mess room.

7.4.1.1.2 Proposed solutions to consider in the preliminary design stage

Limited crew space on board mega yacht is one of the biggest challenges a ship designer has to face. This problem could be solved either by cutting down in the number of crew, or increasing the dimensions of the living room in order to comply with the dimensional design principles (Appendix B, I). Mainly the second solution would have a large impact on the total ship design, as also demonstrated in the section 'naval architectural commends (see also 7.4.1.1.3).

Fig. 30 Above layout is shown of the mega yacht X's bottom deck crew mess, which is extended in dimensions by cutting down in size of the engine room; below picture shows the original layout of the Bottom deck engine room and crew mess

7.4.1.1.3 Naval architectural comments

As described above, maintaining the same number of crew and adhering to the key principles of dimensional design at the same time means that the crew mess-room dining booths has to increase in size by at least 50% in order to meet with the comfort design standards as explained in the last section. In order to do this, it has been established that placing the engine room bulkhead 1m to the aft, would mean a world of difference. This, however, influences the space available for machinery if the same ship length is maintained. The choice could be made to lower the required ship speed so that less main engine power would be required and therefore the size of the engines plus supporting equipment can be decreased (example Fig. 30).

Increasing the ships' length with one meter is another option, but changes the hull shape and therefore changes the ships' resistance, which will influence the ships' speed and may need a redesign of the propeller or different choice of main machinery. Increasing ships length, however, does not necessary lead to an increase of resistance and would therefore not necessary lead to an increase of required propulsion power in order to maintain the same contractual speed. Lengthening ship hulls has proven to be beneficial to the wave making resistance, in some cases resulting in slightly higher ship speeds with the same installed propulsion power (a phenomenon used in the enlarged ship concept).

Above clearly demonstrates that observing the key human elements closely in the design stage would have told the interior designer and naval architect that one extra meter could mean a world of difference from a human comfort point of view. This knowledge needs to be implemented very early in the design stage as it may affect the ships' main dimensions or available propulsion power. These are important factors in the naval architectural design as it concerns design choices the naval architect has to make very early in the design stage.

7.4.1.2 Physical ambient; comfort of light

An important key element to comfort is the presence of light. On the bottom deck there are no windows. This means that comfortable lighting in the crew main livings space completely relies on a good artificial light (see Fig. 28).

7.4.1.2.1 Identified gaps

The Daylight Factor is the ratio of indoor to outdoor luminance under an overcast sky. This is the factor used to characterize the level of daylight inside building or a room. Conventionally the overcast sky has been used for daylight design in the UK. Various techniques are used by specialised light designers to calculate the required daylight ratio. The required amount of daylight depends on factors such as the dimensions of the space, the size of the windows, the function of the room, equipment in the space (such as big TV screens, and large fixed furniture).

7.4.1.2.2 Proposed solution to consider in the preliminary design stage

When the construction of the yacht permits, the ideal situation would be to possibly rearrange the ships layout in a way to implement some natural daylight for the crew mess room. As the construction of the ship leaves it impossible to design the bottom deck spaces with natural daylight, the following is proposed as to increase human comfort:

- Apply enough artificial light to the mess room as to replace daylight and improve on the human performance (50-100 Lux)
- Design additional small coffee facility rooms/corners on other decks, which provide enough natural daylight for the crew to beat fatigue. Coffee-mess room facilities elsewhere on the ship can be beneficial for the work performance to those crew members working in dark enclosed spaces all day. The overall ships

layout can be adjusted in the preliminary design stage as to implement the comfort design factor: physical ambient; natural light, to this deck

It is also important to consider the amount of daylight that is required for every space on board, before the total lay out and construction of the hull is determined. Below the water line windows and openings are limited on board the ship construction, stability and safety reasons (See Appendix C3 and SOLAS chapter II-1, part B). To prove the necessity of implementation of human orientated design key factors in the preliminary design stage of the mega yacht ship design process the following example is addressed on layout design (Fig. 31):

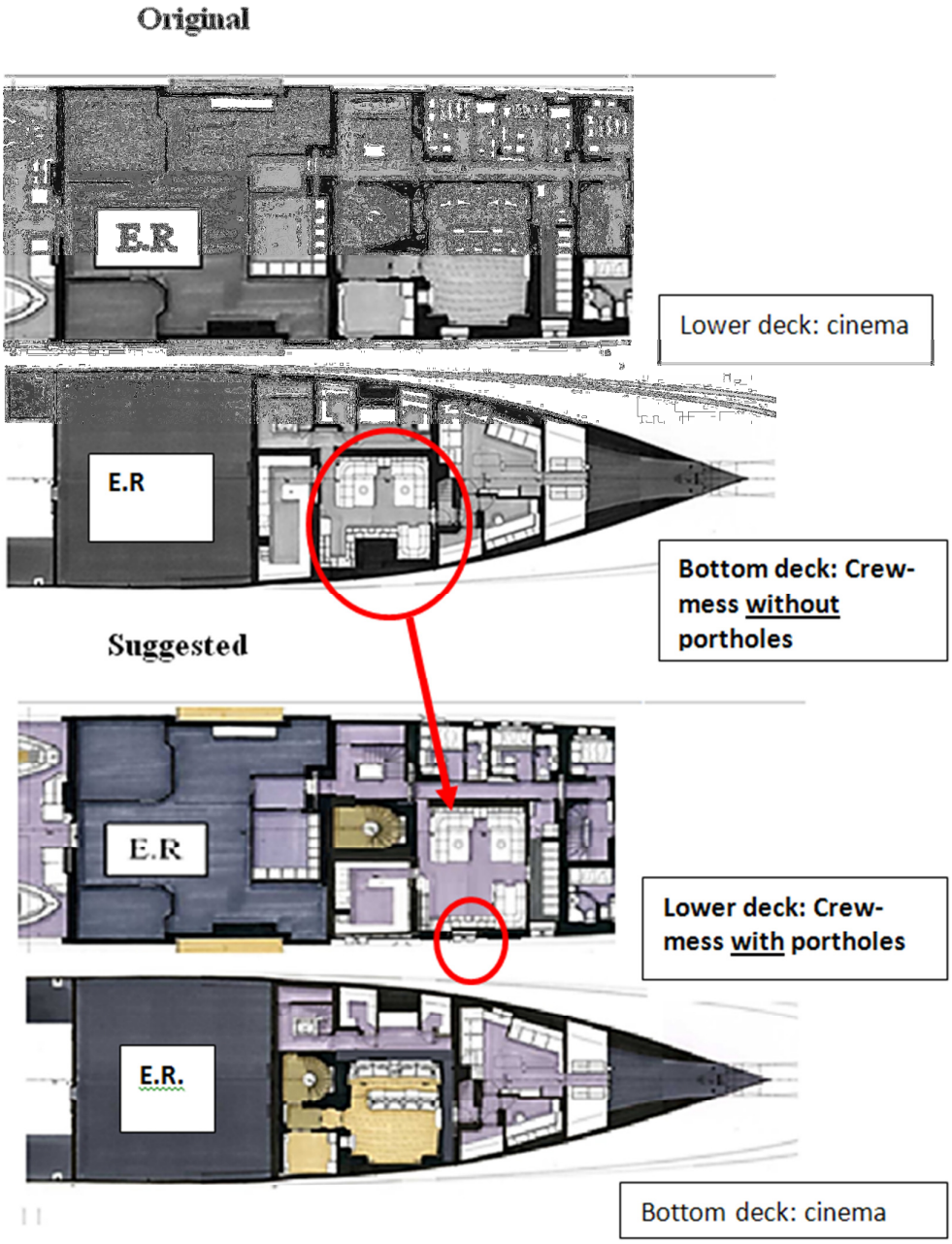


Fig. 31 Mega yacht X; top: original layout and below; cinema has been relocated to the bottom deck, whereas the crew mess is relocated to the lower deck in order to add natural daylight to the crew-mess

When the crew's lower deck is been reviewed on board mega yacht X, the cinema at the lower deck (Fig. 31) show two small portholes (windows). The cinema does not require any daylight, whereas the crew's mess room have no portholes. In this case the cinema and crew mess room could change deck-locations in order to provide

daylight to the crews mess room. The top situation as shown in Fig. 31 presents the original layout; cinema is located on the lower deck, whereas the situation below shows the suggested layout; the. The suggested crew mess room location show two small portholes.

7.4.1.2.3 Naval architectural comments

In order to provide the crew with more daylight, it has been suggested to swap the location of the crew messroom and galley with the location of the cinema. This may have an effect on the weight distribution and stability of the vessel which has to be taken into consideration in an as early as possible stage in the design process as possible demonstrating again the importance of the human orientated integrated design spiral.

7.5 Lower deck

An average crew cabin on the lower deck is analysed for gaps in the human orientated interior design by identifying the missing key human elements with the use of the principles as presented in Appendix B. This deck mainly contains crew cabins. A well-rested crew is very important for their working performance and has a direct impact on the safety and wellbeing of the passengers and owner and also directly affects the quality of their mega yacht experience.

Also is demonstrated how early naval architectural design choices could have made implementation of the missing key human elements possible or easier.

7.5.1 Crew cabins

The Table 7-5 below presents an overview of the analysis to comfort design for the lower deck crew cabins (double occupancy) and the proposed solutions to avoid this

in the future, together with the naval architectural comments. The Table is accordingly discussed in this section.

Table 7-5 overview of the analysis to comfort design for the Lower deck crew cabins

Lower deck				
Spaces type analysed	**Analysed missing comfort design factors**		**Appendices to the comfort design principles**	**Suggested solutions**
Crew cabin	Dimensional comfort	X	B1.1-I-2.3	**R**earrange room layout and implement mapping elements **A**pply principles to Human comfort design factors (Appendix B)
	Comfort in use	X	B1.2-2.2-3.3	
	Postural dimensions	X	B2.1-2.2-2.3	
	Comfort of interactions	X	B1.4-3.3	
	Physical ambient	Unknown	B3.1 B1.1-2.4-3.4	
	Sensory comfort:	Unknown	B1.1-1.3	**R**earrange the room-layout **A**pply priciples
	Visual	Unknown	B2.3-2.4-3.4	
	Hearing	Unknown	**B2.5**	**R**un questionniares amongst Passengers/crew and measure noise and vibration levels. **R**elocate areas in order to avoid noise and vibrations disturbance from adjecency rooms **P**lace Isolation between rooms/decks
	Vibratory comfort		**B1.3-2.5-3.2**	

As shown in Table 7-5, this section will demonstrate that 4 out of the 4 analysed human comfort design factors are missing for the crew cabins.

7.5.1.1 Dimensional and postural comfort

The distribution of the limited space on board the yacht is a very complex process and decisions need to be made with the owners about the priority of certain rooms. The cabin space for crew is not just a place to rest, but more importantly a place for privacy and to spend some valuable quality time to be alone, to relax, work, internet or read something (Fig. 32).

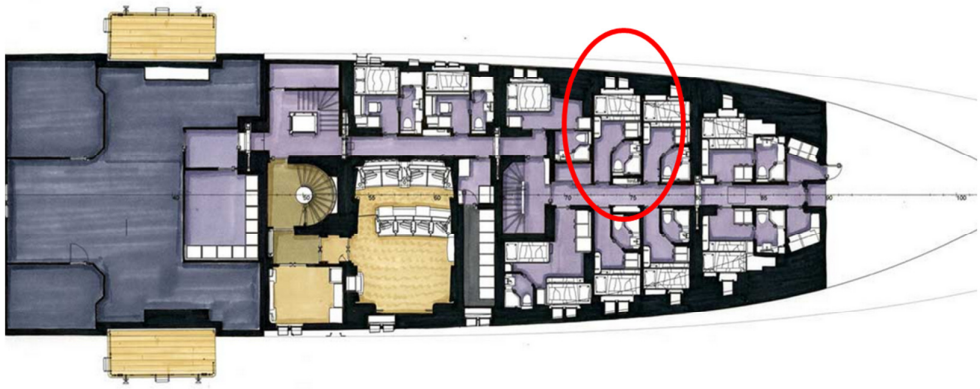


Fig. 32 Mega yacht X-Lower deck front; crew cabin; double occupancy

7.5.1.1.1 Identified gaps

The size of one crew cabin is roughly half the size of one standard guest cabin and has to be shared by two crewmembers by means of bunk beds. As shown on the layout of mega yacht X (Fig. 32), the crew cabins with two berths are roughly: 2.5 to 3.0 by 3.5 to 5.0 meters (9 to 15 square meters floor space) of which one third of these floor space is sanitary space. The actual cabin floor space to move around minus the sanitary space is about 6 to 10 square meters. That means an average of 4 square meters per person. The Maritime Labour organisations (MLO Convention C092 Accommodations, Article 10) provide minimum requirement for the total floor space per crewmember:

Petty officers: one or two persons per room, and in no case more than two; (d) other ratings: two or three persons per room wherever possible, and in no case more than four.

The floor area per person of sleeping rooms intended for ratings shall be not less than:

- 25 sq. ft. or 2.35 sq. m. in vessels of 800 tons or over, but under 3,000 tons (mega yacht X is 2200 GT)

Although the approximately 9 square meters floor space for a 2 person's crew sleeping cabin (4.5. m. / per person) is well above the ILO meeting criteria of 2, 35 sq. m; it is about half the required size of the minimum required size double room for 1 star rated hotel for example, namely: 14 sq. m. The Table 7-6 below show the comparison between the crew cabin on board mega yacht X and the minimum required bedroom floors space for dwellings in London (12 sq. meters). They are accordingly compared to the minimum standards as set by the classification agencies and further compared to the minimum required size double room for 1 star rated hotel bedroom (14 sq. m).

Table 7-6 Minimum required floor space for double bedrooms

Min floor space (sq. m) Double occupancy room	1 star hotel	Classification regulations (passenger ships 1000-3000 tons)	Dwelling space standards (London) 2 persons bedroom	Mega Yacht X Crew cabin	Passenger cabin/ two persons on board passenger ship; classification requirements
	14 sq. m	4.70-12 sq. m (2.35-6.0 sq. m per crew member)	12 sq. m	Smallest : 9.0 Average crew cabin: 15.0 sq. m	13.9 sq. m
Ceiling height minimum in meters	2.5 m	1.98-2.05 m	2.6 m	unknown	2.05 m

From Table 7-6 can be seen that the smallest crew cabin floor space (9 sq. m including the sanitary floor space) does not fulfil the requirements for a one star hotel double bedroom (14 sq. m). The minimum requirement for a double bedroom for a dwelling (house or flat) in London for example, where space is extremely limited and very expensive, needs to meet with the standards of a minimum of 12 sq. meters. Compared to the smallest double occupancy crew cabin on board mega yacht X of 9 sq. meters, again the crew cabin floor space does not meet with the minimum dwelling standards.

Also in the Table is shown the ceiling height for a typical cabin on board passenger's ship of 2.05 meters, whereas the minimum required ceiling height of a London bedroom is about 2.6 meters. When compared to the one star hotel bedroom, where the ceiling height needs to meet the standard of a minimum height of 2.5 meters, it is safe to say that overall dimensional comfort standards of the average crew cabin does not meet with the minimum required comfort standards set by the Interior design industry.

False expectations of working on board a luxury mega yachts amongst the crewmembers can cause irritation, disappointment and have an overall negative impact on the work performance. The small cabins can cause fatigue, lack of personal space and sharing a cabin for long periods of time can also cause irritation towards each other and influence the work performance.

7.5.1.2 Comfort in use and interaction

Comfort in use is described by factors that are responsible to the human comfort while using the room. Comfort in use is necessary in order to satisfy the customer or increase crewmembers performance in her or his mega yacht experience. Human factors that are responsible to comfort in use of a room are amongst others; traffic patterns in the room. The traffic flow in the crew cabins are analysed according to their principles as described in Appendix B.

7.5.1.2.1 Identified gaps

There are traffic patterns on two levels; the first level is the traffic pattern for the overall ship layout, where people would move from space to space and from deck to deck. This level needs its own implementation of human orientated design principles and is concerned with its own complexity in design, like separation of crew and passenger areas and therefore was analysed in 7.3.3. This section is about the second level in traffic patterns: the traffic patterns within the room itself.

Principles to human orientated design for this level are amongst others related to the emergency exits within the room in relation to the number of occupants; also the traffic flow within the room needs to be free from any obstruction.

If the dimensional comfort for crew cabin space does not meet with the comfort design standards, the logistics of the cabin space is not comfortable either. Taken into account the postural dimensions when two persons are in the cabin in the same time difficulties in traffic flow in the room occur. If the bathroom door opens outwards the traffic flow in the cabin is obscured from the bed to the exit. The same can be said for the desk in the cabin. The dimensional proportions of the room make it impossible for the traffic flow to meet with comfortable design standards, which say that the traffic flow must be free from obstructions. When a person is working on the desk with the chair pulled back, the traffic flow from and to the door and bunks are obscured (See Fig. 33)

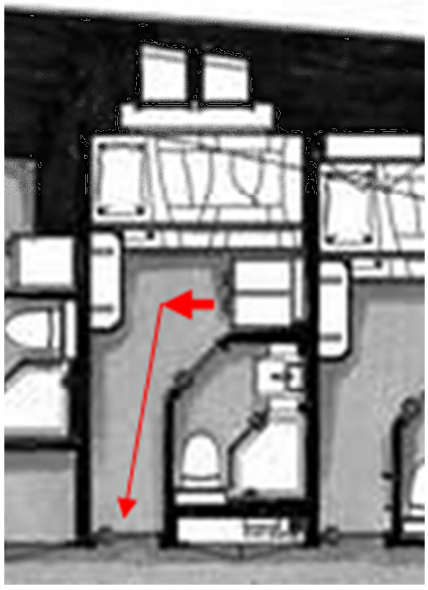


Fig. 33 Crew cabin mega yacht X; double bunks; show the traffic flow arrows

7.5.1.2.2 Proposed solution to consider in the preliminary design stage

'The first part of the solution is that somebody cares about crew comfort. It's easy to solve the problem; you just have to give up more space to the crew, which costs money. The new MLO rules coming into effect on bigger new builds does a bit to address these issues, but more than likely the yacht sector will see exceptions to the rules just like in every other safety sector.' (H. Heinemann, 2012).

Cabin space in general is according to most owners not valuable enough to worry about, as this space is not be used during daytime. If the owner can choose what to do to save space, likely there will be cuts in the size of the cabins and extra space is used for additional lounge areas. The space on board is just too precious to waste it on spaces rarely used. However, for crew cabin space, the opposite can be stated. As crew cabins on board mega yachts are considerable smaller in size compared the average general cargo ship. The following suggestions are made to improve on comfort for crew cabin spaces:

1. Consider the parameters of the principles to human orientated design of Appendix B1-3, as far as possible for this stage
2. Improve on comfort design factors by implementation of the room-mapping elements (Appendix B1.1/I)
3. Rearrange room dimensional layout
4. Improve on cabin dimension by adding more space per person
5. Limit number of crew and guest on board (when considering limitations on crew members do consider a certain decrease in guests as well, this too avoid an increase in work pressure on the crew. This suggestion is more realistic on for a private yacht as there is no money making business involved, such as on a charter yacht)
6. Add in mega yacht dimensions; length, width or rearrange overall layout

7.5.1.3 Naval architectural comments; summery

It has become clear from the discussion on the issue to solve the problem of lack of dimensional and postural comfort, as analysed in the previous sections, by simply decrease on the crew numbers, that this is not fundamentally a spatial and a safety problem, but a matter of owner's choice as well. To explain this, it is useful to add, that most owners' sail with crewmember from a variety of flag states and most of them are willing to work for a very good salary whilst having limited living space on board the yacht. However, crew from the UK and Western European a country demand more space and for those yachts that are willing to sacrifice the space on board to create more space for crewmembers, this is only possible to do so in the preliminary design stage of the yacht.

This proves again how the lack of key elements to human factor orientated design is linked to design parameters and naval architectural decisions that have to be made in a very early stage of the design process. Providing extra crew cabin space, whilst maintaining the same number of crew, may require an increase of the overall main parameters of the vessel (length, breath), especially when the owner does not want to sacrifice passenger space for crew space. Main parameters immediately affect the ships' stability, ships' resistance (and therefore the required engine power in order to

achieve the contract speed). This proves the necessity to integrate human factor considerations into the design spiral right from the beginning of the design process.

7.6 Main Deck

This section analyses the main living spaces on board mega yacht X's main deck for gaps in the human orientated interior design. This is done by identifying the missing key human elements. Furthermore it is demonstrated how this can be improved by implementing the missing human principles into the preliminary design stage of mega yacht X.

7.6.1 Living room area

The Table 7-7 below presents an overview of the analysis to comfort design for the living room and the proposed solutions to avoid human orientated design problems in the future, together with the naval architectural comments. The Table is accordingly discussed in this section.

Table 7-7 overview of the analysis to comfort design for the main deck living area

Main deck				
Spaces type analysed	**Analysed missing comfort design factors**		**Appendices to the comfort design principles**	**Suggested solutions**
Living room	Dimensional comfort	X	B1.1-I-2.3	**A**pply the principles to dimensional comfort design factors into the preliminary ship design stage
	Comfort in use	V	B1.2-2.2-3.3	
	Postural dimensions	X	B2.1-2.2-2.3	
	Comfort of interactions	X	B1.4-3.3	Rearrange room layout in order to improve on visual comfort
	Physical ambient [artificial and day light, temp, climate etc]	X	B3.1 B1.1-2.4-3.4	
	Sensory comfort: [comfort of the senses]	Unknown		**R**un questionniares amongst Passengers/crew and measure noise and vibration levels.
	Hearing			
	Vibratory comfort			

As shown in Table 7-7, this section will demonstrate that 4 out of the 5 analysed human comfort design factors are missing for the main living area on board mega yacht X (missing key elements are marked with an X).

7.6.1.1 Dimensional comfort and physical ambient comfort

Spaciousness can be created by means of optical illusion (see for principles Appendix B/1.1-II). When analysing other types of mega yachts, some have different interior design ideas to create a sense of space than others. The following example is used to demonstrate how to use the optical spatial comfort factors as were described in Appendix B 1.1-II.

7.6.1.1.1 Identified gaps

Fig. 34 Mega yacht X living room on the main deck (Oceancoyacht.com)

The following gaps have been identified on board mega yacht X which may contribute to a lack of dimensional comfort:

- Low ceiling

- View from the seats is obstructed by cabinets blocking the line of sight to the windows as demonstrated in Fig. 35

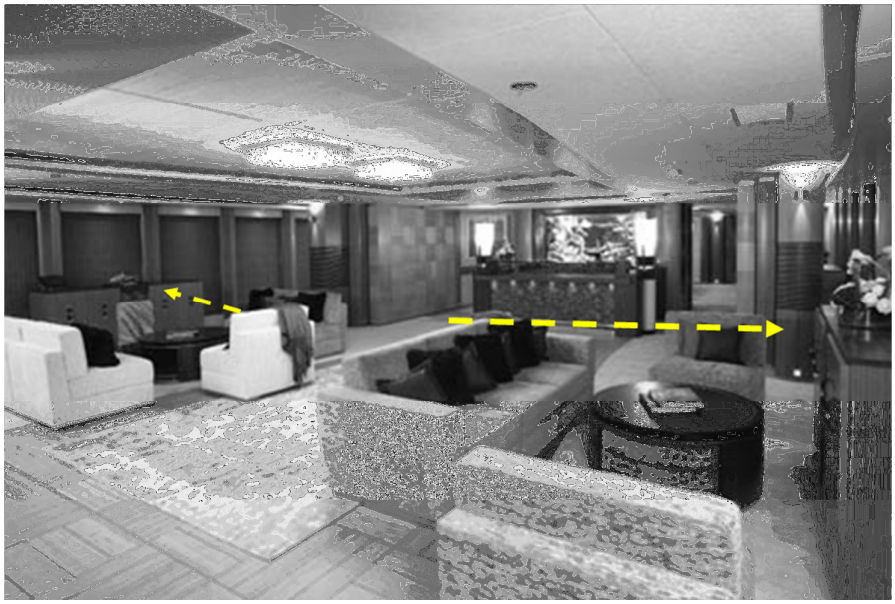


Fig. 35 Main living room seating area, showing the obstructed view in yellow arrows (Oceancoyacht.com). [Window shutters are shown down on this photo].

As was discussed in the Critical Review; the lack of discomfort in this room does not automatically mean comfort. As mega yachts should aim for the highest comfort standards available, this living room does not meet with its human comfort factors requirements.

The example in Fig. 36 shows the main Living area on board the Yacht 'Reborn build by Amels in Holland. The living room on board the Reborn is a good example of how to implement spatial comfort factors (Yachtcharter, 2011):

Fig. 36 Charter yacht Reborn Main saloon area (Yachtcharter, 2011)

- The illusion is created of spaciousness by an extension of the view; large windows in the living room. The windows reach from floor to the ceiling and add in the optical illusion of an extended living room. The view can be admired from every seating position in the room. These surrounded windows provide optimum use of natural daylight; physical ambient.
- The Reborn shows a huge open space in the middle of the main living area which creates a light and spacious surrounding due to its double height atrium ceiling and natural daylight coming from two floors. Spatial design factors utilized in this space are :
    - ✓ Add extra dimension to the room by increase on ceiling height
    - ✓ Increase natural daylight levels
    - ✓ Optical space illusion: expanded view (large windows all around)

The down side of a huge open space is the loss of deck space above the main living and the possibility of more noise nuisance due to refection and echo's. Larger rooms have longer echo times than small rooms. The large rooms shall need more absorptive materials to balance the noise nuisance. When interior design of the yacht

is taking place all elements of design should be considered at the same time in full cooperation with each other.

The dimensional comfort design factors of the living room on board the Reborn (Fig. 36) are analysed against mega yacht X's dimensional comfort factors for the main living space (Fig. 34), in order to elaborate on the analyses of the missing gaps.

7.6.1.1.2 Proposed solution to consider in the preliminary design stage

Possible solutions are to rearrange the seating area by re-mapping the room, as proposed in the Appendix B; principles to visual comfort. The view of users of the seating area should be unobstructed. By mapping the room and its furniture position carefully in a way that the user has an unobstructed view out of the window will increase on the physical ambient comfort. Repositioning the cabinets to improve on the view increase the optical illusion of space and also will increase the comfort of use.

The missing key elements: dimensional, physical ambient and comfort in use can only be solved or adjusted by the naval architect in the preliminary design stage. In the preliminary design stage the naval architect can consider extra-large windows in the seating area to improve in the optical space illusion: extended view and to make use of maximum natural daylight comfort.

7.6.1.2 Comfort of interactions

The seating areas as shown in Fig. 34 is analysed on comfort of interactions by implementing the design principles to comfort of interactions, as found in Appendix B, 1.4.

7.6.1.2.1 Identified gaps

The comfort design standards have certain legroom guidelines the industries can implement to maximize guests comfort in seating. The designers should take at least 864 mm of leg space into account for comfortable seating, 914 mm is considered to be ideal. Although the leg space for the guest in the seating area in Fig. 34 is difficult to measure without actually being present on the yacht, from the photo it appears the leg space does not meet with the comfort standards.

7.6.1.2.2 Proposed solution to consider in the preliminary design stage

The living room area, however, have enough floor space to rearrange the seating area and thus the solutions are not relevant to discuss with a naval architect as these problem can easily be solved in final design stage, unless the floor space is limited. In that case the seating arrangement should have been taken into account before the final layout parameters would have been final.

7.6.2 Dining room area

The Table 7-8 below presents an overview of the analysis to comfort design for the main deck dining room and the proposed solutions to avoid human orientated design problems in the future together with the naval architectural comments. The Table is accordingly discussed in this section.

Table 7-8 overview of the analysis to comfort design for the Main deck dining area

Main deck				
Spaces type analysed	**Analysed missing comfort design factors**		**Appendices to the comfort design principles**	**Suggested solutions**
Dining room	Dimensional comfort	X	B1.1-I-2.3	**R**earrange room layout and implement mapping elements **A**pply principles to Human comfort design factors (Appendix B)
	Comfort in use	X	B1.2-2.2-3.3	
	Postural dimensions	X	B2.1-2.2-2.3	
	Comfort of interactions	X	B1.4-3.3	
	Physical ambient	X	B3.1	
	Sensory comfort:		B1.1-1.3	**R**earrange the room-layout **A**pply principles
	Visual	X	B2.3-2.4-3.4	
	Hearing	Unknown	**B2.5**	**R**un questionnaires amongst Passengers/crew and measure noise and vibration levels. **R**elocate areas in order to avoid noise and vibrations disturbance from adjacency rooms **P**lace Isolation between rooms/decks
	Vibratory comfort		**B1.3-2.5-3.2**	

As shown in Table 7-8, this section will demonstrate that 5 out of the 5 analysed human comfort design factors are missing for the main dining area on board mega yacht X.

7.6.2.1 Dimensional and postural comfort

In this paragraph the dining room area is analysed for dimensional and postural key factors.

7.6.2.1.1 Identified gaps

The dining table setting in Fig. 37, set for 12 persons, two important questions arise:

I. **Comfort in use**; traffic flow and logistics in the dining room area; are the walking areas/lanes wide enough for crew to comfortably wait for the guest?

II. **Dimensional and Postural comfort**; ergonomics in relation to the space dimensions; is there enough freedom of movement for the guest while having dinner and how does this possibly relate to the choice of dimensions of the dining room space?

General guidelines given by the American Institute of Architects on dining areas and personal space, the following can be stated: 300 square inches or 0.19 square meters is used in general per person for comfortable dining (LLC, 2006). Analysing the missing human key factors for the dining space on board mega yacht X, Fig. 37, reveals that there is not enough personal space per guest to fully enjoy their meal on the comfort level required on board luxury mega yachts.

Fig. 37 Mega yacht X main dining Area (Oceancoyacht)

Layout of the main dining area in Fig. 37 on the right shows the dining table in the middle of the space with 10 chairs around it and 4 chairs for spare on the side. The layout however, shows an unrealistic view, because there are 12 guests in total and not 10. The Fig. 37 on the left shows a picture of the same dining table with a setting for 12 guests. When dining with 12 guests at the same time, there is less than 30 cm apart, which is the most intimate personal distance and therefore does not meet up with the design principles on comfortable dining. When dining for more than 2 hours, postural comfort will decrease and the lack of comfortable freedom of movement should increase the discomfort levels and mood of the guests. Taken into account that when eating, several motions of the arm and hands are needed, and thus to make the overall dining experience more pleasant and comfortable; at least the chairs need to be 30-45 cm distance apart in commercial restaurant areas. The most luxurious mega yachts should exceed this 30 cm comfort principle.

The above mentioned factors affect personal space. The type of space on board, their occupancy, type of ship and destination and sea keeping behaviour of the ship are all

influencers of personal space and need to be considered in the preliminary design stage in order to personalise the space.

As most interiors of ships are designed after the preliminary design stage, the general layout spatial dimensions are already predetermined. When the design space for the dining room is set out, crammed feelings and uncomfortable personal space is a result. Designers need to keep in mind that design rules for a mega yacht, or any ship, are different than from on land spaces, because of possible rolling and pitching movements of the ship due to seagoing behaviour. As even the subtle movements are noticeable, more personal distance is required.

7.6.2.1.2 Proposed solution to consider in the preliminary design stage

See also upcoming section 7.6.2.2 for physical ambient comfort

Dining should be an experience; designing the correct comfortable table setting is therefore a very complex subject and has many influencers in order to make the customers feel comfortable, as was discussed in the Critical Review. Time and target group are key influencers to the design of the chairs and the setting of the furniture. In non-commercial settings, like the private mega yachts' dining rooms, owners can choose what is comfortable and desired for them in order to entertain the guests. Most owners choose the furniture from an aesthetic point of view rather than an ergonomic one. It is the task of the interior designer to consider both aesthetics and ergonomic design guidelines.

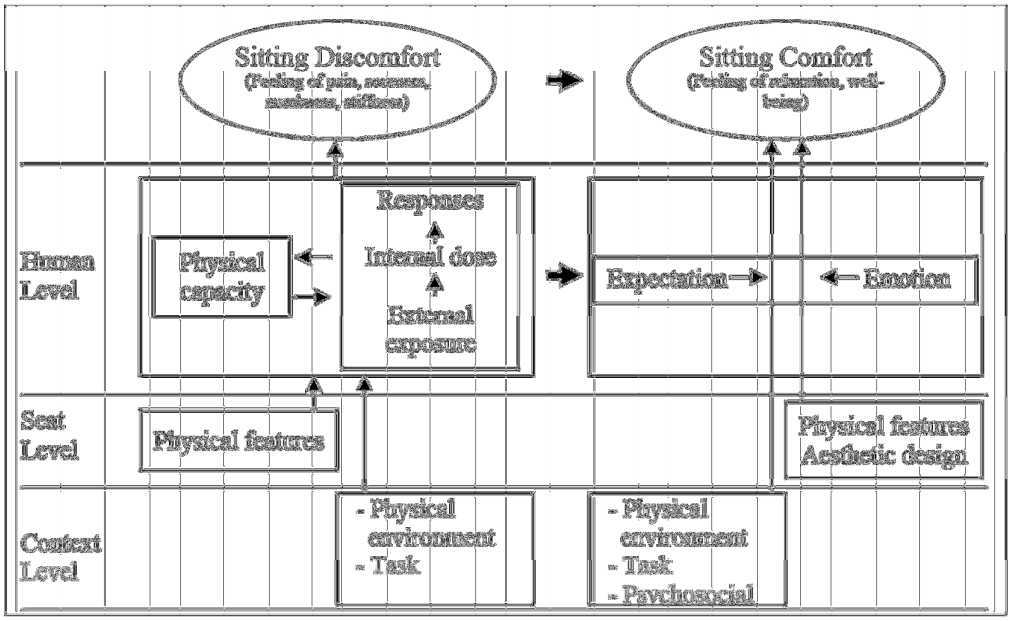


Fig. 38 reasoning scheme of comfort and discomfort and its underlying factors at Human level, seat level and Context level (M.P. de Looze, 2003)

The, de Looze et al reasoning scheme (Fig. 38), can be used as a guideline. The three underlying levels of comfort and discomfort are shown in relationship towards each other; Human level, Seat level and Context level. Shown at the right side of the scheme are the underlying factors of discomfort sitting on human level, physical capacity, that have an influence on the comfort sitting at the same time and the expectations and emotions of the persons. Together with the underlying factors on seat level, which are for discomfort sitting physical factors and for comfort sitting physical features and aesthetic design, these underlying factors determine the persons overall wellbeing and comfort when sitting in that chair. One thing is missing in at two levels and that is the influence of the environment and the task that need to be carried out, these are shown at the Context level on both sides. The absence of comfort doesn't necessary mean discomfort and the absence of discomfort doesn't guarantee the persons comfort.

By implementing these factors into the preliminary design stage, the naval architect can consider the rearrangements of the main deck's layout. The designer could

propose to arrange for a more open plan design in a way to create more table space for each guest.

7.6.2.1.3 Naval architectural comments

Yet again the lack of human oriented key factors to interior design is also related to lack of space. Creating extra space on the vessel has a major impact on all main naval architectural design parameters and affects weight distribution, required engine power and stability.

7.6.2.2 Physical ambient comfort, comfort of use and comfort of interactions

In this section the dining room area is analysed for physical ambient comfort, comfort of use and comfort of interactions

7.6.2.2.1 Identified gaps

Analysed in the previous section was the line of vision from the seating area in Living room; the view outside the window in the dining area even so is obstructed from a seating position, by cabinets positioned in front of the windows.

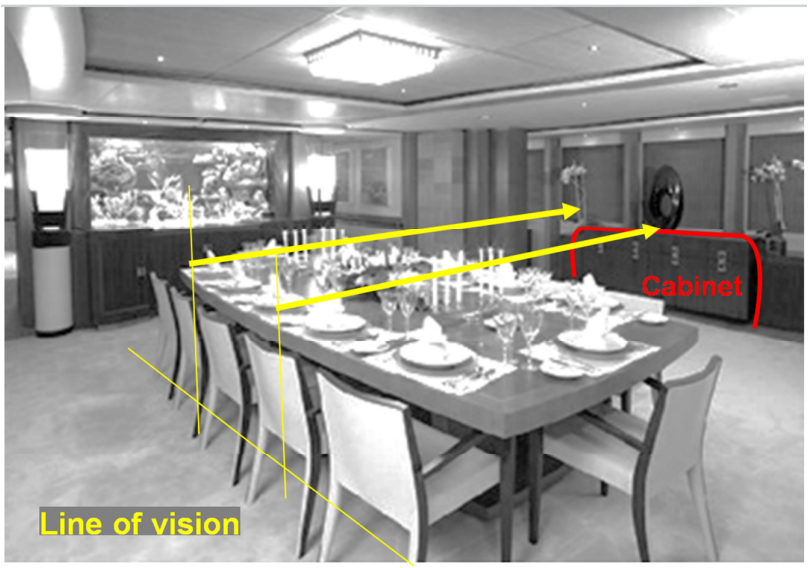


Fig. 39 dining room on board mega yacht X; obstruction of the line of vision, caused by high positioned windows and a cabinet (Oceancoyacht)

- Limited physical ambient comfort; comfort of natural daylight; The windows are large, but not as large as shown on other mega yachts, and therefore this dining room is limited in fulfilling their guests needs to create maximum physical ambient comfort
- Limited spatial comfort and comfort of use: The guests in the dining room area, when seated, have no view outside the window, as their view is obscured by the cabinets placed in front of them. The windows are not from floor to ceiling as shown on other mega yachts (Fig. 40).

7.6.2.2.2 Proposed solution to consider in the preliminary design stage

A rearrangement of the room layout needs to be considered in the preliminary design stage in order to adjust the parameters of the ship when needed or to make necessary changes in the overall ships layout. Fig. 40 is an example of how the dining room in yachts could look like when the naval architect implements the analysed missing comfort factors into the preliminary design stage of the yacht:

- Physical ambient comfort: comfort of natural daylight
- Comfort of use: spatial traffic flow, for crew to wait on the guest while enjoying their meal
- Comfort of posture: there is enough space in-between the chairs. The chairs are arranged in a way that each guest have more than 30 cm of personal space, as was discussed in the previous section.
- Dimensional comfort: large windows give an optical illusion of space by the extended view.

Fig. 40 Dining room mega yacht: good example of implemented physical ambient comfort (natural daylight comfort); Dimensional comfort (optical illusion of the extended view) and comfort in use (space for crew to wait on the guest) and postural comfort (chairs with enough space in between them for maximum comfort of movement) [photo: MY Pegasus V: Charterworld, 2010]

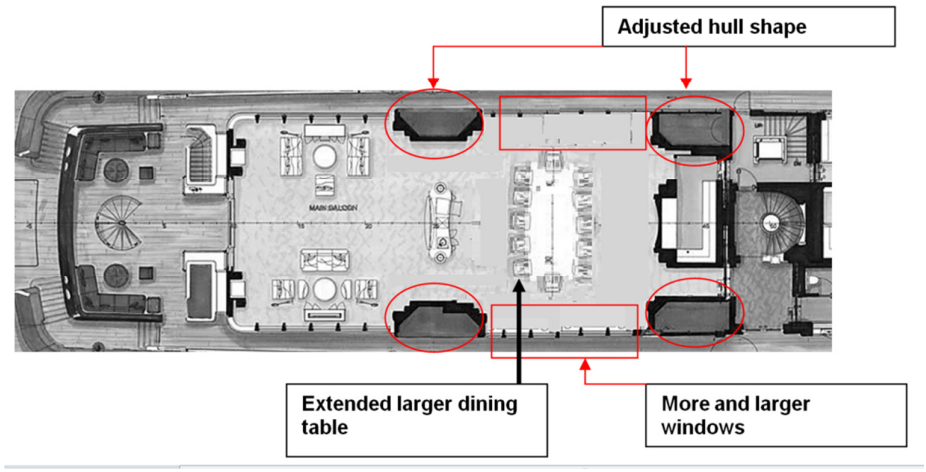


Fig. 41Mega yacht X's main dining room area with the implemented analysed missing comfort design factors

Fig. 41 shows the layout of the main dining area on board mega yacht X with the analysed missing comfort factors as described above. The proposed solutions are for the naval architect to:

- The A/C units and the likes are kept within the red-circled grey areas, as shown in Fig. 41. This takes up a lot of main deck living room space. Rearrange the general lay out and consider the relocation of the A/C units to create more personal space per guest.
- Design larger windows to create more natural daylight without view obstructions as shown in the example in Fig. 40
- Extend in length or width when necessary and rearrange the main deck's layout to create more space for the dining table suitable to give 12 guests the personal space they need and expect form a luxury mega yacht

7.6.2.2.3 Naval architectural comments

Once more the lack of human oriented key actors to interior design is related to lack of space. Creating extra space on the vessel has a major impact on all main naval architectural design parameters and affects weight distribution, required engine power and stability. Increasing size of the widows affects the stiffness of the ship's structure. This is an important factor when considering ship vibrations. Extra stiffeners may be required for the support of the deck above, which affects the weight distribution of the vessel.

7.6.3 Corridors

The Table 7-9 below presents an overview of the analysis to comfort design for the Main deck corridors and the proposed solutions to avoid human orientated design problems in the future together with the naval architectural comments. The Table is accordingly discussed in this section.

Table 7-9 overview of the analysis to comfort design for the Main deck corridors

Main deck				
Spaces type analysed	**Analysed missing comfort design factors**		**Appendices to the comfort design principles**	**Suggested solutions**
Corridors	Dimensional comfort	X	B1.1-I-2.3	Apply the principles to dimensional comfort design factors into the preliminary ship design stage
	Comfort in use			
	Postural dimensions			
	Comfort of interactions			Rearrange room layout in order to improve on dimensional comfort; only if owner decide this is miscarry
	Physical ambient [artificial and day light, temp, climate etc]			
	Sensory comfort: [comfort of the senses]	Unknown		
	Hearing			
	Vibratory comfort			

As shown in Table 7-9, this section will demonstrate that 1 out of the 5 analysed human comfort design factors are missing for the main deck corridor on board mega yacht X.

7.6.3.1 Dimensional comfort

In this paragraph the dining room area is analysed for dimensional comfort.

7.6.3.1.1 Identified gaps

Fig. 42 shows the corridor width between the guest cabin areas on mega yacht X, which is about 1.1. m. For safety purposes the building codes require a minimum comfortable corridor width of 2.44 m (or 8ft) in hotels (Binggeli, 2012), that is at least twice the width as the minimum required width on board passenger ships, according to the ABS passenger comfort guide (ABS, Passenger comfort on ships, 2002), which is 1.1 m. (See also SOLAS, Chapter II-2, regulation 28). For the guests the corridor may therefore appear uncomfortably narrow or crammed which compromises the perception of dimensional comfort.

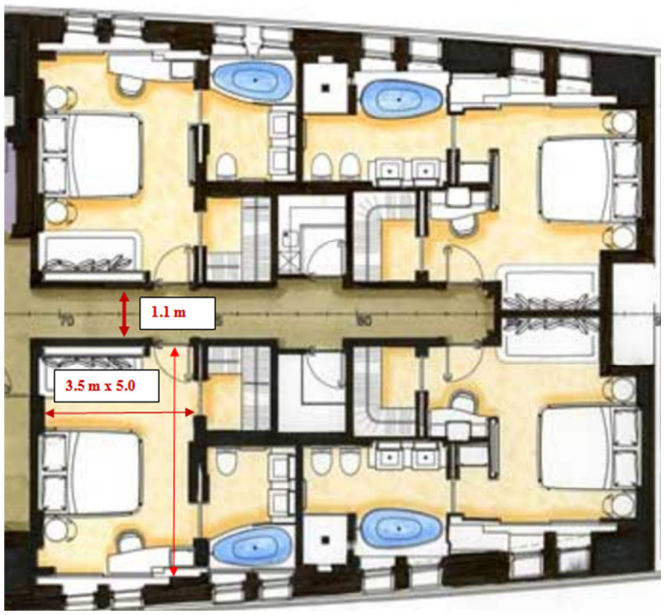


Fig. 42 Interior dimensions of the VIP rooms and guest rooms, as shown in the layout of Mega yacht X

To further demonstrate that corridor width does affect the perception of luxury. Fig. 43 shows an example of a mega yacht corridor where dimensional comfort has been implemented correctly according to the design principles (Appendix B- I).

Fig. 43 Voronoi mega yacht corridor design (Kim, 2010)

The corridor area of this design award winning mega yacht design ticks all the boxes considering the dimensional spatial comfort. This high level of comfort has been achieved by applying the following principles:

- Symmetry and alignment for both port and Starboard side
- Asymmetrical balance on port and on Starboard side
- Radial balance; central focus point; art object in the middle
- Colour balance and harmony; white, bright colours in the space that even so create the optical illusion of spaciousness because of the reflection of light.
- The Golden ration is applied (corridors compared to the overall space). The ratio of the sum of the quantities to the larger quantity is equal to the ratio of the larger quantity to the smaller one.
- Visual weight has been increased by the 'floating' floors and cabin doors that seem to disappear into the walls.

7.6.3.1.2 Proposed solution to consider in the preliminary design stage

Following the last example analysed shown in Fig. 43 an open-plan arrangement may be a solution to introduce dimensional comfort in the corridors. There are other ways to improve spatial comfort such as carefully mapping of the spaces in the preliminary design stage in order to be able to introduce symmetry and alignment, radial balance and implementation of the golden ratio.

Mega yacht designers choose to save the extra space from corridors, in order to create extra space for accommodation areas, and for this reason; not all the comfort design principles are relevant in the mega yacht interior design Industry. If the safety regulations are properly implemented there is, in this case, no need to waste extra space on comfortable corridor width. The choice is the owners.

7.6.3.1.3 Naval architectural comments

Some naval architectural comments are to be made concerning corridors and spatial and optical comfort. Above suggested solutions may impact the following:

- Noise and vibrations

- Weight distribution and stability
- Safety

7.6.3.1.4 Noise and vibrations:

Although the open-plan Voronoi design corridor may be comfortable considering comfort of space, there are some concerns for the effect this layout may have on noise and vibrations.

Open-plan arrangements are likely to increase noise and vibration annoyance, which affects the sensory comfort. Sound reflection may occur creating echo effects which make the space feel hollow. In addition, sound propagates more effectively as there are little obstructions blocking its transmission path. Both machinery noise and noise generated by the activities of people on board, need to be considered.

In order to increase the perception of spaciousness, the corridors have been designed as cantilevered structures. These structures need to be carefully analysed in the design stage for natural frequencies in order to prevent high vibration levels. Additional stiffness may be required which may increase the weight of the structure.

7.6.3.1.5 Weight distribution

Open space arrangement hugely impacts the general layout, stability and weight distribution of the ship. Other solutions have been suggested which involve introduction of visual balance through, symmetry, alignment and radial balance. These are considerations that need to be done very early in the design stage as applying symmetry; alignment and radial balance affects the layout of the vessel which has implications on primary naval architectural design parameters.

7.6.3.1.6 Fire safety

Fire safety regulation will need to be observed as well. Open spaces may not comply with these fire and safety rules (See SOLAS 14B.2.3 and Appendix C2).

7.6.4 Guest cabins

The Table 7-10 below presents an overview of the analysis to comfort design for the main deck guest cabins and the proposed solutions to avoid human orientated design problems in the future together with the naval architectural comments. The Table is accordingly discussed in this section.

Table 7-10 overview of the analysis to comfort design for the main deck guest cabins

Main deck				
Spaces type analysed	**Analysed missing comfort design factors**		**Appendices to the comfort design principles**	**Suggested solutions**
Guest cabins	Dimensional comfort	X	B1.1-I-2.3	1. Implementing postural dimensions of the average person into the preliminary design stage of the layout plan, 2. Rearrange the fixed furniture layout plan by adding the design principles for furniture arrangement and postural dimensions
	Comfort in use	X	B1.2-2.2-3.3	
	Postural dimensions	X	B2.1-2.2-2.3	
	Comfort of interactions	X	B1.4-3.3	
	Physical ambient	X	B3.1	
	Sensory comfort:			
	Visual			
	Hearing	X	B2.5	**For more research:** **R**un questionnaires amongst Passengers/crew and measure noise and vibration levels. **Preliminary design stage** **R**earrange room layout in order to avoid noise and vibrations disturbance from adjacency decks and rooms
	Vibratory comfort		B1.3-2.5-3.2	

As shown in Table 7-10, this section will demonstrate that 6 out of the 6 analysed human comfort design factors are missing for the guest cabins on board mega yacht X.

7.6.4.1 Dimensional, postural comfort, comfort in use and sensory comfort

The following two sections show the analysis to the missing comfort design factors: dimensional postural comfort, comfort in use and sensory comfort

7.6.4.1.1 Identified gaps to dimensional comfort

In order to analyse the missing comfort factors on board mega yacht X's guest cabins, an evaluation is made for the hospitality industries' most luxury hotel rooms as of the resemblance in human comfort factors and their equality in target groups; wealthy families, affluent leisure and business travellers. Fig. 44 shows a standard guest cabin on board mega yacht X.

Fig. 44 Right: mega yacht X guest bedroom, left VIP room (Source: charteryacht.com)

In the ABS, passenger comfort guide (2002), or other classification societies, like RINA, Lloyds etc., criteria are set for dimensions for passenger cabins, doors, edges of furniture etc. As these criteria are mainly set for passengers on board commercial ships or yachts, this is not necessarily required for private yachts. The dimensional criteria are set for a standard passenger cabin is 13.9 ^{2} m in area.

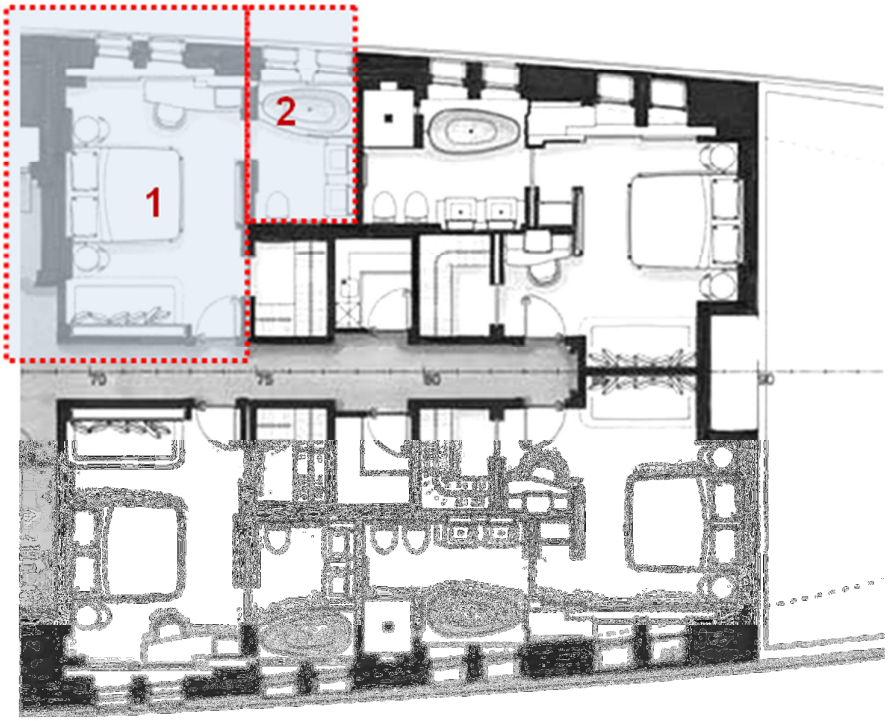
Mega yacht X's guest cabin is analysed by means of a typical hotel star rating system (see Fig. 45). The higher the stars, the more luxury the customers expect. Analysed research show that the average passenger ship guest cabin's dimensional standards of 13.9 m^{2}, resembles that of a typical 1 star hotel room.

Hotel	Double Room size minimum	bed size minimum
1 star	14 m²	140 x 190 cm
2 star	18 m²	150 x 190 cm
3 star	22 m²	160 x 200 cm
4 star	34 m²	180 x 200 cm
5 star	34 m²	180 x 200 cm
ABS Passenger comfort	13.9 m²	
Mega yacht X	17.5 m² exl. Bathroom and wardrobe	153 x 203 UK (60" x 80 ")
	27.5 m² incl bathroom and wardrobe	

Fig. 45 Comparison between requirements of hotel room dimension and that of mega yacht X and Passenger accommodation regulations

Analysing the mega yacht guest cabin of Fig. 44, the table of Fig. 45 shows that an interior dimension of 17.5 m² and a bed size of 153 x 203 cm resemble roughly that of a 3 star hotel room. The conclusion is that the mega yacht guest cabin does not meet with the luxury comfort standards as required by this type of upper class public.

Another analysed example to demonstrate the missing comfort factor in postural and dimensional comfort on board mega yacht X is the following:



Guestroom configurations			
	Ideal dimensions Hotel	Dimensions guest room onboard Mega Yacht X	Comparison between Hotel deluxe room and Mega yacht guest room
Area 1: Bedroom	24 sq m or width 4.6 m with a min of width of 3.7 m	17.5 m² (3.5x5) or width of 3.5 m	Under the minimum width required for a hotel room.
Area 2: Bathroom	Width:2.77 m (required min is 2.62 and comfortable is 2.69 m	7.5 sq m (3x2.5) or Width +/- 3m	Deluxe

Fig. 46 Interior design guidelines and guestroom configurations; Hotel room deluxe versus mega yacht X

Fig. 46 shows the layout of the guest cabin located on the main deck. Area 1 is the bedroom and area 2 is the bathroom area. The table of Fig. 46 presents the minimum width for a typical hotel room of at least 3.7 m in width, while on board mega yacht X the guest cabin width shows 3.5 m. This is below the average required minimum width for hotel standards.

The bathroom area on board mega yacht X that has a width of 3 m, however, is in agreement with the luxury design standards, where the required minimum width is

2.7m. These results can be confirmed by the interior design guidelines as presented in Appendix B.

7.6.4.1.2 Identified gaps to postural comfort

To analyse the missing gap in postural comfort on board mega yacht X, the following analysis show that guest bed dimensions are not according to the luxury comfort standards as also demonstrated in the previous section.

The most important focus point inside a cabin is the bed. The minimum bed size requirements, created by the for example the Qatar Building requirements a star rated hotel room should have the following bed size dimensions:

- 1 star rated hotel room, bed size of 140 x 190 cm
- 2 star rated hotel room, bed size of 150 x 190 cm,
- 3 star rated hotel room should have a minimum bed size of 160 x 200 cm
- and in 4 and 5 star hotels this should be 180 x 200 cm

The mega yacht guest cabins and VIP cabins have a standard bed size; of 153 x 203 cm - 160 x 200 cm, also referred to as: queen size (the actual Queen size measurements depends on the country). According to the star rating system the bed size on board Mega yacht X belongs in a 3 star hotel room, as also was demonstrated in the previous section.

As can be concluded out of the above; as the size of beds is already small considering hotel standards, for mega yachts this size of the beds could even lead to postural discomfort. The ships' constant movement, caused by sea swell, rolling and pinching creates a higher need for personal space, as was demonstrated by research presented in the critical review of this thesis.

7.6.4.1.3 Proposed solution to consider in the preliminary design stage

As shown in this section the guestrooms on board the mega yacht X fulfil the requirements for only a 3 star hotel room. This is mainly due to lack of space. Owners may consider fewer guests on board the yacht to improve on dimensional and postural comfort. To implement these missing comfort design factors as analysed above, improvements only can be made when the parameters of the ship and overall layout has not been finalised. The way to accomplish this is to first implement the parameters to the dimensional comfort into the preliminary design of the yacht (See Appendix B-I). This means that the size of the corridors, the beds, furniture layout, and routing, emergency exits etc., all need to be well defined before the general ships layout is made final.

In order to show a good example of a mega yacht where the dimension and postural comfort factors are implemented: mega yacht A shows possible solutions to the above analysed problems; Russian billionaire Andrey Melnichenko's yacht, known as 'A', is an unusually designed super yacht by both interior designer Philippe Stack and naval architect Martin Francis (Fig. 47). Fig. 48 shows the interior of the masters bed room found on board mega yacht A. For this cabin all the dimensional comfort factors have been implemented.

Fig. 47 Super Yacht 'A', Philippe Starck (Charteryacht)

There are six guest suites on this yacht, but movable leather-covered walls make it possible to create four larger suites, in order to create larger rooms in case the guests require more personal space.

Fig. 48Mega yacht A: Owners cabin (source: Urdesign.it)

The master bedroom on 'A' is located at the top of the structured tower accommodation, Fig. 48. The interior lay out of the Masters' bedroom appears very spatial due to its implemented spatial design elements (see also principles to spatial comfort Appendix B 1.1 / 2.3). These elements are:

- Mega yacht A: Physical ambient comfort: windows all around to provide maximum comfort of natural daylight
- Mega yacht A: Dimensional comfort: optical illusion of extra space: the many windows provide an extended view.
- Dimensional comfort: optical illusion: The window design is slightly inclined and ensures the guests for some great panoramic views, a different perspective is gained. People's brain will be affected by this trick and it looks like if the space continues outside more than in.

Mega yacht X can rearrange their general layout and hull structure in order to implement more windows or increase the size of the windows where necessary.

- Comfort of use, traffic flow, the routing of the room is designed spaciously around a radial focus point; this will increase the walking flow.

Mega yacht X could make use of this principle too by rearranging the guest cabins' layout or adjust the hull shape and general layout.

The following spatial design elements are also shown on mega yacht A, which add to its optical illusion of space, but do not necessarily need to be implemented in the preliminary design stage, but needs consideration:

- Asymmetrical balance; the interior of the room is asymmetrically balanced, this created a visual illusion of space
- Scale ratio and visual weight; the various objects in the room have been carefully designed in a way that they don't add to visual weight. Visual weight is one of the principles to optical spatial design and by decreasing visual weight of the room, the illusion of space can be created by:
  - Light colours are used for furniture and walls; bright cream white
  - Reflection of light by mirrors; bathroom cubic
  - Create a sense of space by placing the objects off the floor (bed is on a rotating platform)
  - Artificial light all around. Example; above the bathroom cubic is a light spot fixed that makes the ceiling appear higher than it actually is.

7.6.4.1.4 Identified gaps in comfort in use

Interior traffic patterns are of paramount importance to the people on board. Both comfort and safety play a big role in the design of traffic patterns within the interior layout. Principles to human orientated design for traffic patterns within the room itself are presented in the Appendix B1 and B2. The guidelines describe that the traffic flow within the room needs to be free from any obstruction and the exits of the room need to be unobstructed.

Lack of comfort in use for mega yacht X cabin mainly concerns the interior traffic patterns (see Fig. 49):

The location of the desk and the chair in the cabins negatively affect these traffic flows. The desk and chair are obstructing the interior traffic route in the cabin between the cabins' wardrobe and the cabin door. Even so when the writing desk would be in use there is little space for the user to move backwards without blocking the two entrances or traffic route in the room, as indicated by red arrows. The normal traffic flow patterns are indicated by arrows (Fig. 49).

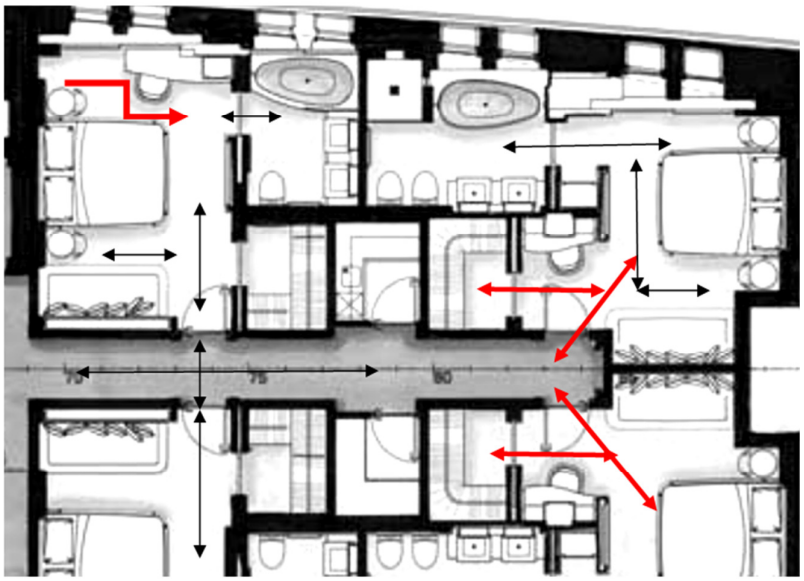


Fig. 49 Cabin desk and chair in VIP Guestrooms blocks the traffic flow, when the chair is pulled backwards, as indicated by the traffic flow arrow in red, against the normal traffic patterns in the cabins indicated in black.

Another example to demonstrate the discomfort of use on board mega yacht X is the blocked traffic flow between the guest cabin entrance and the corridor.

Fig. 50Cabin desk and chair in VIP Guestroom: walkway is blocked by the desk chair when in use

Fig. 50 shows the layout of the entrance to a guest cabin on board mega yacht X. The positioning of the desk and the chair in the cabin is positioned near the entrance of the walk-in wardrobe as well as the main cabin entrance. When the desk is in use or the chair is completely pushed back to allow the user to walk away, both entrances are completely blocked and will cause a problem specifically to the safe exit access travel route. Between the walk-in wardrobe and the exit of the cabin is very little space for the possible desk user when sitting behind the desk to push the chair backwards without blocking either the entrance to the wardrobe or the exit of the cabin. This safety aspect could have been resolved when considered in an early design stage.

7.6.4.1.5 Proposed solution to consider in the preliminary design stage

In order to implement the parameters of comfort of use, the principles are listed in Appendix B 1.2. The layout of the structure, exits and even the main furniture need to be mapped carefully before the parameters of the room are finalized.

7.6.4.1.6 Identified gaps to sensory comfort: noise and vibrations

There are many noise and vibrations rules and regulation and guidelines such as (ABS, Guide for the class notification Comfort-yacht (COMF(Y)) and Comfort plus-yacht (COMF+(Y)), 2008). There is still a lot of research going on in that field investigating the effect of noise and vibrations on human performance and perception of comfort. One of these projects is SILENV, a Collaborative project funded by the European Commission under the 7th Framework Program, Theme Transport - Grant Agreement N° 234182t. For this project Strathclyde University in Glasgow has developed mathematical models calculating the effect on human performance and perception of comfort for given noise and vibration levels.

Long exposure to continuous high levels of noise causes fatigue and hearing degradation on people working and living on board and cause serious discomfort for passengers (Kurt et al, 2010). This section analyses the missing comfort factor of hearing for the front two guest cabins.

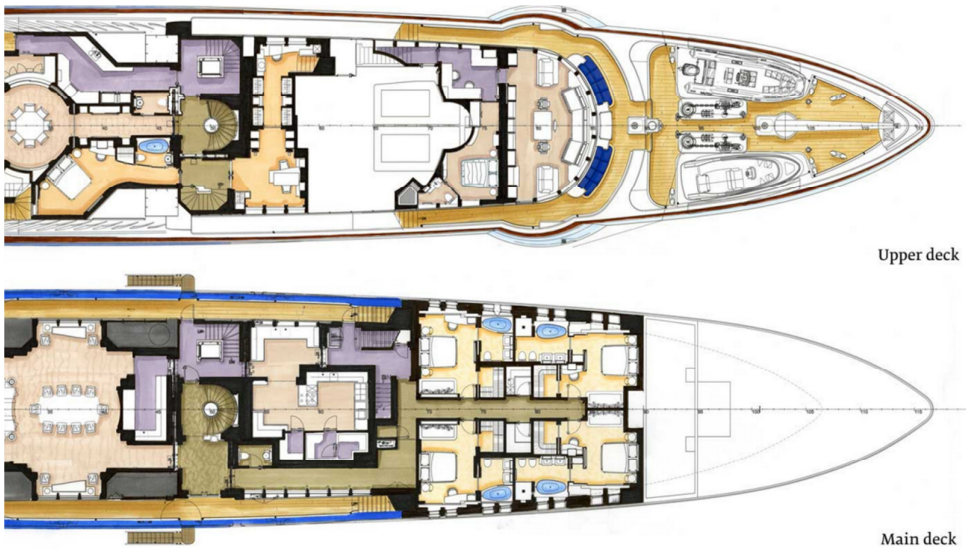


Fig. 51 Mega yacht X; main deck guest cabins and adjacency deck: Upper deck with deck equipment

Fig. 51 presents the main deck guest cabins and adjacent deck: upper deck with deck equipment. Although these analyses require measurements on noise levels in order to

analyse exactly if the guests in the front 2 cabins experience any irritation or fatigue from the adjacency deck above, the following prognostication is made:

- Guest sleeping in the front two cabins might experience a certain discomfort coming from the deck equipment on the upper deck, when in use. The head side of the bed is positioned to the bridge adjacent bulkhead which might cause disturbance of sounds when the deck equipment is in use
- Guest resting in the front two cabins might experience discomfort of sound at night when officers on duty on the above bridge deck chat or walk up and down the deck. The same might be the case for the Captain's cabin (upper deck) adjacent to the bridge; the captain's double bed is positioned with the beds head to the bridge adjacent bulkhead.

7.6.4.1.7 Proposed solutions to consider in the preliminary design stage

1. Consider the parameters of the principles to human orientated design of Appendix B1-3, as far as possible for this stage,
2. Improve on comfort design factors by implementation of the room-mapping elements (Appendix B1.1/I)
3. Rearrange room dimensional layout,

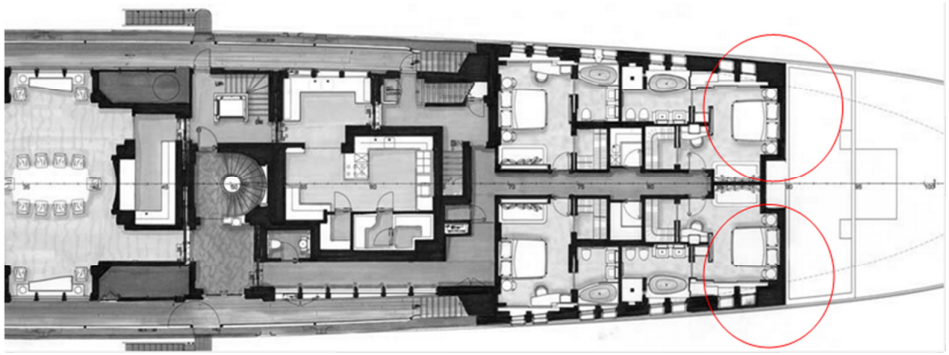


Fig. 52 Suggestion for the preliminary design stage: front two guest cabins need rearrangements of the room layout

Fig. 52 presents suggestions for the layout of the front two guest cabins as to implement the missing comfort factors of sound. The original layout shows the front two guest cabins with the pillow end of the bed towards the bulkhead that adjoins the outer decks. The room could easily be rearranged in way that the pillow end of the bed is positioned to the other end of the room. In this way there is no connection to the bulkhead that might cause discomfort of sound coming from the deck equipment

The same can be suggested for the Captains' cabin located on the bridge deck or upper deck.

Principles to sensory comfort are described in Appendix B [B1.3/2.5/3.1 and 3.2]. The greatest concern for room comfort is sensory comfort, or background noise in the room. One way to measure the quality of the sound in the room is to take the average sound absorption coefficient for all materials combined in the room, include windows etc. The outcome of this number will be an indication for the comfort concerned with noise in the room. Sound absorption materials are used in a room to control noise levels or shorten the reverberation time. At ships extra challenge is to avoid noise travelling from the engine rooms, propellers etc. Besides the choice of the naval architect to locate certain accommodation rooms as far as possible from the noise sources on board, add sound absorption material in the room is of paramount importance to add in sensory comfort of guests and crew on board.

7.6.4.2 Naval architectural comments

Applying the dimensional, postural and comfort of use factors described in the above sections can only be done in close cooperation with the naval architect. Already in the preliminary design stage, size of main furniture needs to be known in order to optimise the cabin layout for a comfortable internal routing. This layout of the cabin affects the required space for all cabins, which could have implications on either the number of people that can be accommodated, or the overall ship size. Not only should dimensional, postural and comfort in use be considered when designing a cabin layout. There are also safety and fire requirements for the routing.

Noise irritation can be split into two main areas: the first one is machinery generated noise and the second one human generated noise, of which one is noise transmitted between areas on board and two is noise irritation caused by reflection. The best way to avoid discomfort of noise is:

- Re-locate certain accommodation spaces and make sure they are not directly adjacent to the source of noise.
- Isolate certain accommodation areas by means of staircases, corridors and by placing extra walls in-between the noise areas and the accommodation rooms.
- Other steps the interior designer or the naval architect can consider to mitigate nuisance of noise see Appendix B [B3 Noise and Vibrations].

The above demonstrates the necessity of implementing the human factors in the preliminary design stage of the design spiral, as the naval architect needs to make adjustments to the general layout. Good cooperation between all parties is of paramount importance.

7.7 Upper deck

This section analyses the main living spaces on board mega yacht X's upper deck for gaps in the human orientated interior design by identifying the missing key human elements and how that can be improved by implementing the missing human principles into the preliminary design stage of mega yacht X.

7.7.1 Saloon

The Table 7-11 below presents an overview of the analysis to comfort design for the upper deck saloon or game room and the proposed solutions together with the naval architectural comments, to avoid human orientated design problems in the future. The Table is accordingly discussed in this section.

Table 7-11 overview of the analysis to comfort design for the Upper deck Game room area

Upper deck				
Spaces type analysed	**Analysed missing comfort design factors**		**Appendices to the comfort design principles**	**Suggested solutions**
Saloon	Dimensional comfort	X	B1.1-I-2.3	**R**earrange room layout and implement mapping elements **A**pply principles to Human comfort design factors (Appendix B) **R**earrange general layout to create more space for the Saloon's Table and seating area
	Comfort in use	X	B1.2-2.2-3.3	
	Postural dimensions	X	B2.1-2.2-2.3	
	Comfort of interactions	X	B1.4-3.3	
	Physical ambient		B3.1 B1.1-2.4-3.4	
	Sensory comfort:		B1.1-1.3	
	Visual		B2.3-2.4-3.4	
	Hearing	Unknown	**B2.5**	
	Vibratory comfort		**B1.3-2.5-3.2**	

As shown in Table 7-11, this section will demonstrate that 4 out of the 5 analysed human comfort design factors are missing for the Saloon area.

7.7.1.1 Identified gaps for dimensional, postural, comfort in use and comfort of interaction

Although the dimensions of the Upper decks Saloon area are quite large (about 11 meters in length, Fig. 53), the traffic patterns (shown in the Figure with red arrows) do not apply with the comfort principles. The traffic patterns within the room and around the furniture are narrow and not save to use as they interfere with the furniture obstructing and blocking the traffic patterns. When the guests want to make use of the facilities present on the end of the Upper decks corridor (the red square in the Fig. 53), the following is analysed:

- The toilet door is obstructing the corridor main traffic flow because the door is opening outwards towards the corridor, which is only about 1 meter wide.
- The toilet door, when left open even so blocks the path towards the staircases
- For the crew to serve the guests, they need to be able to walk in safety around the tables and furniture to wait on the guest.

The table in the saloon sitting area, set for four persons can obstruct the traffic patterns when the chairs are in use and pushed backward for the guest to sit comfortably (See Appendix B 1.5, comfort of interactions principles). Similar problems can be expected in the games room.).

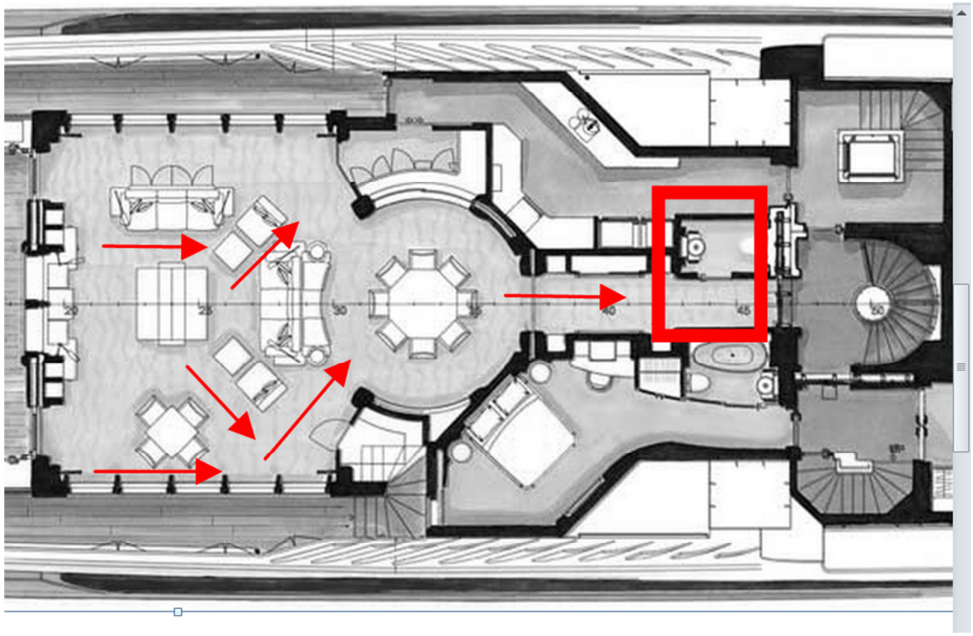


Fig. 53 Upper deck mega yacht X; Saloon

Fig. 54 Upper deck mega yacht X; Game room table, set for 8 persons (Source: yachtforum.com)

Fig. 55 Upper deck mega yacht X's Saloon; Narrow traffic patterns are shown with interference of furniture

Fig. 55 show little red circles where guest or crew can hit themselves when they are walking through the room. The square sharp edges and the narrow traffic patterns in the room together with the dynamic behaviour of the yacht, can make this room uncomfortable in use (absence of the key human factors: comfort in use).

7.7.1.1.1 Proposed solutions to consider in the preliminary design stage

- Rearrange the room layout; less furniture
- Restructure the general lay out, the VIP cabin on starboard side in Fig. 53 can be removed, as discussed in the previous section on adjacency and general layout 7.3.1.

The layout of the servant galley and VIP cabin can be used to restructure the layout to create more space for a game table and facilities that will not block the traffic routes in the room and corridors etc.

7.7.1.1.2 Naval architectural comments

Missing comfort factors identified for the top deck for mega yacht X are all related to lack of space, or, too much furniture. The solution lies within either decreasing the pieces of furniture (less people can be accommodated) or increasing the size of the rooms. Both decreasing the number of passengers and increasing the size of the rooms affects the general layout of the vessel and design parameters that have to be decided on very early in the design stage.

7.7.2 VIP cabin

The Table 7-12 below presents an overview of the analysis to comfort design for the upper deck VIP cabin and the proposed solutions to avoid human orientated design problems in the future together with the naval architectural comments. The Table is accordingly discussed in this section. The VIP cabin was also discussed and analysed as part of the interior routing and layout section (7.3).

Table 7-12 overview of the analysis to comfort design for the Upper deck VIP cabin

Spaces type analysed	Analysed missing comfort design factors		Appendices to the comfort design principles	Suggested solutions
VIP room	Dimensional comfort	X	B1.1-l-2.3	**R**earrange room layout and implement mapping elements **A**pply principles to Human comfort design factors (Appendix B)
	Comfort in use	X	B1.2-2.2-3.3	
	Postural dimensions	X	B2.1-2.2-2.3	
	Comfort of interactions	X	B1.4-3.3	
	Physical ambient	X	B3.1 B1.1-2.4-3.4	
	Sensory comfort:		B1.1-1.3	**R**earrange the room-layout **A**pply priciples
	Visual		B2.3-2.4-3.4	
	Hearing	X	**B2.5**	**R**un questionniares amongst Passengers/crew and measure noise and vibration levels. **R**elocate areas in order to avoid noise and vibrations disturbance from adjecency rooms **P**lace Isolation between rooms/decks
	Vibratory comfort	Unknown	**B1.3-2.5-3.2**	

Analyses of the missing key factors for the VIP cabin located on the upper deck is summarised in Table 7-12. Boxes ticked with an X are the key factors that are missing. It shows that 6 out of 6 key factors are analysed as missing.

7.7.2.1 Identified gaps for to sensory of hearing

The close-up in Fig. 56 shows the third VIP cabin located on the upper deck. This cabin is located in the game room area, which can cause human activity generated noise problems, especially because the head of the queen size bed is situated towards the poker room (Table 7-12; sensory comfort, hearing), demonstrated in section (7.3). The poker or game room is designed for entertainment and guests will have a drink here, enjoy each other's company or play some games etc. This could annoy the person who is trying to sleep in the VIP room. Sensory (dis)-comfort caused by human activity generated noise is a very important psychological key element and is missing in this cabin.

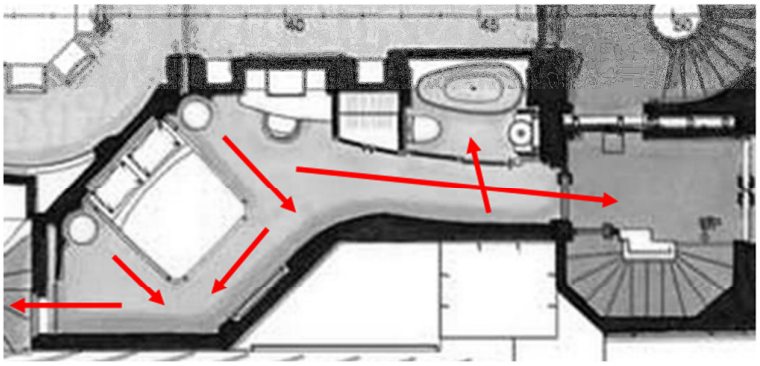


Fig. 56 mega yacht x: upper deck VIP cabin which shows the internal routing with red arrows

7.7.2.2 Identified gaps for to comfort of use, interaction and physical ambient

There is one difference to this VIP cabin compared to the other VIP and guest cabins located on the main deck, namely: comfort of use. The traffic flow and logistics (comfort in use) within the cabin is better organised. The red arrows shown in Fig. 56 represent the flow in the cabin. The flow within the cabin is consistent and no

entrance is being blocked. The furniture in the cabin can be moved and be used as intended without blocking the flow in the room.

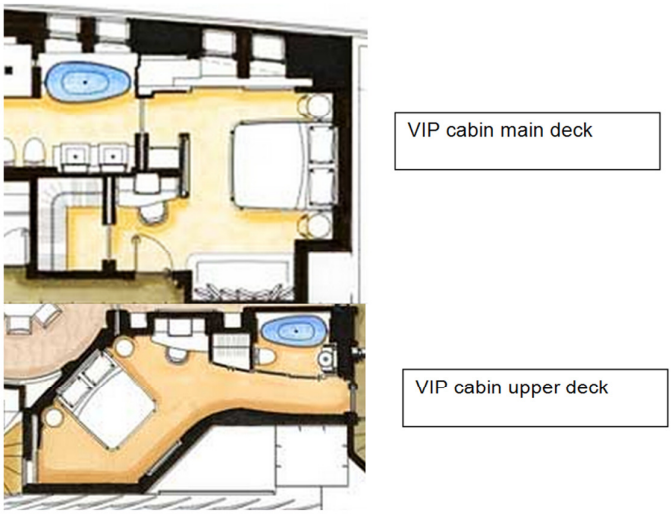


Fig. 57 lay out VIP cabins main deck (above) and upper deck (below)

In Fig. 23Mega yacht X General Arrangement can be shown that the 2 guest cabins and 2 VIP cabins located on the main deck have an indoor walk-in closet (see also main deck VIP cabin in Fig. 57, above). The VIP cabin on the upper deck as shown in Fig. 57 below, doesn't, however, have such a walk-in closet. The main decks' VIP cabins bathrooms even so appear larger and are fitted with two sinks, a toilet and a bidet. The upper decks' VIP cabin is only fitted with one sink and a toilet and in a much smaller space.

The other huge difference is for this VIP cabin compared to the VIP cabin on the main deck is the missing large windows and the sofa. The main deck's cabin has 4 large windows; two in the bathroom and two in the bedroom, and is furnished with a large comfortable sofa, whereas the upper deck's cabin only has one small window in the bedroom, a door to the outer deck and no space for a sofa. The missing key human factor, comfort of use, also leads to the missing key factor, comfort of interaction, as the bed, bathroom and the space in the cabin, is meant to be shared by two people.

The standard used for comfort of use and physical ambient therefore for the other guests and VIP cabins on the main deck are set visibly higher.

Out of this section can be concluded that, however the traffic flow inside VIP cabin appears to be sufficient, the comfort of use and physical ambient for this VIP cabin does not meet with the standards as seen in the other cabins.

The VIP cabin furthermore takes on board the same missing human elements, as analysed for the other guest cabins presented in section, 7.6; Main Deck. This section analysed to the guest cabins' missing key factors; dimensional and postural comfort. A small summarize of this section is presented below.

7.7.2.3 Identified gaps for to dimensional and postural comfort

The most important focus point inside a cabin is the bed. The minimum bed size requirements, according to the hotel star rating standards are 160 x 200 cm for a 3 star hotel bedroom and 180 x 200 cm for a 4 and 5 star hotel room. However the mega yacht VIP cabins have a standard bed size of 153 x 203 cm - 160 x 200 cm, also referred to as: queen size. According to the star rating system this bed size belongs in a 3 star hotel room, as also was demonstrated in section 7.6/ Fig. 45. As can be concluded out of the above; as the size of beds is already small considering hotel standards, for mega yachts this size of the beds could even lead to postural discomfort. The ships' constant movement, caused by sea swell, rolling and pinching creates a higher need for personal space, as was demonstrated by research presented in the critical review of this thesis.

7.7.2.3.1 Proposed solutions as to implement in the preliminary design stage

Although noise generated problems can be solved by noise absorbing walls, the sounds caused by the pleasure time of the guests in the game room can be disturbing to the resting guests in the adjacent VIP cabin. As described, above adjacency analysis needs to be considered before the design of the general layout is determined.

Human generated noise irritation can be mitigated by isolating walls, rearrangement of the general ship layout or rearrange the cabin layout. The following spatial elements could be revised in order to increase comfort in the cabin:

- The bed head in the cabin should not be adjacent to the game table, but could be positioned in another corner of the room
- Extra service corridors in-between the cabin and the game room can function as isolation space to avoid irritation coming from human generated noise in the adjacent rooms
- Consider 11 guest instead of 12, so the VIP cabin on the upper deck can be eliminated
- Relocation of the VIP cabin to the main deck and enlarge the cabin area on the main deck to 5 cabins instead of 4

Above-mentioned advice in order to improve *comfort in use* can also be described as; improvements to the layout interior design and general ships layout as to optimise the adjacency comfort to the persons on board, as was demonstrated in section 7.3: General layout and interior design of mega yacht X.

7.8 Chapter summery

This chapter presented the Case Study in which the identified comfort factors to human orientated design were implemented in an existing mega yacht layout. Subsequently new solutions were proposed for the missing comfort key factors and verified with a naval architectural approach in order to demonstrate the necessity to implement human orientated design into the preliminary design spiral of mega yacht ship design.

8 CONCLUSIONS

Many problems in the mega yacht industry are experienced with the level of comfort and luxury on board the vessels not being in line with the expectations of the mega yacht owner. This leads to disputes between mega yacht owners, shipyards and interior designers. The main aim of this work is to help the naval architect and interior designer to design a mega yacht that does offer the (extreme) luxury and comfort standards a (future) mega yacht owner expects, while complying with the engineering standards.

The first step for that purpose was to identify the key factors to human comfort. In the critical review, 11 comfort factors have been identified and are extensively described (Section 3.10.2.).

In addition, interviews with mega yacht designers, naval architects and ship builders have been carried out. In these interviews the industry acknowledged a lack of awareness of the importance of human elements during the design stage. It also has been established that applying the key factors to human comfort can only be done effectively by considering these factors as early as possible in the design stage. This is why a new integrated design spiral has been suggested (chapter 5).

The importance of integrating interior design key elements to human comfort considerations with naval architectural design configurations has been demonstrated through analysis of the interior layout of mega yacht X (chapter 7; Case Study). Many key elements to human comfort design were missing as shown in Table 8-1. Considering parameters presented in the Appendix B; many areas on mega yachts X do not meet up with the upper class leisure industries comfort standards.

The parameters and principles to the key human elements were implemented in the Case Studies' lay out (mega yacht X); in order to identify the gaps in the human

factor orientated interior design. It has been demonstrated that in general 4 out of 5 human factors that were analysed are missing in the main living areas on board the case studies' mega yacht X (Table 8-1).

Table 8-1 overview of the analysed missing key factors per deck and per analysed room, as demonstrated in the Case Study

Deck and analysed space type	Table	Analysed missing comfort design factors	%
Bottom deck	**N**		
Crew mess		4 out of the 5 analysed are missing	**80**
Lower deck			
Crew cabins	**O**	4 out of the 4 analysed are missing	**100**
Main deck			
Living room	**Q**	4 out of the 5 analysed are missing	**80**
Dining room	**R**	6 out of the 6 analysed are missing	**100**
Corridor	**S**	1 out of the 5 analysed are missing	**20**
Guest cabins	**T**	6 out of the 6 analysed are missing	**100**
Upper deck			
Saloon	**U**	4 out of the 5 analysed are missing	**100**
VIP cabin	**M**	6 out of the 6 analysed are missing	**80**
Total average			**94**

The 5 analysed human comfort design factors were: dimensional comfort, comfort in use, postural dimensions, comfort of interaction and physical ambient. The 6th analysed comfort factor was 'sensory comfort', but only could be analysed in several areas; dining room, guest cabins and VIP cabins. The other areas could not be assessed for the presence of sensory comfort.

The most consistent missing comfort design factor in all 8 rooms analysed was 'dimensional comfort' (Table 8-2 and Fig. 58). After implementation of the parameters and principles to dimensional comfort, it was concluded that only by consideration the parameters to dimensional comfort in the preliminary design stage, the problem could be solved completely. Solutions proposed were amongst others to rearrange the room or ships general layout to allow more space for each guest. Reducing the number of people on board or increasing the size of the ship has been suggested as well. The naval architect needs to anticipate on the interior dimensions before the general layout is finalized.

Table 8-2 Overview of the in the case study analysed main living spaces on board mega yacht X. Marked with X are the missing factors.

Comfort factors	Analysed rooms								Total times missing
	Crew mess	Crew cabins	Living	dining	corridor	Guest cabins	Saloon	VIP cabins	
Dimensional comfort	X	X	X	X	X	X	X	X	8 from 8
Comfort in use		X		X		X	X	X	5 from 8
Postural dimensions	X	X	X	X		X	X	X	7 from 8
comfort of interactions	X	X	X	X		X	X	X	7 from 8
Physical Ambient	X		X	X		X		X	5 from 8
Sensory comfort									
Visual	not measurable (nm)			X	nm	nm			1
Hearing						X	nm	X	2

The most present comfort design factors were comfort in use and physical ambient, but were still missing in 5 out of the 8 analysed rooms (Table 8-2 and Fig. 58). Comforts in use of traffic patterns within the room are of the utmost importance to both safety and comfort of people.

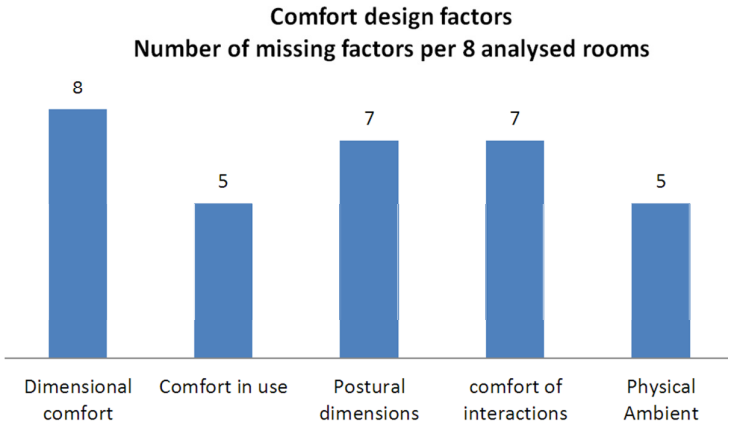


Fig. 58 Number of rooms are shown in where the analysed comfort design factors are missing

It was demonstrated in the sections 7.6.2-7.6.3 and 7.6.4, amongst others, that solutions have their implication on preliminary design parameters like; main dimensions, ship resistance, weight distribution, stability and required engine power. This clearly indicates the need for the integrated human orientated design spiral. Rooms need to be mapped carefully, considering the furniture in the room before the dimensional parameters of the room are finalised, so that emergency exits and corridors are not blocked and effective interior traffic routing within the rooms themselves are guaranteed.

9 FUTURE RESEARCH AND DISCUSSION

9.1 Chapter outline

In this chapter the future research recommendations are discussed as a possible extension to these thesis research areas and could help in raising the awareness for the necessity to human oriented mega yacht design.

9.2 Future research recommendations

As the mega and super yacht business grows, this relatively new industry is still very unfamiliar territory for many naval architects, designers and shipyards. Many complications occur in the final interior design process when the yacht is already in its deliverable state. The high demands of its rich owners and inexperience of working with customers in an upper class leisure industry brings great risk to the shipyards. Small shipyards go bankrupt after complications in the interior design occur in the final state of the building process because the customer does not want to pay for this. Although the many classification societies and IMO regulations give guidelines on the technical human needs in order to avoid discomfort on board the yacht; noise, vibrations, temperature and indoor climate, the Critical Review of this thesis demonstrated that the main problem is the gap in implementation of the factors to psychological human needs. The mega yacht industry recognises that there is lack of awareness of the importance of human elements in design and especially the knowledge of what they can do for the overall design results for mega yachts.

As was demonstrated by this thesis research study that it is necessary to implement human elements into the preliminary design stage of a mega yacht ship design process, it is suggested to bring the importance of the human orientated design

process under the attention of yacht owners, ship builders, interior designers and naval architect's alike. As was confirmed in this thesis' Field Study; in the interview with Bouwhuis (chapter 4), the mega yacht design industries' approach towards interior layout design is very traditional but extremely complex. In times of poor economical market, owners, designers and architects are less prepared to take risks and are less likely to research the possibilities beyond traditional layout design. In order to merge human elements in the preliminary design stage of the mega yacht, it is necessary to bring the importance of this matter under the attention of the mega yacht industry. Research furthermore demonstrated that it is not due to the unwillingness of the mega yacht industry that the human elements are not taken into consideration, but more due to the unawareness of its existence, and moreover, the importance of what it can mean to the overall final design stage of the mega yacht. By demonstrations how implementation of the comfort design factors could be beneficial to all parties involved in the mega yacht design process, problems like these could be solved.

Following the outcome of this research the following future research topics are suggested:

- Developing a framework to human orientated interior design for merchant, passengers and cruise ships.
- Developing a framework to human orientated exterior design.
- Expand upon the human orientated design framework to include easy mega yacht maintenance; interior and exterior design.
- Expand on already existing human orientated design software, such as Kansei engineering, commonly used in Japan for customized car design (see critical review).

9.2.1 Framework to human orientated interior design for merchant, passengers and cruise vessels

It could be researched if it is possible to identify the key human elements to passenger and cruise line interior design too, as well as for Merchant Marine ships, in order to create a comparable human orientated design framework as to implement these elements into the preliminary ship design stage. These two industries have a very different design approach from mega yachts and therefore require a different implementation process. The latest has already been researched for numerous projects for the naval and merchant shipping industry as to mitigate incidents at sea and improve the safety of the seafarers.

9.2.2 Framework to human orientated exterior design

More line of reasoning is the exterior design of mega yacht X. The sharp hull lines of mega yacht suggest a high speed. The exterior design with its priority on aesthetics and appearance is very important as well. However, the sharp hull however can bring a negative impact on the interior and that is that a narrowed down space in front of the ship will be extremely be more difficult to utilize as additional living space. As the exterior design is prioritised above interior design and aesthetics is prioritised above comfort, inconvenience arises in later stages of the design process. Mega yacht owners often buy the yacht as a status symbol; they buy what the yacht represents; a product that offer them a certain social status. The mega yacht designers therefore need to look beyond the usability and functionality of the design and need to consider what the yacht actually represents for the owners.

9.2.3 Human orientated design for easy crew maintenance

Another missing comfort factors to design that needs to be discussed and researched is the functionality with regards to maintenance of the exterior and interior design

elements of mega yachts. The cleaning routine for crewmembers on board mega yachts needs to be considered in the choice of material in the design stage. Many mega yachts are designed with lots of luxury materials like, glass, mirrored and crystal surfaces but has a negative side effect for crew, namely; the high maintenance degree to keep it shiny and sparkling all the time. An otherwise simple routine job can turn into a long complex process because often the aesthetics and performance of mega yachts often is prioritised above the functionality for crew. Routine maintenance that needs to be carried out by crewmembers is complex on mega yachts and these needs to be taken into consideration in the exterior and interior design of the ship.

9.2.4 Expand on already existing human orientated design software

More and more product developers are making use of Kansei engineering, as discussed in the critical review. Kansei engineering means integrating of customers' preferences in terms of emotional requirements into the design process. Designers need to know why the customers want to buy this product, for what reason (status, functionality?) and what emotions. Why do we buy? What type of design elements evokes the required emotions with the customers? Software developers in Japan already invented a computerised system that can predict certain responses and emotion with certain types of design elements. For the mega yacht industry, more research is needed in order to find a way to improve human orientated design elements by means of implementing Kansei engineering. As to me 'emotion' design is the future.

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APPENDICES

A Field study

B Parameters of the principles to Human orientated design

C Basic safety requirements for preliminary mega yacht design

Appendix A – Field study

Appendix A present the full interviews held with different people from within the mega yacht industry as to analyse the research question to this thesis: *Can human elements be merged into the concept design stage of mega yacht design, in place of the final stage?*

The questions as asked in the interviews are shown in *red Italic text*, whereas the answers are shown in non-Italic black text.

A.1 Interview with classification society: Lloyds registers

Appendix A.1 presents the questions asked to Mega yacht Expert Lloyds register on October 2011:

Could human factor related problems be avoided by implementing the human elements into an early stage of design instead of in the final phase?

Yes, I believe so. We raised the awareness of human elements by means of our project called: Alert. This project has a quarterly newsletter funded by Lloyds as part of our human elements awareness initiative. Alert and an associated web site http://www.he-alert.org/ describe and illustrate the human element within every aspect of the maritime industry, from equipment manufacturers to ship owners to naval architects to seafarers.'

Do you have experienced any problems concerning this subject?

We always suggest having kick-off meetings with all involved parties during the pre-contract stage. This allows all stakeholders to identify and clarify any eventual issues in the design stage avoiding delays and costing modification in the latter stage. This

is valid also for human factors which unfortunately in the yachting industry are sometimes penalized by the fact that aesthetic prevail.'

Please can you tell me if there are more problems that the industry can focus on in future research?

Bridge and ECR ergonomic, complexity of machinery and equipment systems and recruitment, training and crew retention might be something where human factors can play a big role in assisting yachts operators.
Quote: 'Have Kick off meetings during the pre-contract design stage with all parties involved' (Lloyds, 2011).

A.2 Interview with (mega yacht) designer: Hyun Seok Kim

Appendix A.2 presents the questions asked to Interior and Exterior yacht designer Hyun Seok Kim on October 2011:

Could human factor related problems be avoided by implementing the human elements into an early stage of design instead of in the final phase?

'As I know, the very first layout is determined by the designer. After that, engineering determines very basic functions for propulsion, balance, safety, living supplements and so on. After positioning these parameters, the designer can finally verify the decks and so on.'

Are there problems with the communication of the interior designer and naval architect?

'I don't feel very much that I have to convince the naval architects, I have to convince the investor or ship owner. Sure I always have to discuss the design with the engineer for improvement on the ship building. That's true and I know it,

however, engineering and technology is helping me for realization, not for disturbing.'

Do you have experienced any problems concerning this subject?

'Because the layout including deck plans are already in my mind before I decide the dimensions. Everything is clear and no conflict appears. However, I considered very few engineering technical data when designing the mega yacht Voronoi; as you know there was almost no limitation. So I can be very brave.'

'If I am hired just to design the interior this means that the exterior is predetermined. This is difficult to deal with as this can be seen as hardware and hard ware is fixed. Please think why apple I phone is an evolutionary device. Apple designed both the hardware and the software; however, Samsung for example designed just the hardware and is less successful and revolutionary in their designs. If I can design both the hardware (exterior) and the software (interior), I can go wild every time.'

Please can you tell me if there are more problems that the industry can focus on in future research?

- 'We have to choose more space for better cruise life with fewer guests on board.'

- 'Fewer crews and no compact crammed spaces anymore, instead of lack of personal spaces but more guests on board with more crews'

- 'Owners do pay a lot of money for ship building and ship maintenance and no one requires these packed cruising. Nowadays technology supports so many areas; less crews, small engines, alternative energy, and so on. There are possibilities for better Ship layouts'

A.3 Interview with naval architect: Martin Francis

Appendix A.3 presents a summary of the telephone meeting with Francis Design. This appendix show the questions asked to mega yacht naval architect Martin Francis on March 2009. The interview with Francis elaborated even so the differences between cruise ship and a mega yacht design

According Francis the key differences between Cruise ship design and Mega yacht design are:

- A mega yacht is built with aesthetics as her main priority. Rules and regulations for more than 12 passengers, when the yacht needs to be regulated, as a passenger ship is therefore a problem. For example the lifeboat rules and regulation are not in line with the aesthetics the owner wants to create. More aesthetics problems do occur within follow up these regulations

- On a mega yacht there is more accommodation space per person and when follows up the rules and regulations when the yacht has 12 persons or less, there are fewer limitations than when designing a Cruise Ship

- There is more budget available when building and designing a mega yacht

Do you think a naval architect can be the interior design and exterior designer in the same time?

'We do think that the designer of hull form must be the designer of the yacht as well, they must work together at least, and it must fit or make sense somehow.'

What do you think about seasickness and interior design?

'Again this depends on the owner. The nicest space for the owner's cabin is on the top deck, with the best view. Seasickness is almost zero according to Martin. The

mega yachts are very stable and do not sail very often in bad weather or bad weather routings, they avoid bad weather, so this could not be a problem.'

What is your future perspective?

'The yachts are becoming smaller again. More owners do think it is important to know their crew by name. But if your yachts are 130 meters and you have 65 crew this is very unlikely. '

What can you recommend for future research? Where is some research needed?

'I will recommend more research in risk analysis, safety records and quality of track record. For example there are more people killed in accidents happened in training with the lifeboats than the amount of people that thank their life on a lifeboat.'

A.4 Interview with mega yacht Design Company: Vripack

Appendix A.4 presents the interview with naval architect and yacht designer Mr Bouwhuis from Vripack on December 2011:

Do you think that if the naval architect and the interior designer would work for the same company, this would have a positive influence on the overall project?

Definitely, although I do admire the interior designs of an external design company very much, as they have inspiring creative ideas. In general it is very good for the project that the engineers and designers work for the same company or if the designer would have an engineering background. In this case they have a better understanding of the design and this will speed things up. An external stylist would be too much focussed on the styling and design of the project rather than the complete design process. External design and internal design cannot be seen separately and the methodology toward design is different every time; rules and

regulations, customer's ideas and technology all are part of the design process and each design is seen as a new challenge.

Can you tell something about the companies work methodology and Motto?

The Functionality of the design and Aesthetics should be in good balance. In our company Functionality and Quality has priority. Functionality is crucial. We build for example a good quality engine room that have minor failures and complication on the long run rather than choose for example for smaller engines and thus a smaller engine room that saves some valuable extra accommodation space for the owners of the yacht but have less quality. We believe in Functionality and Quality together with a good balance in aesthetics.

The mega yacht building and design is a very complicated process and is not less complex that an aircraft design. Customer, Architects and Designers' ideas are not always the same. On a mega yacht the technical aspect, owner/customer, crew and charter aspect all needs to be merged into a very limited number of spaces; this asks for highly skilled professionals and as mentioned before preferably all working for the same company as teamwork is a key element toward a successful design.

The aim of this research is to see if human elements can be merged into the basic design stage of mega yacht design. The first layout of the mega yacht design process is crucial towards a successful design; can you tell me more about the human elements key factors in layout design?

It is crucial for the design to have healthy balance between functionality and aesthetics but at the same time the complexity is to create a good balance between hotel function of the yacht and the Living spaces for the guests and families on board. One of the key elements toward human orientated design is therefore the Service routing on board the yacht and its functionality of the layout for the crew and the guests on board the yacht.

In many designs today there is more focus on the passengers and guest areas, like the cabins and salons etc. then there is on the quality and functionality of the service routing for the crew. Service routing and layout should therefore always be taken into consideration at the earliest design stage to avoid crucial mistakes at the end when nothing can be corrected anymore.

The importance of taken service routing seriously and in the early design stage is another important key element to add to the reason why designers, engineers and Architects should work internal for the same company. External design companies are often the cause of mistakes that occurred in a final design stage when it's too late to adjust. For example sometimes it happens when the designer has some nice ideas about the function of the space and in reality the passengers and guest or crew will use the space as an extra storage or else. Functionality and space are crucial and need to be determined in the Basic design stage of the yacht.

With a Multi-disciplinary team, team spirit is essential for both on board the yacht as in the design team. Another crucial point of focus is maintenance. Design for maintenance is very important. As aesthetics is often prioritised above functionality and additionally maintenance, problems could occur with crewmembers being unsatisfied due to major maintenance work. Too many details in design , like for example on mega yacht 'A' by Philippe Starck, could be a real problem for the crew, as the yacht have to be maintained and cleaned every day. Large windows for example in the hull would be beneficial for comfort but have to be washed every day too; this should be taken into account right from the start.

I noticed during my research that almost all of the mega yacht lay outs have the same routing and dividing of the main living spaces. Can you tell me more about the way the layouts of the mega yachts are designed, why are they always the same?

Tradition is the main reason for the layout the way they are now. The customer or owner of the yacht has the last say in the design. Most owners choose for a traditional design because they think the yacht can be sold better in this way. The

inexperienced customer is reluctant to take a big challenge and choose for a different layout that might be more functional and therefore choose for the certainty of a traditional layout. The more experienced customer, however, will think in a bigger picture where a more comfortable lay out will be more functional as well and thus can be sold onto the market better.

The only reason for the layouts on yachts the way they are now is thus that this is tradition. It is very hard in this complex market to break with tradition and present a new creative design. There is a lot at stake in this industry.

Do you think it is possible to merge Human elements into the Basic stage of mega yacht design and does your company already make use of this technique?

Yes definitely! In our first design process all of the customer's wishes and technical human elements are taken into consideration, like noise and vibrations in relation to the overall lay out and comfort of the people on board. For example the cabins right under the anchor chain should be extra isolated or moved elsewhere, a captain's cabin located directly against the galley's wall will cause for disturbance, all of these factors should be discussed beforehand and taken into account. Human factors, however, on a more personal level, like comfort, perception, personal space and ergonomics and human body sizes etc. are for the mega yacht design industry still a level to high. Design of mega yacht is still such a complex project that design on this specific level of human comfort is not done yet.

What action in your opinion is necessary to introduce customized human elements on a personal level into the basic stage of yacht design?

It all depends on the function of the yacht. Is the yacht build for private or for charter and the regulations that need to be considered? Charter build would have a different approach toward the design that if the yacht is built for the family, also the yacht is like a home, the more functional space onboard is design, the better the yacht will sell.

I do agree with the customized human elements need to be considered in an early design stage and that these will be beneficial toward the overall design and avoid problems in a later stage of the process. The main reason why these are not considered yet is because the owners are not aware of these human elements yet. The owner or customer has always the last say in the design process. The owner thinks in a way that the yacht needs to be sellable at the same time, they are reluctant to change too much of the traditional design because they are afraid that the yacht will become unsellable. There need to be more awareness amongst the owners, as well as in the design industry itself. Larger yacht companies like us have all the different expertise working for the company, like indoor climate, air-conditioning, noise and vibration experts etc. but the smaller design companies don't have this expertise.

More awareness is needed on customized human elements in the future as well as the awareness that a happy crew is a happy owner. More attention needs to go toward the design for crewmembers, like mess-rooms and cabin quarters. Most yacht owners prefer to save in crew accommodation design and have more accommodation for them.

It is not the comfort of the design that count the most but more the perception of comfort and the experience of comfort that counts as a key element toward good design. A happy crew is a happy owner as well as the team spirit amongst the crew is crucial for the functionality of the yacht. The owners should be aware of this and this should be taken into account in the early ship design process.

Is seasickness and space layout in relation to the most optimal location on board taken into consideration?

Yes, seasickness is taken into consideration in an early design stage, although with today's most advanced stabilizer techniques, seasickness is not really an issue anymore and on top of that for most mega yacht counts that they do not sail in heavy weather of outcasts heavy swell-routings. But if seasickness is the case, the most

perfect location for anti-seasickness is amidships lower deck, and owners always favour view and location above comfort of absence of eventual seasickness.

If you would have design freedom to adjust the traditional layout of mega yachts, what is it you would change?

Again for the most efficient layout the service routing is one of the key factors towards a successful layout for both crew and guests. For the layout, when considering the traditional lay out as it is designed today, with on the main deck the salon. The guests rarely are using this space. The problem with the main salon is that it is too formally designed. The space is self in this way is useless and would not be used very often. When redesigning a layout, the main deck still needs a living space near the aft deck as the aft deck is frequently used as the outdoor living area, but the design of the main salon aft should be less formal. The traditional layout itself could be far more efficient by having the lower deck entirely used by the crew and the main deck just for guests' cabins and a good modest salon aft toward the main decks, accordingly the upper decks could then be used as living and dining space entirely. As we look at the traditional designs, it is often the case that there are 3 salons or more, depends on the size of the yacht, this is unnecessary as the salons are just a copy of each other with maybe a change in theme and as mentioned before not even used all the time, especially the formal salon on the main deck. When the yachts grow bigger the layout is expanding too but does not have more variety.

It is true that a functional yacht, which is built within an economical budget and has a high usability factor and is both beautifully designed as well as having an ingenious layout, is definitely a huge challenge.

Can you advise us about the future research areas concerning mega yachts?

- Think about the Service routing on board the yacht
- Take maintenance into account in the basic yacht design stage
- More awareness is needed in human orientated design for as well the customers as for naval architects.

- Favourably the naval architect and the designers should work for the same company as to avoid important errors and speed up communication and the overall understanding of the design, as internal and external design, technical and human factors cannot be seen as a separate task or project.

APPENDIX B: Parameters of the principles to human orientated design

CONTENTS

Appendix B – Parameters of the principles to Human orientated design

Appendix B presents the parameters of the principles to Human orientated design.

B.1 Parameters to the principles as presented in Table 5-1 chapter 5: Identified key human elements necessary to the design of the spatial elements plan

B 1.1 SPATIAL COMFORT:

Comfort in the use of furniture in relation to the spatial dimensions of the room and visual comfort: visual balance, alignment and a focus point. When a map of the space is created, the dimension of the room is determined by its need to function properly according to its related activities. In order to be able to determine the required main dimension of the space, from a human oriented point of view, information is gathered such as: the safety and comfort travel distances between furniture pieces and exits, availability of windows and daylight that is required for this space and its related activities.

For example in a work related space, one need to work on a desk which require some natural daylight in order to feel comfortable when working, therefore the desk position preferable needs its position near a window. The position of the desk at that point determines the traffic flow of the room and the traffic flow is accordingly adjusted around this desk position. In other words all of these above-mentioned elements are called ‘mapping elements’ or spatial elements. In order to create spatial comfort all the spatial elements in that room needs to be in harmony with each other in order to create a comfortable space.

B1.1 / I. Dimensional: Avoid conflict with structure

Avoid conflict with structures in the room by mapping the room first, according to its function and related activities, and accordingly determine the main dimensions of the room [setting up a furniture layout and adjust dimensions accordingly]:

Mapping

There three components for the analysis of environmental imaging: 'Object in the background', 'in relationship to each other' and 'Personal society'. The mapping elements are:

- Paths [channel of movements],
    - Taken the related safety rules into account: (Interior graphic standards by Binggeli [2012], pg. 1-33), (also see basic safety regulations for mega yachts SOLAS regulation 28: means of escape or MSN, LY2: 14A3)
        - Number of people in the room,
        - Emergency exits,
        - Width of exits,
        - Exits through intervening spaces,
        - Door encroachment,
        - Travel distance to exits,
        - Arrangements of exits,
        - Common path of travel around the furniture
- Edges [boundaries that break, contain or run parallel to forms],
- Districts [areas of recognizable identity],
- Nodes [places of intense activity],
- Landmarks [Points of reference that are visually distinguishable]
- Way-finding: refers to the way people orient themselves in a given environment and find their destination (age related)

Key elements to comfortable spatial design (Story, Mueller, & R.L., 1998) referenced by (Kramer, 2011):

1. **Usability** for the people using that space

2. **Functionality** for all the people using the space; the design needs to address a wide range of individual preferences
3. **Simplicity**, the space needs to be easy to understand regardless of the user's knowledge or experience.
4. **Perceptible information**; effective communication of room information
5. **Tolerance for errors**; minimum design errors in an unintended action
6. **Low physical effort**; efficient design and comfortable design, with minimum fatigue
7. **Size and space** for approach and use; regardless the users' body parameters

Other human abilities to take into consideration in order to create a human ergonomic designed room are: cognition, vision, hearing and speech, body, arm and hand function and mobility. All of these above mentioned factors need be carefully considered in the preliminary design stage for the reason that these factors have a direct influence on the comfort of the people in the room.

Personal distances

Intimate = 152-457 mm, Personal = 457-1219 mm, Social = 1219-3658 mm, Public = 3658 mm and more

Accessible routing

Accessible routes must be located as follows:
Interior routes, where an accessible route is required between several decks, and the general circulation path between levels is an interior route, the accessible route must be also an interior route.
Relation to circulation paths: accessible routes should 'coincide with, or be located in the same area as, a general circulation path.

B 1.1 / II Optical

Create Spaciousness by Optical illusion: In order to create a sense of space where there is lack of space, there is need to create an optical or visual illusion that there is space by applying the following set of principles:

a. **Create spatial comfort by Visual comfort:** designing for equal distribution of daylight throughout the complete room, if possible, if not apply artificial daylight in the room.

b. **Create spatial comfort by visual balance**
    - Symmetry balance or alignment:
        - Asymmetrical balance
        - [Radial] balance: make use of a [central] focus point
    - Create spatial comfort by applying colours that are in harmony with each other
    - Scale ratio and visual weight

In order to create harmony in the room there is need of an equal distribution of all of the above principles

a. **Visual comfort: Create spatial comfort by designing for equal distribution of daylight throughout the complete room, if possible, if not apply artificial daylight in the room:**

Definition Daylight (Kelly & Connell., 1997):

'*Daylight is the natural light to which the human eye has become adapted over millions of years. In particular colour rendering by daylight is the subjective standard by which we normally measure the colour performance of an electric lamp*'

The nature of the setting of the space determines daylight and thus window preferences. Biner and Butler theory: Living spaces: preferences in size of these windows are at least 2.13m x 2.13m (7Fx7F). No windows were necessarily required

for working spaces (will only cause glare on computer screens etc), private rooms and bathrooms etc. (Ne'eman and Hopkins, 1970).

***The Daylight Factor (as used in the interior architecture)*;** the ratio of indoor to outdoor illuminance under an overcast sky is the factor to characterize the level of daylight inside building or a room. Conventionally the overcast sky has been used for daylight design in the UK. A vary of Techniques are used by specialised light designers to calculate the daylight ratio and can influence many factors of comfort and design, amongst others the dements of the space, the size of the windows, the function of the room, equipment in the space, like big TV screens, and large fixed furniture who will influence the Luminance of the room. The average daylight factor can be calculated by the following, by means of a special formula by knowing the following factors:

- Total glazed area of the windows
- Total area of ceiling, floor, walls and windows
- Average reflectance of ceiling, floor, walls and windows
- The vertical angle in degrees subtended at the centre of the window by unobstructed sky

Daylight varies with latitude, season, coastal or inland location, climate and air quality. The amount of daylight received within a room depends on its orientation, the presence of obstructions and the reflectance of adjacent structures. The area in a room to which daylight will be considered to contribute significantly to task illuminance extends to about twice the window height - provided glass is clear, there are no obstructions (inside or outside) and the window sill is not significantly higher than the working plane. (Clear glass in high windows is likely to cause problems of glare.)

Formula used: $DF = (Ein / Eext) \times 100$

DF: Daylight factor

Ein: Interior illuminance at a fixed point on the workplane (desktop, or work surface)

Eext: Exterior illuminance under an overcast sky.

How much light does the space need?

'According to the British Standards Institution for example a space with a mean daylight factor between 2% and 5% is considered well lit and requires little or no additional lighting during daytime. A space with a daylight factor of less than 2% appears dimly lit.'

Depth of a Room

'A well-established rule of thumb for assessing the area in a room which will have acceptable daylight is to determine the "No Skyline Point". This is the point at which the skyline is no longer visible (see Fig. 1).

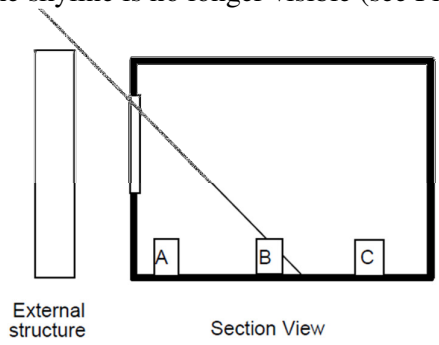

Fig. 1 Office space with three desks and a window, showing the Skylight point (Kelly & Connell., 1997)

Example shown in Fig. 1: All points further from the window are not considered to have acceptable daylight Desks A and B are OK but desk C does not have adequate daylight A B C External structure Section View'

References

- Physiological and psychological effect of illumination and colour in the Interior environment (Küller, 1986)
- Interior graphic standards, (Binggeli, 2012)

- Interior lighting design- a student guide (Kelly & Connell., 1997)
- Calculating The Daylight Factor (Ananthakrishnan. & DECaestecker, 2011)

b. Create spatial comfort by visual balance

In the interior architecture, the designer makes use of the creation of 'visual balance' in the room. Visual balance builds on top of 'visual weight'. When objects are of equal weight, they are in balance. If there are several small items on one side, they can be balanced by a large object on the other side etc. Visual balance works in much the same way. It can be affected not only by the size of objects, but also their value (i.e. lightness or darkness, termed visual weight). In very simple words, visual weight is created by dark, textured or heavenly decorated objects placed in the room. Light coloured object, though very heavy in weight, have a lighter visual weight than the same heavy object in dark colours. Even so can be said that textured object appear even so heavier than non-textured objects. The following set of principles is applied in order to create visual balance:

1. Symmetry or alignment
2. Asymmetrical balance
3. Radial, makes use of a central focus point
4. Colour balance or harmony in colours
5. Scale ratio and visual weight

1. Symmetry or alignment

Symmetry (of a room) is the measure of whether visual weight of the layout is equal to either side of the chosen dividing line (dividing line can be chosen accordingly: room walls /furniture pieces or corner or other focus points).

2. Asymmetrical balance

Visual weight is balanced but the actual shapes of the room or its spatial elements are not.

3. Radial balance

Visual balance is created around a chosen central focal point (example of a focal point could be a grand furniture piece, like piano, painting, large window or even a superb spiral staircase).

4. Colour balance or harmony in colours

Create spatial comfort by applying colours that are in harmony with each other

The colour theory in order to create spaciousness:

Optical effects of colour: a room which is coloured in a light shade appear larger than the same room coloured in dark shade, this because light shades tend to recede while dark shades advance. Warm colours appear closer while cool colours seem far away. Visual illusions are created by for example: a narrow room will appear less narrow, when the far walls are darker than the side walls that are given a light colour. Even so a low ceiling will appear higher when its coloured in a light shade.

The properties of colour are based on three dimensions:

1) *Hue*: is the identification name of the colour (red, blue, yellow). Hues are defined an organized by the colour wheel, existing of 12 colours, each on their full intensity: primary colours: red, yellow and blue; secondary colours: orange, green and violet; Tertiary colours: Red-Orange, Orange-Yellow, Yellow-Green, Green-Blue, Blue-violet, Violet-Red.
2) *Value*: is the lightness or darkness of a colour that indicated the quantity of light reflected, determined by the amount of white or black present in the colour. A *shade* is created when black is added to darken a colour, and gives the colour a low value. A *tint* is created when White is added to lighten a colour and gives a colour a higher value.
3) *Intensity:* the saturation or strength of a colour determined by the quality of light reflected from it. A vivid colour is of high intensity, a dull or muted colour is of low intensity

To create a certain harmony inside the room there are many different and complicated theories, but probably one of the most commonly used one is the theory of Ostwald (1916): 'Colours harmonise when they have equal white, black or hue content'.

Another much used theory is the Coloroid system (Nemcsics, 2003), two of the main principles of colour harmony based on the Coloroid system:

- Component colours have the same hue and saturation, but their lightness values constitute an arithmetical or geometrical sequence.
- Component colours have the same hue and lightness, but their saturation values constitute an arithmetical or geometrical sequence

In general can be said, supported by many different colour theories, 'Colours harmonize is they are in the same hue, chroma or if they are in complementary in hue'.

Color characteristics (the following is directly cited from the lighting lab guidebook):

'The color characteristics of light in space are determined by the spectral power distribution (SPD) of the light source and the reflectance properties of the surfaces in the room. The color of light sources is usually described by two properties, namely the correlated color temperature (CCT) and general color rendering index (CRI). The color appearance of a light source is evaluated by its correlated color temperature (CCT). For example, incandescent lamps with CCT of 2700 K have a yellowish color appearance and their light is described as warm. Certain type of fluorescent lamps or white LEDs have CCT of around 6000 K with bluish appearance and light described as cool. The CRI of the CIE measures how well a given light source renders a set of test colours relative to a reference source of the same correlated color temperature as the light source in question (CIE 1995). The general CRI of the CIE is calculated as the average of special CRIs for eight test

colours. The reference light source is Planckian radiator (incandescent type source) for light sources with CCT below 5000 K and a form of a daylight source for light sources with CCT above 5000 K. The higher the general CRI, the better is the color rendering of a light source, the maximum value being 100. The CIE general CRI has its limitations. The shortcomings of the CRI may become evident when applied to LED light sources as a result of their peaked spectra. The CIE (CIE 2007) recommends the development of a new color rendering index (or a set of new color rendering indices), which should be applicable to all types of light sources including white LEDs. CIE technical committee TC1-69 Color rendering of White Light Sources is currently investigating the issue. The Kruithof effect describes the psychological effects of preferences for varying CCT and illuminance level. It proposes that low CCTs are preferred at low illuminances, and high CCTs are preferred over high illuminances (Kruithof 1941). The Kruithof effect is not, however, generally supported in later studies (Boyce and Cuttle 1990, Davis and Ginthner 1990). It is also suggested that color adaptation occurs when people spend certain time in a space, after which it is no more possible to compare lamps with different CCT. It is obvious that the color temperature preferences of people are culture and climate-related, as well as dependent of the prevailing lighting practices in different regions (Miller 1998, Ayama et al. 2002). Recently, it has been suggested that high color 3 LIGHTING QUALITY 47temperature light could be used in increasing human alertness (see Ch. 3.5). More research is needed to confirm this and to apply these postulates in lighting design.'

(http://www.lightinglab.fi)

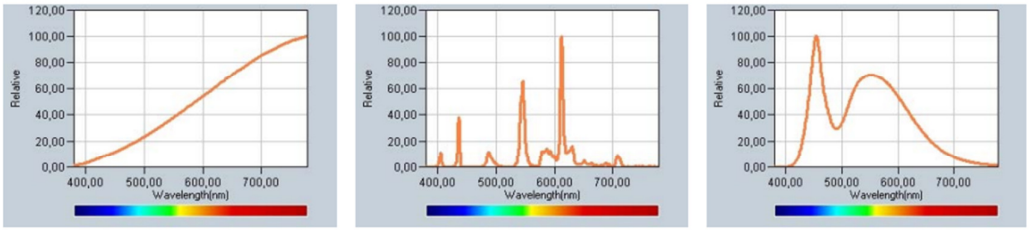

Fig 2. Light source spectrum, i.e. radiant power distribution over the visible wavelengths, determines the light colour characteristics. Examples of spectra of an incandescent lamp (CCT= 2690 K, CRI= 99), a compact fluorescent lamp (CCT= 2780 K, CRI = 83) and a white LED lamp (CCT= 6010 K, CRI = 78).

References

- Physiological and psychological effect of illumination and colour in the Interior environment (Küller, 1986)
- Colour in the interior environment (Inui, 1969)
- Relationship between colour and emotion: a study of college students (Kaya & Epps, 2004)
- Colour emotion associations; Past experience and personal preference (Kaya & Epps, 2004)
- Existing theories of colour harmony: (Munsell, 1969); (Nemcsics, 1993)
- www.lightinglab.fi
- CISB code for Interior Lighting, 1985

5. Scale ratio and visual weight

Golden Ratio

Down size scale for smaller spaces, use the Golden ratio-law: the ratio of the smaller section to the larger section should be the same as that of the larger section to the whole. A universally pleasing proportion in a rectangle is to have the length 1.618 times the width.

References for the Golden ratio law

- Berger, 1998
- Lok et al., 2004
- Ching & Binggeli, 2012
- Panacentriclimited, 2001-2007

B 1.2 COMFORTS IN USE

B 1.2 / I Traffic patterns

Interior traffic patterns are of the utmost importance to both the comfort and the safety of the people within the space and are very much dependent on the type of persons or group that use the space. The traffic patterns on board ships are interior routes passengers and crew uses to navigate the inside of the accommodation. The traffic patterns needs to be analysed and carefully chosen for as well as within the room itself as well as within the layout in general and are to be chosen in relation to the complete layout of the yacht. The overall traffic flow must be taken into consideration before the traffic patterns inside the room can function properly.

Principles to the traffic patterns within a room; the traffic patterns must be:

- Convenient and direct
- Save to use
- Provide adequate space without wasting it
- Provide easy access from the entrances to other parts of the yacht
- Separate traffic to the work areas from traffic to the quiet and social areas
- Avoid cutting through the middle of rooms
- Avoid interfering with a good furniture arrangement or interrupting activities within a room
- Avoid interfering with the privacy in areas of the yacht where privacy is expected
- Avoid cutting through a galley, engine room, or other related work areas, or any other hazardous area
- Separate crew working and living areas from passengers/owners areas but consider the overlapping paths in order for the crew to serve the passengers on board
- Provide direct access from utility area to the outside service zone
- Allow room for doors to swing open, drawers to be opened and chairs to be pulled out (use the Interior graphic design standards [* Binggeli, 2012] for

specific numbers and sizes on human measurements and rules and regulations for different spaces, utilized to the type of furniture used, anthropometrics of the customers and type of space)

*[Binggeli, *chapter 1; pg. 3, chapter3; pg. 18- 22, chapter 9; pg. 326/* 2012]

Traffic patterns inside the room depend on factors such as:

- Type of activity of the room
- Functions of the room
- Interior elements of the room
- Regulations on safety that need to applied; emergency exits, fire zones etc. (MCA-LY2, SOLAS)
- To avoid crowdedness: number of persons that use the space need to be taken into account
- In order to create comfort: ergonomics and anthropometrics of the persons who use the space, like age, and average size or any disabilities (wheelchairs need more alley width, this different routing space etc.)

Steps to space planning [mapping] and traffic pattern analysis are accordingly (modified with the owner):

- Apply space plans to traffic patterns.
- Identify the general areas of the space, and the desired characteristics of each area.
- Discuss the space requirements for each basic room type and for the concept of "planning for people."
- Analyse furniture and equipment owners' requirements for basic room types.
- Apply the space planning techniques to architectural changes in traffic patterns.
- Identify the advantages and disadvantages of a variety of room layout arrangements and floor plans.

- Incorporate a variety of room layout arrangements and floor plans into a personally designed floor plan.
- Discuss the process and limitations of making architectural feature changes in the design process and working around existing constraints.

References

- Interior design, visual presentation (Mitton, 2012)
- Pegler, M (1995). *Dictionary of Interior Design.* New York, NY: Fairchild.
- http://www.dtae.org
- http://www.cam.k12.il.us
- Pile, J.F. (1988). *Interiors Design.* Englewood Cliffs, NJ: Prentice Hall

B 1.2 / II Anthropometrics and ergonomic use; height and usability of equipment's and furniture

The anthropometrics of the furniture heights and usability etc. needs to be in agreement with the above mentioned traffic patterns principles.
Please see for the anthropometric standards in design:
(Binggely, 2012), *Chapter 1; Human factors pg., 1-10- Chapter 3, Accessible design basics pg. 20-23*

References

- Interior graphic standards, (Binggeli, 2012)

B 1.3 SENSORY COMFORT

B 1.3 / I Noise and vibration reduction

[See Noise and vibration principles to design in AppendixB3/2.5: Dimensions of the space itself and Appendix B3/3.2: Space location on board the ship]

B 1.4 COMFORT OF INTERACTIONS

B 1.4 / I Personal space/interaction with others, traffic patterns, communication distances

This section presents the Interior Graphic standards for design of living spaces; dining areas, conversation areas etc., used in the interior design in order to present comfortable conversation distances. (See also spatial comfort: personal distances and mapping/accessible routes).

In order to present principles and parameters to comfortable communication distances and acceptable distances for interaction, first of all the function of the space and the activities carried out in that space is needed, as well a number of persons who is using the space and if they have any disabilities. Roughly two types of spaces can be defined: residential or commercial and living space or working space. For dining areas, like in restaurants etc., there interior design guidelines to use for a comfortable seating experience, certainly when in a dining environment with more than 4 people.

Hospitality spaces

Seating arrangements guidelines for banquette: Table 1 presents the seating arrangements guidelines for banquettes

Table 1 seating arrangement guidelines for banquettes: round tables, square tables and rectangular tables

Number of persons	Diameter for round tables	Number of persons	Diameter for square tables
4-5	914-1067 mm	2	610 x 762 mm
6-7	1067-1372 mm	4	914 x 1067 mm
7-8	1372-1524 mm		
8-10	1676 mm		

Number of persons	Rectangular tables length x width
2 on one side (4)	1219 x 762 mm
3 on one side (6)	762 x 914 mm
4 on each side (8)	914 x 1067 mm

The dining-table length also depends on the type of chairs used and the setting occasion. Cocktails drinking at a bar area requires less space than the dining area for long and intimate dinners.

There are roughly three types of settings that designers use for banquette seating:

1. Spacious dining setting 1.3 SQ M/person
    - Large dining chair 559 x 457 x 457-508 mm (overall depth x seat depth x width)
2. Average dining setting 1.1 SQ M/person
    - Average dining chair 483-508 x 406 x 406 mm (overall depth x seat depth x width)
3. Compact dining setting 0.9 SQ/person
    - Compact dining chair 432-457 x 381 x 356 mm (overall depth x seat depth x width)

Also the aisles and minimum width and space allowance between tables and chairs are given, depending on the type of space and setting required. In general the aisle access way should be 305 mm minimum clear when distance from the aisle to centreline of farthest chair is between 1.8 -3.7 meters). For wall seating allow 762 mm minimum between the walls and the table in order to safely and comfortably

have access throw the aisle. (For more design guidelines on this particular subject see Binggeli, 2012/ chapter 9, pg. 390-401)

Hotel rooms Interior design guidelines

'Guestrooms (either for hotel design or for mega yachts) are affected by the construction and operation costs. Variation in ceiling heights, large foyers, or large bathrooms can create a feeling of spaciousness' (Binggeli, 2012/pg. 386).

See Table 2 below for guest room sizes are recommended for Hotel interior Design and Fig.3 for the guest room configurations, even so for hotel room interior design. The minimum guestroom width for double occupancy is 3.7 meters; the average width varies between 3.8 and 4.2 meters. Guestrooms over 4.2 meters in width are considered luxurious.

Table 2 Guest room sizes in square meter, as recommended by the Hotel interior design guidelines (Binggeli, 2012/pg. 386).

Hotel	**Average low**			**Average high**			**Luxury**		
Type	**Area**	**width**	**length**	**Area**	**width**	**length**	**Area**	**width**	**length**
Room	18m²	3.7 m	5.2m	22 m²	4.1m	5.5m	24m²	4.6m	5.5m
Bath	4m²	1.5 m	2.4m	4.5m²	1.8m	2.5m	5m²	1.8m	2.7m
Guest room	27m²	3.7 m	7.6m	34m²	4.1m	8m	36m²	4.6 m	8.2m
Factor	7m²	-	-	8m²	-	-	9m²	-	-
Gross area per floor	35m²	-	-	42m²	-	-	45m²	-	-

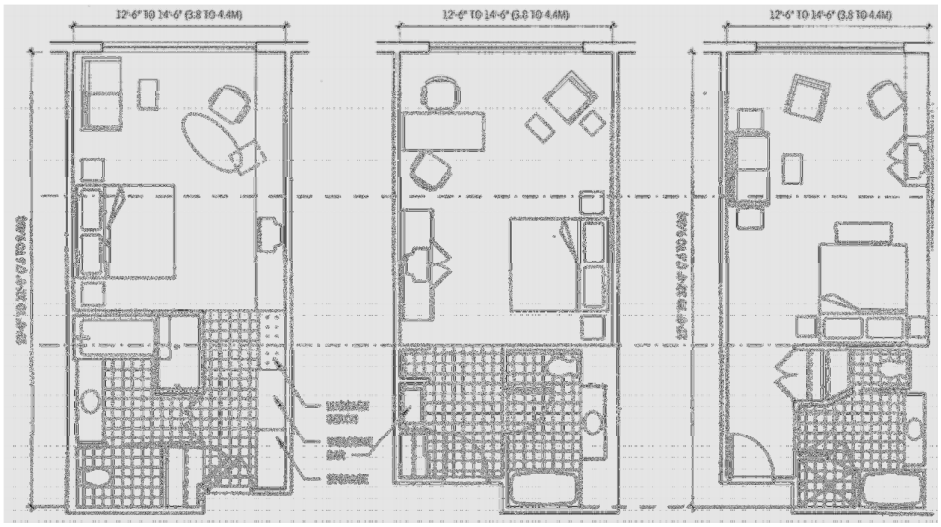

Fig. 3 Guest room configurations in hotels from left to right: Average low, average high and luxury in inches (metric equivalent in mm)

Guestroom bathroom

Interior design Guidelines (Binggeli, 2012/pg. 387-388), gives guidelines on guestroom bathroom design. This example is for a four fixed bathroom: Toilet, sink, shower stall and tub or Toilet, sink, bidet and a tub, see Fig. 4 and Table 3.

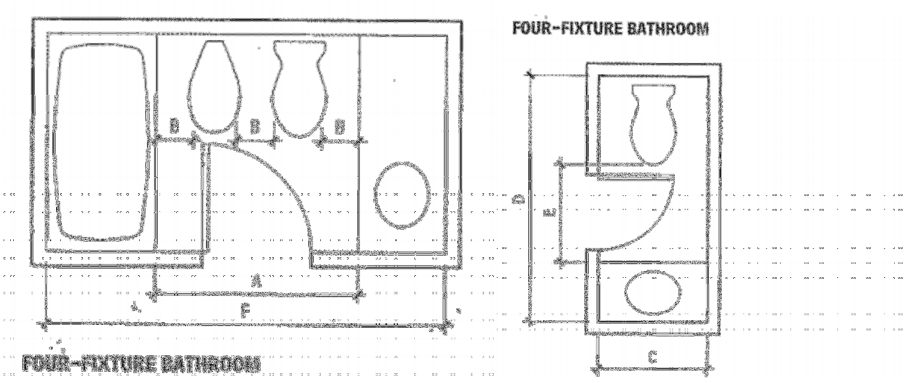

Fig. 4 Bathroom dimensions four fixed bathroom as part of Table 3

Table 3. Bathroom key dimensions from left to right: minimum, comfortable and ideal dimensions

Hotel bathroom key dimensions In meters (m)	**Minimum**	**Comfortable**	**Ideal**
A	1.25	1.32	1.37
B	0.18	0.2	0.25
C	0.81	0.91	0.91
D	1.78	1.98	2.03
E	0.46	0.56	0.61
F	2.62	2.69	2.77

Reading rooms and lounge areas guide lines on design:

For interior design guidelines on reading and lounge areas see Fig. 5 (For more design guidelines on this particular subject see Binggeli, 2012/ chapter 9, pg. 418).

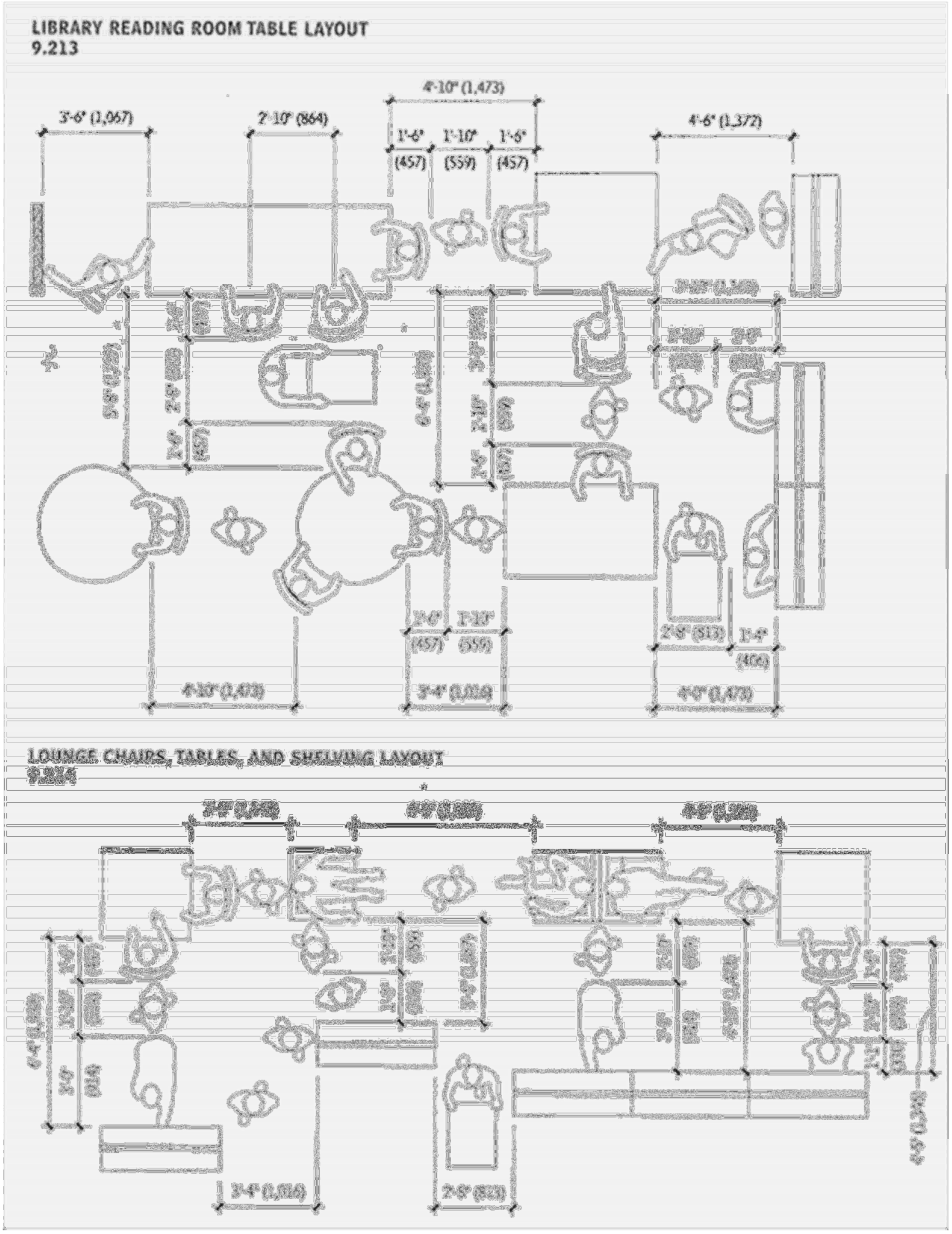

Fig. 5 recommended reading rooms' table layout and lounge areas guide lines on design in inches (metric equivalent in mm) (source: Binggeli, 2012/ chapter 9, pg. 418)

***Traffic patterns*:** See Appendix B1/1.2 Comfort in use

References

- Interior graphic standards (Binggeli, 2012)
- The Hidden Dimensions (Hall, 1966)

B.2 Parameters to the principles as presented in Table 5-2 of chapter 5: Identified key human elements to the design of the dimensions and layout of the space itself

B 2.1 PERSONALISE SPACE: Key elements in order to find the required dimensions of the layout

In order to personalise space there is, together with ergonomics related principles, need to determine the necessary movements in that space, communication distances needed, circulation paths etc. These principles will than form the foundation of an activity and space relationship analysis that is necessary to determine the eventual dimension of the space. In the interior design, designers make use of the Universal design principles; A set of general principles that need to be taken into consideration for comfortable design for people from all ages, with all kind of abilities.

General principles

The 7 Principles and their guidelines to Universal Design (Story et al., 1998):
(Parameters to these principles, see Story et al, 1998)

1. Equitable Use: the design is useful and marketable to people with diverse abilities
   - Provide the same means of use for all users: identical whenever possible; equivalent when not
   - Avoid segregating or stigmatizing any users
   - Make provisions for privacy, security, and safety equally available to all users

- Make the design appealing to all users

2. Flexibility in Use: the design accommodates a wide range of individual preferences and abilities.
   - Provide choice in methods of use.
   - Accommodate right- or left-handed access and use.
   - Facilitate the user's accuracy and precision.
   - Provide adaptability to the user's pace.

3. Simple and Intuitive Use: use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.
   - Eliminate unnecessary complexity.
   - Be consistent with user expectations and intuition.
   - Accommodate a wide range of literacy and language skills.
   - Arrange information consistent with its importance.
   - Provide effective prompting and feedback during and after task completion.

4. Perceptible Information: the design communicates necessary information effectively to the user regardless of ambient conditions or the user's sensory abilities.
   - Use different modes (pictorial, verbal, tactile) for redundant presentation of essential information
   - Maximize "legibility" of essential information.
   - Differentiate elements in ways that can be described (i.e., make it easy to give instructions or directions).
   - Provide compatibility with a variety of techniques or devices used by people with sensory limitations.

5. Tolerance for Error: the design minimizes hazards and the adverse consequences of accidental or unintended actions

- Arrange elements to minimize hazards and errors: most used elements, most accessible; hazardous elements eliminated, isolated, or shielded.
- Provide warnings of hazards and errors.
- Provide fail-safe features.
- Discourage unconscious action in tasks that require vigilance.

6. Low Physical Effort: The design can be used efficiently and comfortably and with a minimum of fatigue
   - Allow user to maintain a neutral body position.
   - Use reasonable operating forces.
   - Minimize repetitive actions.
   - Minimize sustained physical effort

7. Size and Space for Approach and Use: appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility
   - Provide a clear line of sight to important elements for any seated or standing user.
   - Make reach to all components comfortable for any seated or standing user.
   - Accommodate variations in hand and grip size.
   - Provide adequate space for the use of assistive devices or personal assistance

Body function can vary widely according to age, disability, the environment, or the particular situation. This variability should be considered in the preliminary design stage:

B 2.1 / I Age

- Older adults with diminished stamina, balance, or other body functions
- Very young children, with limited physical development

Age: Health safety and design for age

In the Interior design business in order to design a functional and comfortable space the designers will address the continuing needs of any client, at any age. Health and the aging processes are of the utmost importance. Over 38 Million people aged 40 and older have vision related issues. An accessibility entry should be large enough to allow space to welcome the guests and also should be wide as possible: Door openings: Minimum of 914 mm opening and 1067 mm wide and 457 mm clear floor space on the pull side of the door, in order for the user to move away when opening it to greet guests etc. Furthermore choose the colours and furniture and furniture finishing carefully when dealing with design for people with a high age.

A few used examples applicable to people of an older age (note: these safety issues on choosing interior elements are extra challenging and needed when on board of a moving ship with less space than in a building):

- Choosing seat height that are proportionate to the user: between 432-508 mm above the floor
- Choosing sofas with armrests that extend to the front of the seat cushion and high enough backs to provide stability for someone who is either standing or sitting.
- Chairs and sofas with legs allow the person who is seating to put their feet back a little under the chair for stability as he or she want to stand up
- Avoid specifying low, deep chairs and sofas that require someone who is seated to request assistance to get up.
- Smooth rounded corners to avoid injuries and choose furniture and floor colours with high contrast because the contrast from light to dark can help people, identify the edge of furniture when having a light sight problem (when aging)
- Providing table surfaces next to each seating area is key consideration no matter the persons' age or ability, and is particularly important for someone who is not highly mobile

See for all Interior Graphic design guidelines on spaces designed for people with an ability or older age (Binggely, 2012; chapter 9/ pg. 348-367)

Design for small children

Design for small children & Way finding refers to the way people orient themselves in a given environment and find their destinations as was explained earlier in the section spatial comfort: Mapping. There is a relation between the age of people and their ability to find their way in a room or buildings. For example adults navigate wide-reaching, complex environments on a daily basis, but children environment is very limited in range and tend to be perceived on the basis of reference points. What the designer should take in mind the following factors when designing for children:

- Children are naturally oriented in relation to their own positions, children see the world always in relation to them selves
- A child's cognitive map will include details of the environment in which they are involved in
- Think about Furniture for children on eye level, and adjusted to their height, but also keep away electrical equipment and light switches etc.
- Rounded corners to avoid children hurt themselves on the edges of furniture

(More information on Interior guidelines for children: Binggeli, 2012/chapter 9, pg. 402-403)

B 2.1 / II Gender: Female, Male

- Women in later stages of pregnancy, whose balance is affected by the weight of the baby
- Anthropometrical design is different for male and female (Binggeli, 2012/ Chapter 1/pg. 1-9)
- Differs per age and body weight

B 2.1 / III Number of persons

- Necessary for the design space and number of seating space

B 2.1 / IV Time spend in that space

- Time is related to the function of the room and its activities
- For example, dining area: activities are eating; having a light conversation and the related time spend in the dining area is between 1 and 3 hours. The dining furniture is accordingly adapted to the comfort level in relation to function and hours spend in the room.

B 2.1 / V Activities carried out in that space

- See Table D/ pg. 101 'Example list of the most common passenger accommodation spaces and its related function and activities'
    - Relaxing, quiet space
    - Dining area, eating, talking
    - Living spaces
    - Exercise areas' gym, spa rooms

B 2.2 ERGONOMICS

'Basic Ergonomics: body dimensions, the way people move through and perceive spaces are rime determinants of architectural and interior design': Ching and Binggeli (2012) amongst others, provide basic human factors guidelines for standing, sitting and reaching. Even so guidelines are provided for group activities, such as dining or conversing.

Roughly there are two types of dimensions (see Fig. 6):

- Structural dimensions of the body: structural dimensions of the human body
- Functional dimensions of the body: dimensional requirements that result from the way humans need to reach out to something (shelf, or sitting down a table). These dimensions may vary according to the nature of the activity engaged in the social situation.

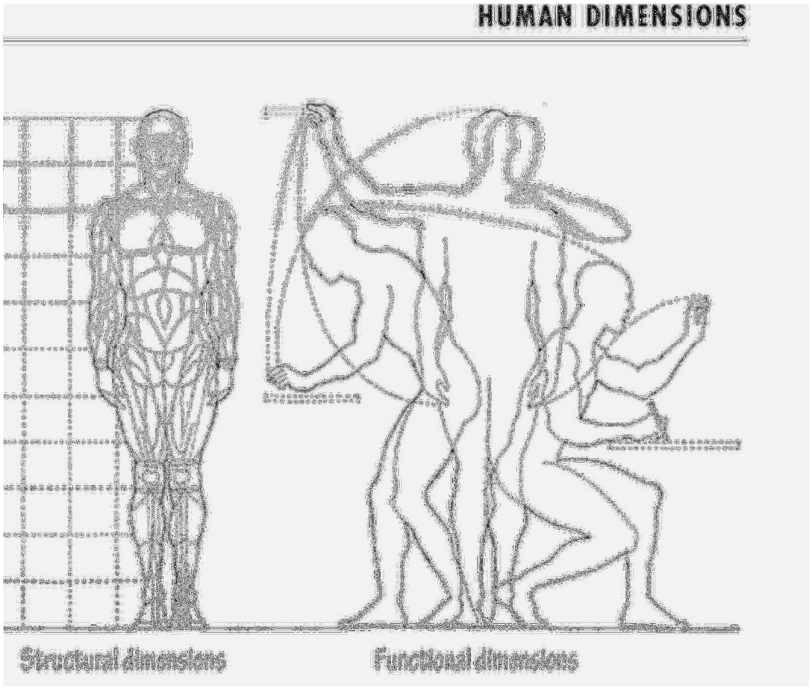

Fig. 6 Human dimensions: structural and functional dimensions

Interior design for people needs to occur for all ages, abilities in order to create a comfortable and functional environment.

B 2.2 / I Postural dimensions of the persons using the space and disabilities, these include special design for people with one of the following limitations:

- individuals of extreme body size or weight
- women in later stages of pregnancy, whose balance is affected by the
- weight of the baby
- individuals with pain or limited range of motion due to temporary or
- minor injuries or illness
- individuals under adverse environmental conditions (e.g., bad weather, extremes of temperature, poor air supply, unstable footing)
- individuals who are fatigued or ill
- individuals with chronic limitations due to:
- epilepsy or other seizure disorders
- allergies

- multiple chemical sensitivities
- asthma
- diabetes
- arthritis
- musculoskeletal injuries or illness
- hernia
- stroke
- etc.

Design according to the standard ergonomic design rules are always done according to the average person. This can be dangerous and sometimes considerations are made to choose for customized design.

For standard average body dimensions in order to follow the ergonomic design rules, see the following (See example Fig. 7; *Functional seating dimensions*)
Ching and Binggeli, 2012/pg. 40-61, Functional dimensions
Binggeli, 2012/ pg. 1-12., Human factors

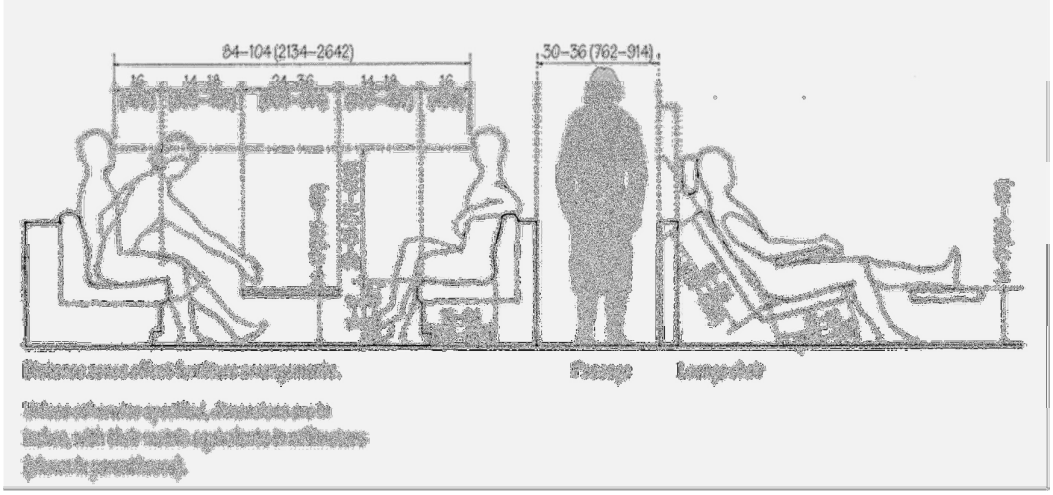

Fig. 7 Functional seating dimensions: recommended guidelines on distance zones affect furniture arrangements in inches (metric equivalent in mm) (source: Ching and Binggeli, 2012/pg. 40-61, Functional dimensions)

References

- Interior design illustrated (Ching & Binggeli, 2012)

- Interior graphic standards (Binggeli, 2012)
- The Universal design File: Designing for people of all ages and abilities (Story et al., 1998)

B 2.3 DIMENSIONAL OR SPATIAL COMFORT

Spatial comfort refers to the comfort experienced in a three dimensional space. Spatial comfort depends not only on the dimensions of the space in relation to the comfort of the personal space that is experienced, but even so on the visual comfort or visual experience of the space. The following 5 principles are responsible to spatial comfort of a room:

I. Ceiling height in relation to personal space
II. Amount of Daylight/artificial light
III. Number of windows and their size
IV. Floor space needed
V. Personal space/ walking space/interaction with others

B 2.3 / I Ceiling height/personal space

Virtual reality: The effects of the lightness of different room surfaces on perceived height.

- The height of a room varies in physical height as well as in the lightness of ceiling, floor, and walls.
- The perceived height increases with wall lightness, and the effects of wall lightness and ceiling lightness are roughly additive, incompatible.
- However, the floor lightness has no significant effect on perceived height, and that the total brightness of the room is not the critical factor influencing the perceived height.

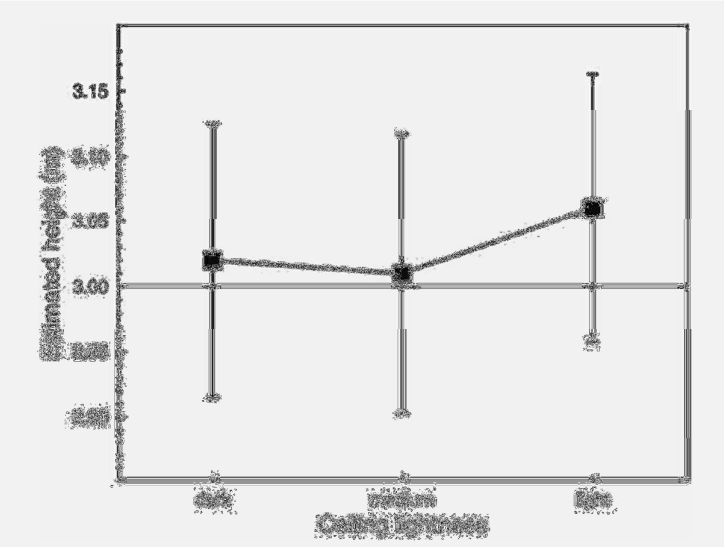

Fig. 8 Ceiling lightness in relation to the mean estimated height in meters (source: Oberfeld and Hecht, 2010)

Fig. 8 shows ceiling lightness in relation to the mean estimated height in meters: the lighter the ceiling the higher the estimated height (Oberfeld and Hecht, 2010)

In general can be stated that

- A room ceiling painted in a light colours appear larger than a room ceiling painted in a dark colour, this because light colours tend to recede while dark colours advance. Even so warm colours seem closer, while cool colours seem farther away. (See also principles in design: Appendix B1 /1.1: spatial comfort and colour).

Note: The relation between colours, ceiling height and perceived overall spaciousness is still in a research phase; no specific numbers can be given, the results of many experiments are psychological effects, based on experimental research with test persons. For more principles and parameters of perceives room height and colours, see below references

Reference

- Surface lightness influences perceived room height (Oberfeld & Hecht , 2010)
- Fashion Versus Perception: The Impact of Surface Lightness on the Perceived Dimensions of Interior Space (Oberfeld & Hecht, 2011)

B 2.3 / II-III Spatial comfort in relation to amount of daylight/window size

Windows and feeling of spaciousness

'The overall thrust of the research findings is that people prefer windowed rather than non-windowed places and windows, particularly windows with views of nature, are important in psychological and physical well-being. Natural window views may help office occupants to restore from stress, and result in a positive mood supportive for satisfaction. Windows provide daylight illumination, which generally is preferred over artificial light. From this study, openness of views emerged as the most important factor for room satisfaction. It would be best then to optimize window views to improve openness feeling and provide a spacious environment. In positioning windows and proper landscaping, the outdoors will enhance these perceptions.' (Ozemir, 2010)

Principles to Daylight/Window size room design

- General people's preferences in size of these windows are at least 2.13m x 2.13m (7ftx7ft) (Ne'eman and Hopkins, 1970),
- No windows were necessarily required for private rooms, like the bathroom. In other words the nature of the setting determines window preferences.
- View is preferred over natural daylight amount and a key factor in room design
- See Table 5-3: Spatial comfort/amount of daylight needed

Principles for space and comfort: artificial light and human factors

Recommended Illuminance in Lux in relation to the space type Table 4 and Recommended illuminance in Lux in relation to the difficulty of the task and area Table 5.

Table 4 Recommended Illuminance in Lux in relation to the space type (CIBS, 1994)

Recommended values for Illumination levels by the CIBSE (1994)		
	Space type	**lux**
Housing	Living room	50-150
	Bedroom	50-100
	Kitchen	150-300
	Bathroom	150
	WC	100
Hotel	Entrance Hall	100
	Reception	300
	Bedrooms	50-100
	Bathrooms	100

Table 5 Recommended illuminance in Lux in relation to the difficulty of the task and area CIBSE Code for Lighting Part 2, 2002)

Illuminance (lux)	Activity	Area
100	Casual seeing	Corridors, changing rooms, stores
150	Some perception of detail	Loading bays, switch rooms, plant rooms
200	Continuously occupied	Foyers, entrance halls, dining rooms
300	Visual tasks moderately easy	Libraries, sports halls, lecture theatres.
500	Visual tasks moderately difficult	General offices, kitchens, laboratories, retail shops.
750	Visual tasks difficult	Drawing offices, meat inspection, chain stores.
1000	Visual tasks very difficult	General inspection, electronic assembly, paintwork, supermarkets.
1500	Visual tasks extremely difficult	Fine work and inspection, precision assembly.
2000	Visual tasks exceptionally difficult	Assembly of minute items, finished fabric inspection.

Light and visual comfort is dependent from the following different factors

- Illuminance on task
- Colour of light
- Directional properties
- Spatial distribution

- Work
- Size (visual acuity)
- Contrast
- Colour
- Complexity
- Form + texture
- Duration and direction of movement

There are three routes by which lighting conditions influence human performance:

1. Visual system; lighting conditions
2. Circadian system; influenced by the light-dark cycle
3. Perceptual system; influenced by many factors, amongst others lighting

Fig. 9 below presents a framework of how the human performance is influenced by this visual system (Boyce & Howlet, 2003)

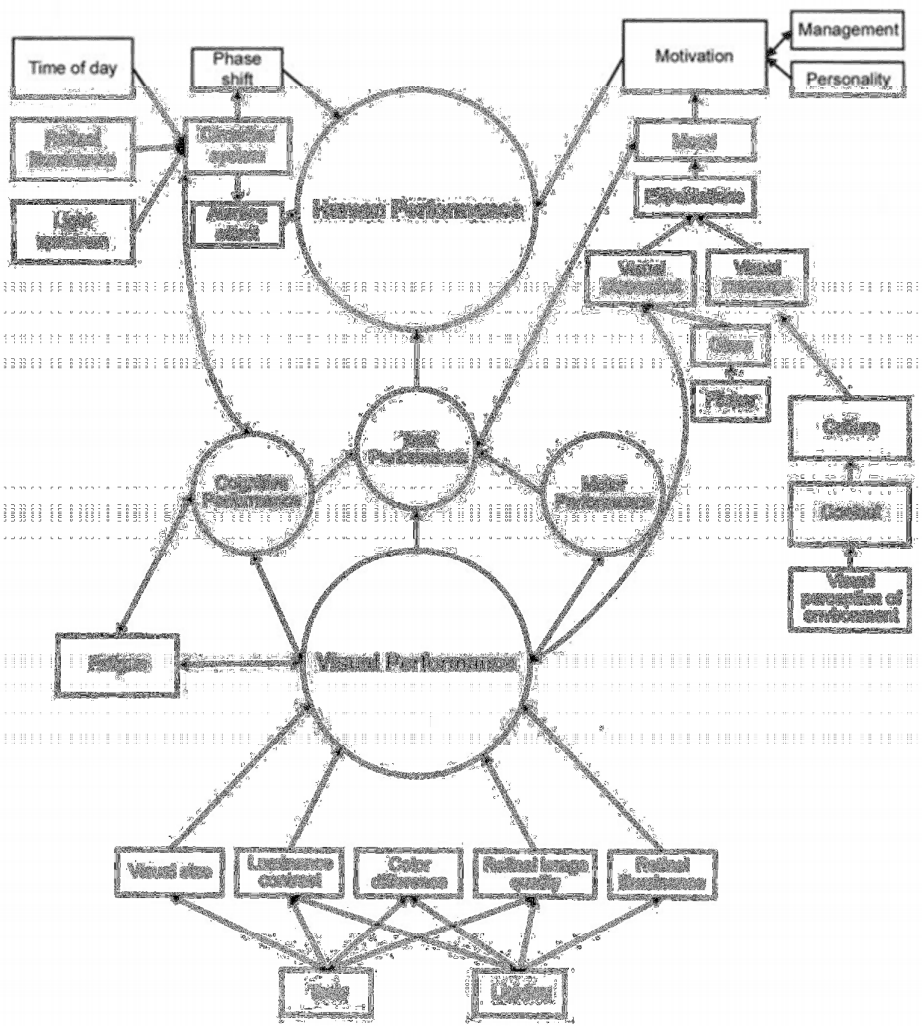

Fig. 9 conceptual framework setting out the routes by which lighting can influence human performance (Source: Boyce and Rea, 2001)

Fig. 9 presents a conceptual framework setting out the routes by which lighting can influence human performance. The arrows indicate the direction of the effects (Boyce and Rea, 2001)

References

- Parameters of Light in relation to perception of space and object: See '*Human factors in lighting*', (Boyce, 2003) second edition, chapter 6, pg. 192
- Parameters of Light in relation to visual comfort: See '*Human factors in lighting*', (Boyce, 2003) second edition, chapter 5, pg. 162.

- The benefits of daylight through windows, Boyce and Howlett, 2003, lighting research centre.

B 2.3 / IV Floor space needed

See: Parameters to the principles Appendix B1-1.4 'Comfort of Interaction'

B 2.3 / V Personal space/walking space/interaction with others

See: Parameters to the principles Appendix B/1.4: 'Comfort of Interaction'

Reference

- Fashion versus Perception The Impact of Surface Lightness on the Perceived Dimensions of Interior Space (Oberfeld & Hecht, 2011)
- Thermal comfort and window size (Ravikumar & Prakask, 2009)
- The effect of window views' openness and naturalness on the perception of room spaciousness and brightness: A visual preference study (Ozdemir, 2010)
- Human factors in lighting, second edition Peter R. Boyce, Taylor and Francis, London and New York, 2003, lighting and the perception of spaces and objects, chapter 6 pg. 192/Chapter 5, light and visual discomfort, pg. 172

B 2.4 AMOUNT OF DAYLIGHT NEEDED

Dynamism of daylight (Majoros, 2005): '*The intensity of daylight can be characterised with the luminance of light sources of day-lighting or with their integrated effect, the illuminance on horizontal surface.'*

In this section:

I. Relation between daylight/function of space and required activity/performance
II. Relation between perception of comfort and performance and daylight amount (lux):

[See Appendix B1.1-IIa: Visual comfort & Appendix B2.3-II; amount of daylight/artificial light]

Visual comfort for a person is that condition of mind which expresses satisfaction with the visual environment (Majoros, 2005). Types of visual discomfort in relation to the dynamism of daylight:

1. Over illumination
2. Glare
3. Unbalance luminance around the task

Design Guidance on daylight needed:

- The depth of daylight distribution is a function of window height relative to the working plane. Increased ceiling height gives more flexibility, allowing devices such as light shelves to bounce light deeper into the interior.
- Design ceiling heights 9 ft. 6 in. or greater to permit the use of taller windows.
- Separate the window into upper and lower portions, to independently control daylight, natural ventilation and view.
- Use light colours on interior surfaces, especially walls and ceilings, to increase the daylight that reaches areas remote from windows.

- Use splayed, light-coloured windowsills and reveals to reduce contrast and glare.
- Align interior partitions perpendicular to windows to avoid blocking daylight.
- Shape the ceiling and use secondary reflecting surfaces to further diffuse daylight

References

- CISB (Chartered Institute of Building Services Engineers) code for Interior lighting, (CISB, 1985)
- Human factors in ship design: preventing and reducing shipboard operator fatigue (Calhoun, 2006)
- The Universal design file: Designing for people of all ages and abilities (Story et al., 1998)
- Energy code from ASHRAE in the USA (ASHRAE, 2010)
- http://www.commercialwindows.org; day lighting
- www.daylightsite.com
- (Boyce, 2003)
- Daylight design from the Architect's perspective (Jacobs, 2010)

B 2.5 NOISE AND VIBRATION

See also Noise and vibration considerations in Appendix B3 [B3.2/I-II]; Dimensions of the space itself and Space location on board the ship

B 2.5 / I Noise reflection and comfort feeling & sound absorption

General

In order to find the parameters to the noise and vibrations and sensory comfort principles when the designer needs to choose its interior elements the following needs to be taken into consideration: Noise irritation from noise reflection (echo/hollow sound) typically experienced in areas with stiff hard surfaces (floors,

walls and ceilings); (Interior elements: Windows (glass), furniture, bar, aquarium, art, stage etc.).

Many studies describe noise irritation and their comfort levels. Many building codes are addressing the type of insulation to use or how to construct in order to absorb as much noise as possible. In order to avoid noise/vibrations and resonance, space needs supportive structure and stiffness of walls in relation with windows, as well sound absorbing materials. However, one of the solutions is to avoid as much uncomfortable noise travelling through the adjacent spaces in the first place by addressing the problem right from the beginning: interior layout plans. It is more expensive after the space is completed to find solutions to the noise problems and expensive isolation and absorption material can reflects poorly on the original design.

For example a large spacious room on board the ship can be comfortable visually but acoustically uncomfortable. Large rooms can work against the designer in for example echoes. Echo time is affected by the size of the space and the amount of reflective or absorptive surfaces within the space. Larger spaces usually have longer echo times than smaller spaces. Therefore, a large space will require more absorption to achieve the same comfort as a smaller space. A space with highly absorptive surfaces will absorb the sound and stop it from reflecting back into the space. However, reflective surfaces will reflect sound and will increase the echo time within a space.

Room acoustics and acoustical comfort

A very important aspect of acoustical comfort is room acoustics. Room acoustics affect the sound generated in the room itself. Concert halls for example are highly concerned with room acoustics as it determines how the sound/music, generated on stage, is received by the audience. An important aspect of acoustical comfort is reverberation of the generated sound. If there is a lot of reverberation in a room, somebody's speech or music played in that room may sound cold, hollow and loud. What causes or this effect is a phenomenon called sound reflection. This is the effect

of sound generated in the room being bounced back from smooth hard surfaces like walls, glass panels and floors (think of church acoustics). How severe this effect is measured through reverberation time. This is the time it takes for an impulse like sound to die away.

From an interior design point of view this effect is minimised by avoiding smooth hard surfaces. Carpets and curtains for instance function as sound absorbers reducing sound bouncing back to the people in the room.

What to do to avoid noise nuisances within the room and in the spatial elements plan:

Furniture layout: Consider the impact of the variety of the noise making sources in that space when mapping the room and designing the layout; example do not position TV sets directly towards the walls, but leave some space in order to avoid resonance and noise nuisance to the others rooms. Think about object such as desks (slamming doors) and other objects that can create noise and do not position them against a wall of which the opposite site is a quiet area (galley drawers directly to the wall where a cabin bed is positioned or lounge room furniture is situated).

Sound absorbing coefficient: 'One measure of the quality of sound in a room is the average coefficient of absorption for all surfaces combined. As determined by using the average of absorption, the quality of sound in a room can be evaluated on a scale from 01 to 0.3 A room with an average coefficient of 0.1 is rather acoustically live, loud and uncomfortably noisy, 02 is comfortable with well controlled noise and 0.3 is acoustically dead (Binggeli, 2012 pg. 14).'See Fig. 10 for an example on various materials.

Surface Treatment	Absorptivity at Frequency 125	250	500	1000	2000	4000
Acoustic tile, rigidly mounted	.2	.4	.7	.8	.6	.4
Acoustic tile, suspended in frames	.5	.7	.6	.7	.7	.5
Acoustical plaster	.1	.2	.5	.6	.7	.7
Ordinary plaster, on lath	.2	.15	.1	.05	.04	.05
Gypsum wallboard, $\frac{1}{2}$" on studs	.3	.1	.05	.04	.07	.1
Plywood sheet, $\frac{1}{4}$" on studs	.6	.3	.1	.1	.1	.1
Concrete block, unpainted	.4	.4	.3	.3	.4	.3
Concrete block, painted	.1	.05	.06	.07	.1	.1
Concrete, poured	.01	.01	.02	.02	.02	.03
Brick	.03	.03	.03	.04	.05	.07
Vinyl tile, on concrete	.02	.03	.03	.03	.03	.02
Heavy carpet, on concrete	.02	.06	.15	.4	.6	.6
Heavy carpet, on felt backing	.1	.3	.4	.5	.6	.7
Platform floor, wooden	.4	.3	.2	.2	.15	.1
Ordinary window glass	.3	.2	.2	.1	.07	.04
Heavy plate glass	.2	.06	.04	.03	.02	.02
Draperies, medium velour	.07	.3	.5	.7	.7	.6
Upholstered seating, unoccupied	.2	.4	.6	.7	.6	.6
Upholstered seating, occupied	.4	.6	.8	.9	.9	.9
Wood/metal seating, unoccupied	.02	.03	.03	.06	.06	.05
Wooden pews, occupied	.4	.4	.7	.7	.8	.7

SOURCES: Backus (p. 172) and L. Doelle, *Environmental Acoustics* (McGraw-Hill, 1972), p. 227.

Fig 10 Example of approximate typical absorption coefficients of various surfaces (Doelle, 1972)

References

- Resonance/ furniture related and adjacent walls (location of piano for example) (Acoustics.com, 2004)
- Interior graphic standards (Binggeli, 2012)
- Absorption coefficients (Doelle, 1972)
- Acoustic Index for Restaurants and Café's (Camp, 2004)
- Acoustics in the Hospitality Industry (Christie & Bell-Booth, 2004)
- Good Practices on ventilation System Noise Control (Department, 2006)

B.3 Parameters to the principles as presented in Table 5-3 of chapter 5: Identified key human elements to the design of the space in relation to the location of the space onboard

B 3.1 MOTION SICKNESS

Motion sickness occurs at low frequency pitch and roll motions below 0.3 Hz range in combination with vertical acceleration magnitudes between 1 and 4 m/s² rms. Grades in seasickness may vary from feeling fatigued or quite ill, to vomiting (Grech, Horberry, & Koester, 2008).

B 3.1 / I Ships accelerations

- In order to prevent seasickness choose a perfect location for the space in mind in relation to the ships layout in combination with its function and activities that are going to be carried in that particular space.
- Choose the key location and living spaces with a minimum exposure to uncomfortable frequencies and a low acceleration level to avoid motion sickness.
- Consider the key location in low acceleration areas is of paramount importance in an early design stage to avoid discomfort amongst the crew and passenger.
- To find the low acceleration areas on board merely depends on the shape of the yacht, but in general can be said that the further away from the centre of gravity the space in located the higher the acceleration would be; (Example locate a fine dining restaurant near the sundeck might be responsible for some discomfort feelings for people with a tendency towards motion sickness.)
- Minimise the effect of acceleration levels to avoid motion sickness by considering one of the following key elements:
    - People in that space-location needs to have a *horizon* to look at
    - Access to *natural daylight*
    - *Avoid adjacent rooms with strong odours/fumes or noise and vibrations*

- When considering motion sickness as a human key factor to design, several key factors can be named that or are known to be responsible to have an impact on motion sickness, amongst other;
    - Gender, (women are likely 1.5 times more receptive to motion sickness than man of similar age.)
    - Fumes and air quality, (can be avoided by avoid that most important rooms where the most amount of time is spend in, are located far from spaces that can create strong fumes, like paint lockers, engine rooms etc.)
    - Availability of natural daylight (daylight and the possibility to see the horizon have a huge impact on the person's receptiveness of motion sickness)
    - People who have a tendency towards motion sickness, living rooms and cabins can be best located far away from these spaces.

References

(Dallinga et al. 2002; Sariöz & Sariöz 2005; Turan 2006; Arribas & Pineiro 2007)

- Ships acceleration
    - Duration during which the passenger is subjected to the acceleration: (Khalid, 2011), choose for the key locations on board, space with a low acceleration level
    - Relation of adjacent rooms: Calhaun LT, 2006; Preventing and reducing shipboard operator fatigue

B 3.1 / II Availability of daylight needed (visual comfort)

References

- Natural light and the view of an horizon have a positive impact (Khalid, 2011),
- Fatigue design as a reaction to motion sickness (Lamb, 2006)
- Relation of adjacent rooms: Calhaun LT, 2006; Preventing and reducing shipboard operator fatigue

- Gender and age (Khalid 2011; Bos et al 2007)
- Human factors in Lighting (Boyce, 2003)

B 3.2 NOISE AND VIBRATIONS

See also Appendix B2; Noise and vibrations [B2.5]

Quote: 'Noise reduction depends on the properties of the room and is the actual difference in sound pressure levels between two spaces. It is the amount of sound blocked by all intervening sound paths between rooms, including the common wall but also the floors (decks), ceilings, outside paths, doors etc., Noise reduction also depends on the size of the room, if the noise source is in a small room next to a large receiving room (cabins next to the living rooms), the noise reduction will be greater than the transmission loss performance of the wall alone because the sound radiating from the common wall between office and gym dissipated in such a large space' [Binggely, 2012 pg. 15].

B 3.2 / I Adjacent rooms

General noise related adjacency theory

To avoid irritation from noise and vibrations from adjacent rooms in the preliminary ship design stage, when the interior designer is considering the space location in relation to the ships' layout, is by looking at the specific space and its function in relation to the location of where most likely the noise and vibrations are coming from. Certain rooms may require less noise and vibrations than others and should therefore not be located next to each other. Most ships noise is produced by the machinery spaces; engine room, propellers, engines, air-conditioning and ventilation units (HVAC-units). Other type of noise onboard could be conversation areas, for example the bar or a children's corner. Idealistically a quiet zone, like a reading room, would not be comfortable to be in as this room is adjacent to one of the noise producing areas onboard.

Many studies describe noise irritation and their impact on comfort levels. For a mega yacht this noise irritation can be split in two main areas:

a. **Noise irritation from machinery noise**
b. **Noise irritation through noise generated by human activities**
    1. Noise irritation from noise transmitted between different areas on board.
    2. Noise irritation from noise reflection (echo/hollow sound) typically experienced in area's with stiff hard surfaces (floors, walls and ceilings)

a. Noise generated by machinery

Traditionally the main focus regarding ship noise is on the noise generated by on board machinery. Main contributors to noise are the propeller, main engines, auxiliary engines, air conditioning, engine room ventilation and exhaust gas noise. Machinery noise in different spaces is assessed by the overall equivalent A weighted noise levels and the shape of the A weighted noise spectra.

Overall noise levels

Noise is primarily assessed based on overall A weighted noise levels expressed in decibels. The A weighting of noise refers to the application of a weighting curve on a noise spectrum in order to correct for the sensitivity of the human ear to noise which is related to the frequency of the noise. The total A weighted noise level is derived from the noise spectrum that has been corrected for the human sensitivity by the A weighting curve.

Regulatory bodies (Like: abs guide for crew habitability on ships, 2012) have defined maximum allowable A weighted noise levels that are primarily based on human health. Guidelines have been formulated by institutions like for noise levels based on perception of comfort through which comfort class notions can be awarded to ships which is of particular interest for passenger ships and yachts. Further guidance with

respect to hearing conservation is provided in the IMO Resolution A.468(XII) (1981) Code on Noise Levels On-board Ships and should be followed for noise levels and exposure duration, particularly for areas with noise levels in excess of 85 dB(A). New better formulated noise limit values are being developed for the EU by Strathclyde University and other project partners based on extensive study of human perception of comfort and work quality impairment of on board crew (SILENV, 2010).

Shape of spectra

On board machinery and propeller induced noise is not only assessed by the overall A weighted values measured in all relevant areas on board. The shape of the spectrum is also of interest. Low overall noise levels may still be harmful when most of the noise energy is concentrated around one or only a few frequencies. This is noise that has a very tonal characteristic and may at least be perceived as very annoying despite its low A weighted overall noise level. In order to evaluate noise, taking this phenomenon into account, noise rating curves are used (see Fig. 11). The Noise Rating - NR - curves are developed by the International Organization for Standardization (ISO) to determine the acceptable indoor environment for hearing preservation, speech communication and annoyance

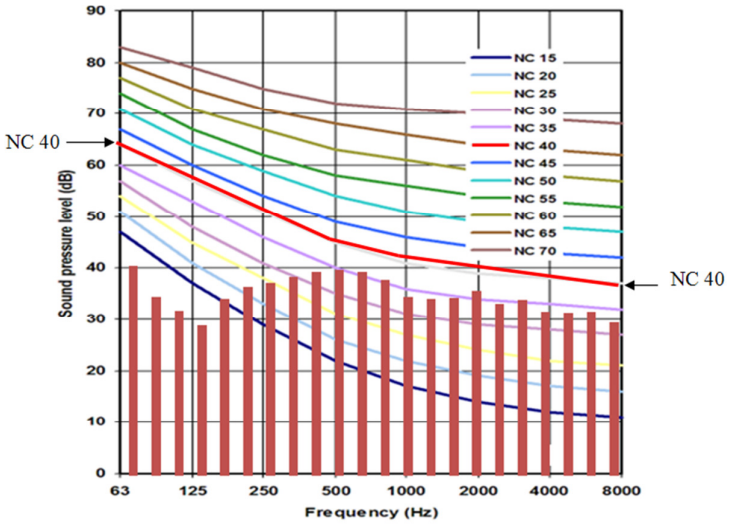

Fig 11 Noise rating Curves: Noise rating of a spectrum measured in a recreational space on board a passenger ship. The spectrum is rated with a noise rating number of 40 (engineeringtoolbox.com)

A noise spectrum is assessed by plotting the noise rating curves in the measured A weighted spectrum. The lowest curve that is not exceeded by any of the measured noise spectrum frequency components carries the rating number that is used to assess the spectrum shape. The higher this rating number, the more annoyance will be experienced. Fig.10 shows how the noise rating curves plotted in a spectrum of machinery induced noise measured in a recreational space for officers on board a passenger ship. This spectrum shape should be rated with a NC number of 40. According to Fig. 12 the Noise Criterion 40 is to be considered very quiet.

Type of Room - Occupancy		Noise Criterion - NC -	Noise Rating - NR -	dB(A)
Very quiet	Concert and opera halls, recording studios, theatres, etc.	10 - 20	20	25 - 30
	Private bedrooms, live theatres, television and radio studios, conference and lecture rooms, cathedrals and large churches, libraries, etc.	20 - 25	25	25 - 30
	Private living rooms, board rooms, conference and lecture rooms, hotel bedrooms	30 - 40	30	30 - 35
Quiet	Public rooms in hotels, small offices classrooms, courtrooms	30 - 40	35	40 - 45
Moderate noisy	Drawing offices, toilets, bathrooms, reception areas, lobbies, corridors, department stores, etc.	35 - 45	40	45 - 55
Noisy	Kitchens in hospitals and hotels, laundry rooms, computer rooms, canteens, supermarkets, office landscape, etc.	40 - 50	45	45 - 55

Fig. 12 Recommended maximum noise levels for different types of rooms and standards (Source: Engineeringtoolbox

General adopted design principles

The following design principles should be observed for low on board machinery and propeller noise:

- Apply dynamic isolation of on board machinery through application of flexible or double flexible machinery mounting systems
- Apply resilient casing around main engines.
- Apply isolation in cabins (floating floors)
- Apply damping materials in cabins and bulkheads
- Apply sound absorbing materials in the interior (curtains and carpets)
- Avoid structural resonance
- Avoid high air speeds in ventilation systems
- Possibly applying active noise cancellation concepts in ventilation ducts

b. Human activity generated noise

An important noise source to take into account with the interior design of a ship is the noise generated by human activities. These activities could be:

- Having a conversation, laughing, singing
- Making or playing music
- Walking around, dancing, jumping, exercising (footsteps on deck)
- Working activities (cooking, cleaning, drilling, brushing, hammering etc.).

How human activities generated noise affects the perception of comfort is assessed both through the quality of the sound in the room where the activities take place (room acoustics), and the noise received by people in other areas of the ship (isolation).

From an Interior design perspective the following two key elements should be considered in the preliminary mega yacht design stage, in order to choose the perfect space location in relation to the ships' layout:

- Adjacency relations between the spaces on board and its function: sound transmission through the ship
- Adjacency relations between the spaces on board and the recommended noise and vibration levels: according to the IMO rules but also according to the Human

performance and annoyance levels, like the SILENV project: (EuropeanCommission, 2010): Noise irritation from noise reflection

B 3.2 / II Sound transmission through the ship

The impact of human activities generated sound transmitted through the ship can be reduced from a ship design point of view through applying isolation. Many building codes are addressing the type of insulation to use or how to construct in order to absorb as much noise as possible. How well this isolation works may be accessed through a STC number as formulated by the American national standard institute (ANSI). Fig.14 shows the STC curves as formulated by the ANSI and Fig. 13shows their Sound Isolation Criteria or STC value/what can be heard.

The reduction of airborne sound transmission, such as conversation noise, is in the building industry rated by STC rating: Sound Isolation Criteria or STC value: This is a value system designed to combine the transmission loss values from many frequencies. The STC number is derived from sound attenuation values tested at sixteen standard frequencies from 125 Hz to 4000 Hz. STC is roughly the decibel reduction in noise a partition can provide, abbreviated 'dB'. The dB scale is a logarithmic one and the human ear perceives a 10dB reduction in sound as roughly halving the volume - a 40 dB noise subjectively seems half as loud as a 50 dB one.

- Hotel bedrooms: Adjacent bedroom, living room or bathroom require 55 STC
- Lobby or corridor require 55 STC
- Adjacent bedrooms and dining areas require 45 STC etc.

STC	What can be heard
25	Normal speech can be understood quite easily and distinctly through wall
30	Loud speech can be understood fairly well, normal speech heard but not understood
35	Loud speech audible but not intelligible
40	Onset of "privacy"
42	Loud speech audible as a murmur
45	Loud speech not audible; 90% of statistical population not annoyed
50	Very loud sounds such as musical instruments or a stereo can be faintly heard; 99% of population not annoyed.
60+	Superior soundproofing; most sounds inaudible

Fig13: Sound Isolation Criteria or STC value/what can be heard.

STC number and noise transmission trough the other side of the wall

To determine the STC number of a wall/ceiling or floor, a noise reduction curve is plotted in a graph together with a set of STC curves (see example of such a reduction curve in Fig. 12). The reduction curve is in fact the **difference** between a noise source spectrum in front of a wall/ceiling or floor and the spectrum of the noise transmitted from that noise source to the other side of the wall/ceiling or floor (also known as: attenuation curve) and reflects how well the wall/ceiling or floor isolates the noise. The STC curve that fits the attenuation curve the best carries the STC number through which the quality of the isolation is reflected. The higher the STC number, the better the isolation properties (see Fig.13).

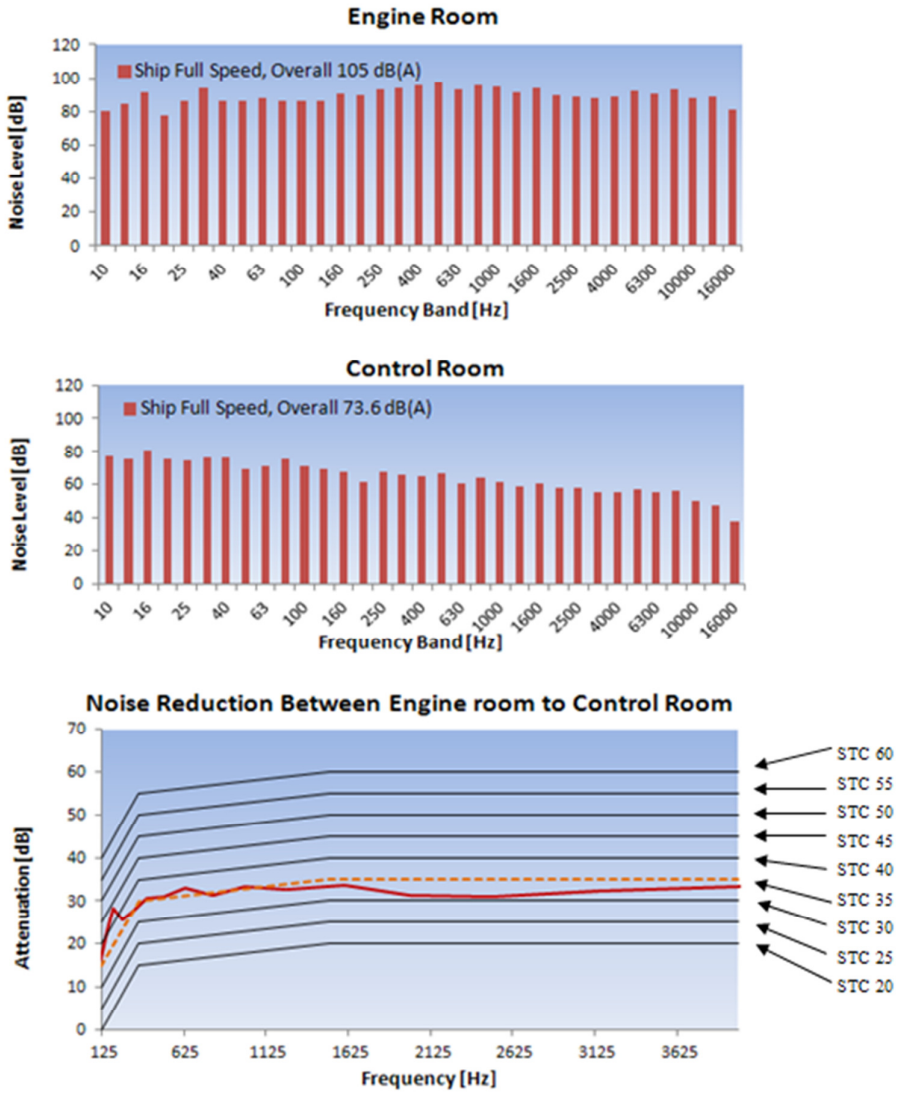

Fig 14 Example of determination of STC number for the assessment of control room isolation on board a vessel; the red line in the last graph is the difference in noise between the engine room and the engine control room. The isolation in this case will be rated with an STC number of 35 (Source: Zoet, 2010; measurements carried out for EU fp7 research project SILENV)

Fig.14 demonstrates how a STC curve of an engine control room wall of a particular vessel can be determined. The type of vessel in this case is irrelevant for the demonstration and thus this method can be applied to all types of vessels. The spectra are obtained from the database of noise and vibration measurement results that has been setup for the EU fp7 research project SILENV. The wall in question is designed to isolate the control room from noise coming from the engine room. In the building

stage of a ship the STC curve is in most cases determined by placing a noise source producing a broadband white noise spectrum on one side of an isolating partition. The broadband noise in this example is produced by the main engines running at 50% power.

Furthermore Spectrum A in Fig.14 shows the measured un-weighted spectrum in the engine room close to the engine control room. Spectrum B shows the un-weighted spectrum measured in the control room. By subtracting spectrum B from spectrum A, the attenuation curve is obtained (red line in the last graph below) and plotted amongst the STC curves. As a result the red dotted STC curve was found to be matching the attenuation curve the best giving the partition an STC number of 35.
What means '*loud speech but not intelligible*'; Fig.13

How good a space is regarding noise comfort in relation to noise reflection (acoustical comfort) is assessed through the reverberation time of the noise. The overall recommendation for is to take the relation and function of the space towards its adjacency spaces into account when preparing an overall ships' layout plan and by using the STC levels, as shown above, as a guide for choosing the correct location of the space on board.

Noise irritation from noise reflection
[See also Appendix B 2.5]

Many building codes are addressing the type of insulation to use or how to construct in order to absorb as much noise as possible. In order to avoid noise/vibrations and resonance, space needs supportive structure and stiffness of walls in relation with windows, as well sound absorbing materials. However, one of the solutions is to avoid as much uncomfortable noise travelling through the adjacent spaces in the first place by addressing the problem right from the beginning: *interior layout plans*. It is more expensive after the space is completed to find solutions to the noise problems and expensive isolation and absorption material can reflects poorly on the original design.

For example a large spacious room on board the ship can be comfortable visually but acoustically uncomfortable. Large rooms can work against the designer in for example echoes. Echo time is affected by the size of the space and the amount of reflective or absorptive surfaces within the space. Larger spaces usually have longer echo times than smaller spaces. Therefore, a large space will require more absorption to achieve the same comfort as a smaller space. A space with highly absorptive surfaces will absorb the sound and stop it from reflecting back into the space. However, reflective surfaces will reflect sound and will increase the echo time within a space.

Avoid acoustic problems in the room by: Isolating the living accommodation spaces from the engine rooms, elevator shafts, ice and beverage dispenser rooms and major duct chases and other sources of noise by buffer spaces. Buffer spaces are for example storage rooms, corridors and staircases that can be placed between the living spaces; like guest rooms and dining rooms etc. and sources of noise.

References

- An experimental study investigating the effects of noise on seafarers' performance and comfort: (Kurt et al, 2010)
- Kurt et al, 2012
- SILENV EU Fp7 project (Europeancommission, 2010)
- Interior graphic standards (Binggeli, 2012)
- Sound Transmission Class ratings on www.acoustics.com, 2004
- Binggeli, 2012
- sound reduction index , ISO 140 (parts 1-14)
- Zoet, 2010

B 3.3 INTERACTION OF ADJACENT ROOMS

B 3.3 / I Function in relation to activities carried out in adjacent room

On board logistics

Although in the naval architecture, adjacency analysis is carried out by means of algorithm logistics, this technique does not take the human psychological elements into consideration. In order to analyse relationships between spaces and how to work together and how each area flows from one to another, an interior designer uses adjacency analysis. These types of analyses are developed to solve many human orientated layout problems, such as traffic flow and complex relationship between spaces and floors. These analyses depend on the users of the space and their specific requirements. In the interior design there are different methods used to accomplish the analysis. The following three methods are used either combined or separately from one another:

1) Space planning and schematic design

Schematic design is an easy straightforward way to simply sketch the complete layout structure of the ship in preparation to a more complex algorithm logistics. By planning the individual rooms together with the customer in their priority in separation in: private, non –private, crew and shared spaces, the designer obtains the human oriented design requirements the ship design process is aiming for (See Fig. 15)

Fig. 15 space planning and schematic design example (source: http://meganmcclunedesignstudio.blogspot.co.uk)

2) Adjacency Matrix (Triangular)

After the schematic design plan an adjacency matrix can be created: used to show relationships between spaces and areas in a design. The matrix is evaluated by looking at each pair of components and assessing them in terms of their relationship to one another (see Fig. 16)

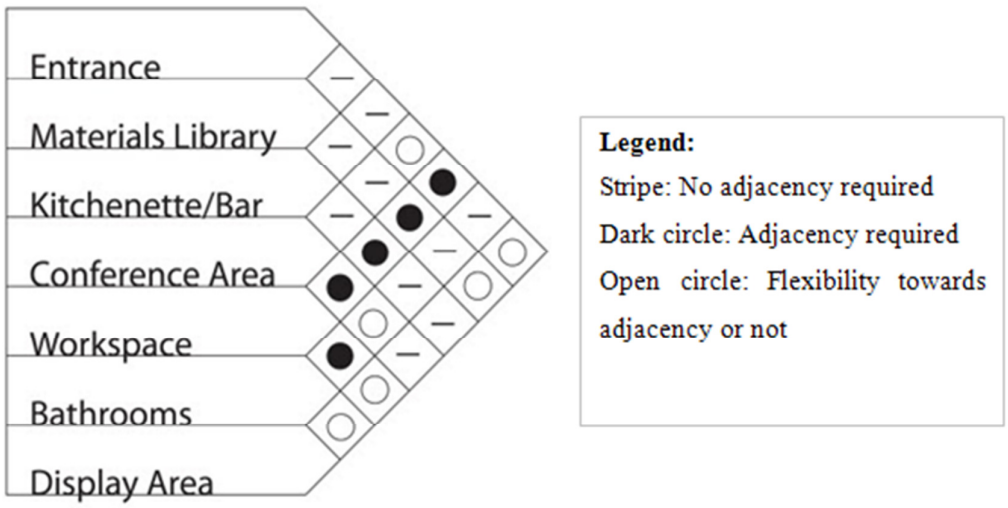

Fig.16 Example of a straightforward adjacency matrix
(Source: http://meganmcclunedesignstudio.blogspot.co.uk/)

Fig. 16 shows a simple example of an adjacency matrix; the matrix will reflect the relationships between the three areas. Various circles or lines can be used to indicate the rooms' priority towards adjacency with the other spaces. White space means there is a lot of design freedom.

Space adjacency analysis takes care of an efficient operation between the several departments onboard. To do this efficiently the designer needs to understand the exact relationship between the several areas onboard; the crew and guests departments and their functional areas etc.

The designers can use the adjacency matrix in the preliminary design stage of the mega yacht before the algorithm logistics can commence in order to sort out the human elemental relations between the rooms first.

3) Bubble diagrams

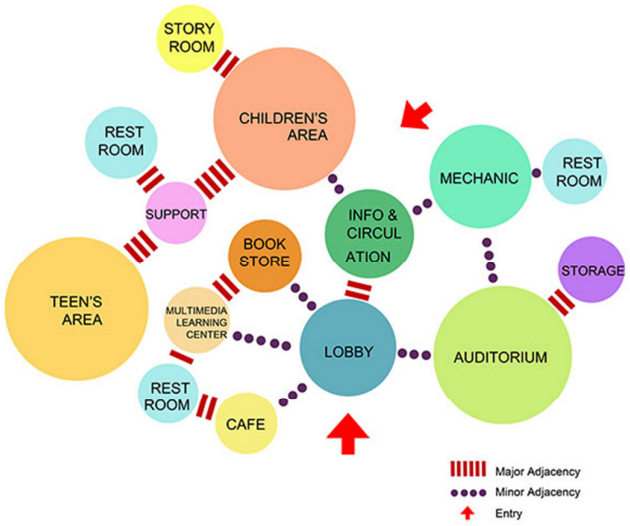

Fig. 17 Bubble diagram example (source: http://www.xzzspace.com/library.html)

Bubble diagrams in the interior design are used after the space adjacency analysis has been made. The connection and relationships between the areas and departments has been analysed and understood and can accordingly be visualised in a Bubble diagram (Fig.17). The Bubble diagram can help to understand the traffic flow, layout, space adjacency and the relative space sizes among others. The Bubble diagrams can be used prior to the algorithm logistics for example in order to brainstorm on Human orientated adjacency analysis problems without the complex calculations or drawings.

In Fig. 17, the relationships between the different areas are presented by means of different colours and line styles etc. The designer can make up their own complexity of colour and line coding, depending on the type of human interrelationships of the layout etc.

References

- Adjacency matrix and Functional diagrams to analyse relationships between rooms (Mitton, 2012)

- Onboard logistics (Mitton, 2012)
- http://www.xzzspace.com/library.html.
- http://ldvalidate.wordpress.com
- http://meganmcclunedesignstudio.blogspot.co.uk

Thermal comfort and adjacent rooms

Human relationship with thermal comfort needs to be considered in the adjacency analyses. Besides the standard guidelines that are provided for indoor climate by the classification societies, there have been numerous researches carried out in thermal comfort and human elements. Relations have been researched between the window openings, number of windows, size, and location in the room and body heat and human comfort relationships when standing near a window. See for models on thermal comfort below reference list.

References

- See for detailed analyses and optimum window openings criteria: Analysis of thermal comfort in an office room by varying the dimensions (Ravikumar & Prakask, 2009)
- Thermal comfort model based on a physical assessment of heat exchange between the human body and the environment. (Awbi HB (2003). Ventilation of Buildings, 2nd edn. London: Spon Press, pp. 1 – 47)
- ABS: Passenger comfort on ships (section 5; indoor climate)
- Evaluation of the psychological bases of thermal comfort models (Doherty & Arens, 1998)

B 3.4 AMOUNT OF DAYLIGHT NEEDED

See also principles to daylight design Appendix B1.1; spatial comfort: Visual comfort, lighting and daylight needed B1 and Appendix B 2.4; Amount of daylight needed.

B 3.3 / I Relation between function of space and required activity/performance and construction possibilities

Daylight varies from latitude, season, coastal or inland location, climate, and air quality. Example: Light designers in the UK use a figure of 10 kilolux for external illuminance when calculating the level of illuminance due to daylight. A minimum of 10 kilo lux will be provided for about 70% of the working day at latitude of 52%N (latitude British Isle).

When the space location is considered the designer should take into account the activities and function of the room and the necessity of daylight. The following Key elements to daylight design for the space location choice should be considered:

- Activity related, desires of the owner taken into account
- Function related
- Ship construction and possibilities of windows
- Ship construction and possibilities for the dimension of the windows

Furthermore:

- The room should have a minimum of task illuminance of 500 lux
- Daylight from a window provides a cross vector of light which will improve modelling and provide a desirable vector/scalar ratio
- Colour rendering will be improved for interiors with good daylight penetration
- Daylight illuminance less than 100 lx are generally considered insufficient either to be the sole source of illumination or to contribute significantly to artificial lighting

Nabil & Mardaljevic (2006) research findings:

- Daylight illuminance in the range 100−500 lx are considered effective either as the sole source of illumination or in conjunction with artificial lighting;
- Daylight illuminance in the range 500−2000 lx are often perceived either as desirable or at least tolerable;

- Daylight illuminance higher than 2000 lx is likely to produce visual or thermal discomfort, or both.
- Any daylight illuminance in the range 100–2000 lx should be considered as offering potentially useful illumination for the occupants of the space.

References

- Interior lighting Design, student guide (1994)
- Human factors in lighting, second edition Peter R. Boyce, Taylor and Francis, London and New York, 2003. Pg. 250; daylight delivery systems
- Useful daylight illuminances: A replacement for daylight factors, Azza Nabil, John Mardaljevic/ Energy and Buildings/ Volume 38, Issue 7, July 2006, Pages 905–913/ Special Issue on Day lighting Building
- CISB code for interior lighting (CISB, 1995)

Appendix C– Basic safety requirements to preliminary mega yacht design

C.1 Basic safety requirements, the rules and regulations that apply to mega yachts, large yachts, either private or in charter

This section presents the basic safety requirements, the rules and regulations that apply to mega yachts, large yachts, and either private or in charter. These basic safety rules need to be applied and considered in the preliminary design stage of the mega yacht design process. The next following 5 Tables show accordingly:

- **Table 1** presents the general overview of the basic safety rules and regulation that apply to large yachts, either private or in charter (Manta maritime, 2010)
- **Table 2** presents a more detailed compliance matrix for large yachts ≥ 3000 GT (Manta maritime, 2010)
- **Table 3** presents the details on Flag State, Organisation and the two main International conventions principal to preliminary Private/Charter yachts Design
- **Table 4** shows the Private Yacht rules compared to the Charter yacht rules
- **Table 5** presents an example of the ABS classification options for large yachts if the owner of the yacht chooses the ABS as classification agency.

Table 1 General Overview of the basic safety rules and regulation that apply to large yachts, either private or in charter (Manta maritime, 2010)

Applicable rules & regulations for large yachts	Private yachts, carrying 12 guests or fewer	Charter yachts, less than 3000GT, less than or equal to 12 passengers	Charter yachts, more than or equal to 3000GT, less than or equal to 12 passengers	Charter yachts, any GT, more than 12 passengers
large commercial yacht codes		X	X	
MARPOL Convention	X	X	X	X
International Tonnage Convention	X	X	X	X
COLREGS Convention	X	X	X	X
International Load Lines Convention		X	X	X
Classification Society rules & regulations		X	X	X
STW Convention &Code		X	X	X
ISM Code		X	X	X
ISPS Code		X	X	X
SOLAS Convention General	X	X	X	X
SOLAS Convention Cargo Ships		X	X	
SOLAS Convention Passenger Ships				X

Table 2 Detailed compliance matrix for large yachts ≥ 3000 GT (Manta maritime, 2010)

COMPLIANCE MATRIX FOR LARGE YACHTS		GT > 3,000	
		Private	Charter
COLREGS		✓	✓
Large Yacht Codes[2]		×	×
International Convention on Load Lines		×	✓
MARPOL	Annex I - Oil Pollution	✓	✓
	Annex IV - Sewage	✓	✓
	Annex V - Garbage	✓	✓
	Annex VI - Air pollution	✓	✓
SOLAS	Chapter I - General	×	✓
	Chapter II - Construction	×	✓
	Chapter III - LSA	×	✓
	Chapter IV - Radio	×	✓
	Chapter V - Navigation	✓	✓
	Chapter IX - ISM Code	×	✓
	Chapter XI-1 - Maritime Safety	×	✓
	Chapter XI-2 - ISPS Code	×	✓
STCW		×	✓

Table 3 Details on Flag State, Organisation and the two main International conventions principal to preliminary Private/Charter yachts Design

	Introduction	Details	Required for
Flag State or Flag Administration	Governmental authority under which a country exercises regulatory control over the vessels which is registered under its flag.	MCA, Maritime Classification Agency; Flag State of the UK MCA = Authority which regulates and certifies all vessels registered in the UK.	All vessels
IMO SOLAS	International Maritime organization, for yachts body that maintains, updates the main conventions: SOLAS = Main International convention: Safety Of Lives At Sea	**Private yachts** officially comply with: SOLAS, Chapter V; Safety of navigation, **Charter yacht ≤ 12 passengers** comply with SOLAS cargo Ship requirements **Charter yacht ≥12 passengers** comply with the rules for SOLAS's Passenger ship rules	**Private yachts:** SOLAS: Charter V: Safety of Navigation **Mega yachts in charter > 24 meters and 500 GT:** SOLAS, chapters I- XI-2: General, Construction, LSA, Radio, Navigation, ISM code, Maritime Safety, ISPS Code
IMO **Load Lines**	International Convention on Load Lines:	gives limits to the draught, external watertight and watertight integrity etc.	Not obligatory for private yacht, only for yachts in charter ≥ 24 meters

Table 4 Private Yacht rules versus Charter yacht rules

A yacht is a Passenger ship when carrying 13 or more *charter* guests, and is required to comply with:
▪ Load Lines ▪ SOLAS Passenger Ship requirements ▪ STCW
A private yacht is a yacht not engaged in trade and is not obliged to meet with any of the above mentioned *Charter* yacht rules. This may vary from different flag state; some flag state may require Private 13+ yacht to meet with the SOLAS passenger vessel requirements or the owner decides to meet with the SOLAS passenger vessel requirements for the following reasons: (Manta Maritime, 2008):
▪ 'It may not be welcomed in the waters of those countries that do have requirements for this type of yacht (Port State Control) ▪ Registered commercial yachts have tax benefits ▪ Pros: can be that because there are no safety requirements enforced by a regulatory authority, the designer, builder, owner/manager and crew are given free design space to do whatever they require reign'
The Passenger Ship requirements of SOLAS that are perceived to be difficult to meet for yachts are (Manta Maritime, 2008):
▪ Watertight subdivision ▪ Emergency escape routes ▪ Provision of lifeboats ▪ Use of non-combustible materials ▪ Management for the ISM & ISPS Codes ▪ STCW requirements prevent MCA 'Yacht' qualified crew from working on board

Table 5 Example of ABS classification options for large yachts

Classification society (depends on where the yacht is flagged) For this thesis study and example, ABS (American Bureau of Shipping) is used					
Reasons to Class	**Protect Your Capital Investment**	**Conform to Underwriting Requirements**	**Exercise Due Diligence**	**Demonstrate Proper Maintenance**	**Comply with Statutory Requirements**
Type of Certifications possible	**ISM** (International Management Code for the Safe Operation of Ships and for Pollution Prevention	**ISPS** (International Ship and Port Facility Security Code)	**MLC** (Maritime Labour Convention)	**HSQEEn** (Health, Safety, Quality, Environmental and Energy)	Furthermore: SOLAS, MARPOL, load line and tonnage certificates
Most common Rules and Guidelines Applicable for Mega yachts applicable for accommodation design					
Mega yachts ≤ 12 passengers	***Comfort – Yacht (COMF(Y)) and Comfort Plus – Yacht (COMF+(Y)).*** This guide complies with the criteria for owner and guest accommodations and the ambient environment (i.e., vibration, noise, indoor climate and lighting)		***Crew Habitability on Ships*** **HAB or HAB+ – yacht** This Guide focuses on all habitability aspects of cargo and passenger vessel design and layout that can be controlled, measured and assessed.		
Mega yacht ≤ 12 Passengers	**Passenger Comfort on Ships**	**Passenger vessels**			

C.2 the rules, regulations and basic safety requirements on accommodation interior design (Rules optional for private yachts ≤ 12 passengers) for the following:

a) General basic safety
b) Choice of spatial elements
c) Interior Space dimensions
d) Space location onboard

a) General Basic safety to apply and consider at all times:

- **International Convention on Load Lines**
- **IMO Lifesaving Appliances Code**
- **MCA 'Code of Practice for Safety of Large Commercial Sailing & Motor Vessels', published in 1997 (LY2)**

- MCA; Chapter 11, Stability requirements
  - 11.1 General
  - 11.2 Intact stability standards
  - 11.3 Damage stability
- MCA; chapter 21. Accommodation
  - 21.1.3 Generally, accommodation standards for the crew should be at least equivalent to the standards set by the International Labour Organisation conventions for crew accommodation in merchant ships. The *ILO Convention* provisions should be practicable with regard to vessels greater than 500GT.
- MCA; chapter 22.5 Noise

a) Requirements that apply for the choice of spatial elements

- MCA. 13 Life-Saving Appliances: Equipment fitted should be of a type which has been accepted by the Administration as complying with IMO Lifesaving Appliances Code and IMO Resolution MSC.81(70
- MCA 14 Fire safety
  - MCA 14.2.1 Sauna's
  - MCA 14.2.3 Galley equipment:
- MCA 14B.2.11.7 Furniture in the corridors and escape routes should be of a type and quantity not likely to obstruct access. Additionally, furniture along escape routes should be secured in place to prevent shifting if the vessel rolls or lists.

b) Requirements that apply when the interior Space dimensions and space layout elements are determined

- **MCA. 5.Weather tight integrity:**
  - 5.5 windows
  - 5.6. ventilations and exhausts
- **MCA 6 water freeing arrangements (should comply with International Convention of Load Lines -ICLL)**
- **MCA 13 Life-Saving Appliances**
- **MCA 14.3 Fire Control Plan(s) General arrangements**
- **MCA 14BStructural fire protection vessels ≥ 500 GT**
  - 14B.2.3 Main vertical zones and horizontal zones
  - 14B.2.4 Bulkheads within a main vertical zone
  - 14B.2.5 Fire integrity of bulkheads and decks
    - Table 1 – Fire integrity of bulkheads separating adjacent spaces

- 14B.2.6 Protection of stairways and lifts in accommodation and service spaces
- 14B.2.7 Openings in 'A' class divisions
- 14B.2.8 Openings in 'B' class divisions
- 14B.2.9 Windows and port lights (Also see 5.4 and 5.5)
- 14B.2.10 Details of construction
- 14B.2.12 Means of escape

c) Requirements that apply to the choice of the Space Location onboard

- **MCA. 5.Weather tight integrity:**
  - 5.5 windows
  - 5.6. ventilations and exhausts
- **MCA 6 water freeing arrangements (should comply with International Convention of Load Lines -ICLL)**
- **MCA 13 Life-Saving Appliances**
- **MCA 14.3 Fire Control Plan(s) General arrangements**
- **MCA 14B Structural fire protection vessels ≥ 500 GT**
  - 14B.2.3 Main vertical zones and horizontal zones
  - 14B.2.4 Bulkheads within a main vertical zone
  - 14B.2.5 Fire integrity of bulkheads and decks
    - Table 1 – Fire integrity of bulkheads separating adjacent spaces
  - 14B.2.6 Protection of stairways and lifts in accommodation and service spaces
  - 14B.2.7 Openings in 'A' class divisions
  - 14B.2.8 Openings in 'B' class divisions
  - 14B.2.9 Windows and port lights (Also see 5.4 and 5.5)
  - 14B.2.10 Details of construction
  - 14B.2.12 Means of escape
  - 14B.2.13 Ventilation systems
    - 14B.2.13.3 Ducts provided for the ventilation of a machinery space of category A, machinery spaces, galley, spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuel, should not pass through accommodation spaces
    - 14B.2.13.11 Where public spaces span three or more open decks
    - 14B.2.13.16 Ventilation openings may be fitted in and under the lower parts of cabin and public space doors in corridor

- **MCA 15B. Fire Appliances – Vessels of 500GT and over**

All vessels should comply with the requirements of *SOLAS 74, Chapter II-2, regulation 10*, and as appropriate to the vessel and its equipment. For the purpose of the *SOLAS regulations*, the standards for a cargo ship apply.

C3 the rules and regulations on basic safety requirements on accommodation interior design, (rules optional for private yachts ≥ 12 passengers), for the following:

a) General basic safety
b) Choice of spatial elements
c) Interior Space dimensions
d) Space location onboard

- **International Convention on Load Lines**
- **IMO Lifesaving Appliances Code**
- **SOLAS passenger vessel (Not obligatory)**

b) General Basic safety to apply and consider at all times:

- SOLAS Chapter II-1 Construction, subdivision and stability, machinery and electrical installations
  - Part B: Subdivision and stability
    - Reg. 15. Openings in watertight bulkheads in passenger ships
    - Reg. 17. Openings in shell plating of passenger ships below the margin line
    - Reg. 18 -19. Construction and initial tests of watertight doors, decks etc.
    - Reg. 22. Stability information for passenger ships
    - Reg. 23. Damage control
  - Part C 39: Location of emergency installations in passenger ships
  - Part D 42: Emergency source of electrical power in passengers ships

- SOLAS Chapter II-2 Construction, Fire protection, fire detection and fire extinction
  - Part A, general:
    - Reg. 2. Basic principles
    - Reg. 3. Definitions
  - Part B, Fire safety measures for passenger ships
    - Reg. 35 details of construction

- SOLAS Chapter III Lifesaving appliances and arrangements
  - Part A: General
  - Part B: Ship requirements
    - Section I passenger ships and cargo ships
    - Section II passenger ships
  - Part C: Lifesaving appliance requirements
    - Section !: General
    - Section II personal Saving applications

c) Requirements that apply to the choice of spatial elements

- SOLAS Chapter II-2 Construction, Fire protection, fire detection and fire extinction
  - Part A, general:
    - Reg. 3. Rooms containing furniture and furnishings of restricted…..in which.
  - Part B, Fire safety measures for passenger ships
    - Reg. 34. Restricted use of combustible materials
      - 6. Furniture in the corridors and stairways enclosures shall be kept to a minimum

d) Requirements that apply when the interior Space dimensions and space layout elements are determined

- SOLAS Chapter II-2 Construction, Fire protection, fire detection and fire extinction
  - Part A, general:
    - Reg. 2. Basic principles
    - Reg. 3. Definitions
    - Reg. 4. Fire pumps, fire mains, hydrants and hoses
  - Part B, Fire safety measures for passenger ships
    - Reg. 24 Main vertical Zones and horizontal zones
      - 1.2 For ships carrying not more than 36 passengers
    - Reg. 25 Bulkhead within a main vertical zone
      - 1.2 For ships carrying not more than 36 passengers
      - 1.3, 2, 3
    - Reg. 27 Fire Integrity of bulkheads and decks in ships carrying not more than 36 passengers
    - Reg. 28. Means of escape
    - Reg. 29. Protection of stairways and lifts in accommodation and service spaces
    - Reg. 30-31. Openings in "A,B" class divisions
    - Reg. 32. Ventilation systems
    - Reg. 33. Windows and side scuttles
    - Reg. 34. Restricted use of combustible materials

d) Requirements that apply to the choice of the Space Location onboard

- SOLAS Chapter II-2 Construction, Fire protection, fire detection and fire extinction
  - Part A, general:
    - Reg. 2. Basic principles
    - Reg. 3. Definitions
    - Reg. 4. Fire pumps, fire mains, hydrants and hoses
  - Part B, Fire safety measures for passenger ships
    - Reg. 24 Main vertical Zones and horizontal zones
      - 1.2 For ships carrying not more than 36 passengers
    - Reg. 25 Bulkhead within a main vertical zone
      - 1.2 For ships carrying not more than 36 passengers
      - 1.3, 2, 3
    - Reg. 27 Fire Integrity of bulkheads and decks in ships carrying not more than 36 passengers
    - Reg. 28. Means of escape
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    - Reg. 30-31. Openings in "A,B" class divisions
    - Reg. 32. Ventilation systems